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VOLUME I.

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J. C. Branner

OUTLINES

OF

MINERALOGY, GEOLOGY,

AND

MINERAL ANALYSIS.

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IN TWO VOLUMES.

VOL. I.

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PREFACE.

The work which I now offer to the public, is the result of a laborious investigation which has occupied almost the whole of my spare time during a period of about ten years. The object in view, was to ascertain the chemical constitution of the different minerals which occur on the surface of the globe. For this purpose, I subjected to a rigid analysis every species that I could procure, except those which had been already investigated with sufficient accuracy by other chemists. During the course of this investigation, I analyzed several hundred specimens, and at least as many more were subjected to analysis by the numerous pupils who attended my laboratory, not a few of whom acquired great dexterity and accuracy in analysis, and have already, or speedily will distinguish themselves as analytical chemists. During these investigations, I met with a considerable number of new species hitherto overlooked by mineralogists, chiefly in specimens from Ireland, North America, and the West of Scotland. These new species, amounting to nearly 50, will be found described in the first volume of this work.

Every true mineral species is a chemical compound, the constituents of which are united in definite proportions, and the greater number of them consist but of a very few ingredients. What makes it difficult or impossible to determine these ingredients with the requisite accuracy, is, that very few minerals are free from a mixture of foreign matter interspersed among their particles. As we cannot at present determine what constituents are essential, and what accidental by actual experiment, we are left in some measure to conjecture, and I have no doubt that I have more than once drawn wrong conclusions from my analysis, respecting the true chemical constitution of the minerals analyzed. I endeavoured, where that was in my power, to examine the same mineral species from different localities. Those constituents which were never wanting, were considered as essential, while those that were wanting in certain individuals, were considered as accidental impurities. But even this method, though at first sight plausible, if not satisfactory, fails in some of the most common mineral species, as *pyroxene*, *amphibole*, and *garnet*, in which we find minerals having the same crystalline form, and yet differing completely in their composition. This is ascribed by modern chemists to what they call *isomorphism* of certain constituents of minerals. Isomorphous bodies may be substituted for each other in the same mineral without any alteration in the crystalline form, and consequently without altering the species. I am rather inclined to believe, that in these cases, two or more species having nearly the same crystalline form, have been confounded together, or occur naturally mixed with each other, in consequence of the similarity of their form. But the subject still requires a more rigid investigation.

The Geological outline which constitutes the first part of the second volume, has been added, to enable the chemical reader to judge of the position of the various minerals, and thus be the better enabled to draw conclusions respecting the accidental impurities which occur in each. At present, *geology* constitutes the fashionable study in this country, and the greater number of its votaries consider mineralogy as quite unnecessary. But no mistake can be greater or more fatal to the true progress of geology. Without an accurate knowledge of minerals, we cannot judge accurately of the nature of rocks, nor distinguish them correctly from each other. The mere knowledge of fossils is considered at present as sufficient to enable a geologist to discriminate between different formations. And there can be no doubt that it is a most important element in such a determination. But it has not yet been proved, that formations may not have been deposited at the same time in distant parts of the globe, and that the fossils which they contain may be different. The animals, for example, in New South Wales and in Britain, are quite different. Hence, it is evident, that were beds formed at present from the debris of the land in each of these countries, and were they to envelope the remains of the animals of each country, these beds, though deposited at the same time, would contain quite different fossils.

The mineral analysis, which constitutes the third part of this work, has been added to enable chemists to judge of the accuracy of the analyses contained in the first part. I thought also that it might be useful to those young British chemists, who were desirous of perfecting themselves in this important branch of practical chemistry.

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VOL. I.

OUTLINES

OF

MINERALOGY AND GEOLOGY.

THE following work is divided into three parts: The first contains a description of all the minerals, (so far as at present known,) by the aggregation of which the globe of the earth is composed. The second gives an account of the nature and position of the different rocks of which the external crust of the earth, so far as hitherto penetrated, is composed. In the third, the methods are detailed by which minerals may be analyzed, and their different constituents determined. The subject treated of in the first of these parts is called *Mineralogy*, that treated of in the second, *Geology*, and in the third, *The Analysis of Minerals*.

PART I.

OF MINERALOGY.

INTRODUCTION.

The term *mineral* is applied to all the solid materials of the globe, when these materials are *homogeneous*, or composed of one substance aggregated together in masses, as is the case with *sulphur*, *iron*, *antimony*, *diamond*, &c., or when they are composed of two or more constituents united together in chemical proportions. Thus, *iron pyrites* is a compound of 1 atom of *iron* and 2 atoms of *sulphur; sulphide of antimony* is a compound of $1\frac{1}{2}$ atom sulphur, and 1 atom antimony; *quartz*, of 1 atom silicon, and 1 atom oxygen. In like manner, *felspar* is a compound of 3 atoms *tersilicate* of *alumina*, and 1 atom of *tersilicate* of *potash*, while *albite* is composed of 3 atoms tersilicate of alumina, and 1 atom tersilicate of soda. When a mineral is not composed of constituents united together in chemical proportions, but which vary in different specimens, such minerals are considered merely as mechanical mixtures, and belong not to mineralogy, but geology.

Mineralogy may be considered as a modern science. It had made no satisfactory progress among the ancients. Theophrastus, indeed, has left us a treatise on stones; but his descriptions are so vague that we are often left to conjecture the minerals to which he alludes; and, even if all the minerals which he describes were accurately known, they would constitute but a very small portion of the mineral kingdom. In the poem on minerals, ascribed to Orpheus, the case is still worse; twenty-four different species of stones are indeed named, but no description whatever is given. Pliny has drawn up a catalogue of a considerable number of minerals; but it consists merely of the names of the species, with a few observations on the uses to which they were put. Of this catalogue, only a small number has been made out by modern mineralogists; by far the greatest portion remains quite unknown.

We can scarcely be said to have possessed any Mineral System till Cronstedt published his *System of Mineralogy*, in 1753. His descriptions are, indeed, very imperfect; but there is an attempt at a systematic arrangement. Werner, in 1773, first contrived a mineralogical nomenclature, and showed how minerals might be described in an intelligible manner to others. It was after the publication of this nomenclature that mineralogy began to improve with rapidity; and Werner himself, who had been appointed Professor of Mineralogy in the Mining Academy of Freyberg, contributed not a little to its rapid extension. He did not, indeed, publish any system of mineralogy, but he arranged minerals according to the system of Cronstedt, as he had improved it. He was indefatigable in collecting minerals, assiduous in describing them, and he drew up every year, for the use of his students, a catalogue of all known minerals, arranged in the way that he was in the habit of describing them. Copies of his lectures were taken down by his pupils, and numerous systems of mineralogy drawn up from them and published. One of the earliest of these was Emerling's, and one of the latest, and most complete, was Hoffman's *Handbuch der Mineralogie*, in four volumes octavo.

Werner added greatly to the number of mineral species; but, as in forming them, he was merely regulated by his own notions, and had never laid down any specific rules, none of his pupils were capable of forming new species. Hence his system was not susceptible of amelioration or correction, and could only therefore last during the lifetime of the original contriver of it.

Hauy first successfully investigated the mathematical structure of crystals, taking up the subject where it had been left by Romé de Lisle. He determined the primary form of every mineral, and showed how all the secondary forms were derived by simple laws of decrement from this primary form. The knowledge of these primary forms enabled him to arrange the mineral species with more precision than had been done before him. He defined a mineral species to be a substance composed of the same constituents united in the same proportions, and possessed of the same crystalline form. In fact, he was almost entirely regulated in his formation of species by the form of the crystal. The chemical composition was taken into consideration only when two minerals, having the same crystalline shape, differ in their composition. Thus the primary form of galena and of common salt is the same, both being cubes. But *galena* is a compound of *sulphur* and *lead*, while *common salt* is a compound of *chlorine* and *sodium*. They must, therefore, constitute two distinct species.

Hauy obtained his primary forms by mechanical division. Such a process in many cases cannot be adopted. When this happened, he chose that form from which the secondary forms could be deduced with the greatest simplicity; and he was often far from happy in his choice. In his measurement of crystals, he employed merely the common goniometer, which is not susceptible of giving the angle within less than half a degree of the truth. This error he corrected, by supposing the primary form which he deduced, either a regular solid, or at least perfectly symmetrical, and from this assumed primary form he deduced all the angles of the secondary crystals by trigonometrical calculations. After the invention of the reflecting *goniometer*, by Dr. Wollaston, which is capable of measuring the angles of crystals within one minute, the angles of all crystalline bodies were again examined by other mineralogists, and it was found that the angles assumed by Hauy were very seldom the true ones, differing from the real angles of the crystals frequently by several degrees. This has rendered Hauy's measurements, and even his calculations, of comparatively little value for the science of mineralogy.

Another unfortunate method adopted by Hauy was to impose a name upon every secondary crystal, and to consider each of their secondary forms as existing by itself independent of all the rest. This renders it difficult to remember all his secondary forms when they are very numerous, as happens with respect to calcareous spar, sulphate of barytes, iron pyrites, &c. It renders the perusal of his book so irksome, that it can hardly ever be undertaken without some specific object in view.

The individuals to whom we lie under the greatest obligations for the measurement of crystals in Great Britain, are Mr. Brooke and Mr. William Phillips. The former gentleman, in his Introduction to Crystallography, has given an alphabetical catalogue of minerals, to a great number of which he has affixed his own determination of the primary crystalline form. Mr. William Phillips, in his Elements of Mineralogy, has not only given the primary form of almost every mineral determined by his own measurement, but likewise figures of the most important of the secondary faces, together with tables of the angles which they form with each other, and with the primary faces. This stamps a value upon the work of no ordinary kind.

In Germany, the mathematical theory of crystals was investigated by M. Weiss; and he conceived the fortunate idea of connecting all the secondary forms with the primary form by simple laws. This makes it much easier to remember the whole, by giving a unity to the subject, which Hauy has failed to do. Most of his calculations were made from the previous measurements of Hauy; but Mohs, who was an excellent practical mineralogist, adopted nearly the same idea. He and Mr. Haidinger, who had made himself a profound master of the theory of crystals, examined anew the angles of a vast number of crystallized minerals, and founded upon these labours a system of mineralogy, which they endeavoured to make independent of every other branch of science. They arranged minerals into classes, orders, genera, and species. Every species is distinguished by a property considered as capable of accurately discriminating it from every other species. This property is called the *characteristic.* It is founded upon three characters of minerals, namely, the hardness, specific gravity, and the crystalline form.

Mohs has arranged all minerals in what he calls a *natural history* order. The object of his arrangement is to enable a beginner to discover the name of any mineral contained in the system by its characters, precisely in the same way as in botany or entomology, any plant, or insect, contained in the system may be discovered by attending to its characters. And M. Mohs considers it as a vast advantage to mineralogy to be thus freed from the trammels of Chemistry, by which it has been hitherto hampered.

It would certainly be a boon to mineralogists of no mean value, if a method could be devised to enable a student to discover the name of any mineral contained in the system. But from the very nature of minerals the discovery of such a method is attended with much greater difficulty than in the other branches of natural history, in which organized beings are arranged; because, in them the form and peculiar structure of the respective organs affords accurate and characteristic distinctions. The only thing analogous to organization in minerals is the form of the crystal; but to be able to deduce accurate distinctions from these forms requires a previous acquaintance with crystallography, which can only be obtained by the study of crystals. That is to say, that before we be in a condition to discover the names of minerals from their crystalline forms, we must be acquainted with them. Besides, minerals do not always occur crystallized; and in such cases, our *characteristic* would be totally at fault, and would leave us incapable of drawing any conclusion.

M. Mohs gets over this difficulty, by affirming, that crystallized minerals alone belong to mineralogy as a science; that amorphous minerals are mere aggregates of minute crystalline particles incapable of description or arrangement. But supposing this to be a correct view of the subject, still, if mineralogy were to be confined to mere crystallized bodies it would be divested of the greatest part of its utility; for a very great proportion of those minerals that are of the greatest utility to man, and which, therefore, it is peculiarly important to be able to distinguish from others, are seldom found in the state of regular crystals. How often do the ores of tin, copper, lead, and iron, occur in an amorphous state? And were a mineralogist incapable of distinguishing them from each other, and from other minerals, except in the rare cases when they assumed a regularly crystallized form, his knowledge would be useless as far as the important arts of mining and metallurgy are concerned.

The specific gravity is certainly a universal property; as no mineral whatever is destitute of it. And when minerals are pure, their specific gravity is pretty nearly determinate; as the range in the same mineral is never very considerable. But specific gravity alone is not sufficient to enable us to distinguish minerals from each other; because many various species have so nearly the same specific gravity, that we might be unable to determine which of five or six minerals we had got if we had no other character to guide us but the specific gravity.

The hardness in general is pretty constant in pure minerals. But our methods of determining it are but imperfect. The consequence is, that many minerals approach each other in hardness so nearly, that by that property alone we could not with accuracy distinguish them from each other.

It appears to me, that mineralogy is so closely connected with *chemistry*, and so dependent on it for its specific distinctions that it would be highly injurious to it, and, therefore, very unwise to attempt to deprive it of so important an ally. It would be nearly the same as if the Astronomer were to announce that his science was independent of Mathematics, and were, therefore, to insist upon banishing that indispensable auxiliary from his sublime science.

Every mineral species is a chemical compound, and it consists of the very same constituents united in the very same proportions. This constitutes the essence of a mineral species, and therefore it can be determined only ultimately by chemical analysis. The mere crystalline shape alone is insufficient to constitute a mineral species; because the same shape often exists when the composition is very different. And this not merely in regular mathematical figures, as the cube and octahedron, in which such a difference has been long admitted; but also in other shapes that possess no such mathematical regularity, as in *Harmotome* and *Phillipsite*, and in two minerals hitherto confounded under the common name of *chabasite*. And in the same way, various minerals at present confounded under the specific names *garnet*, *amphibole*, *pyroxene*, because their crystalline shapes agree, in reality constitute different species, being composed of different constituents.

Unless we admit that a mineral species is composed of the same constituents united in the same proportions, we destroy altogether their fixity, and bring the whole into a chaos similar to the present state of the species amphibole, pyroxene, and garnet. I have, therefore, in the following work, arranged minerals entirely upon chemical principles; and a very few observations will be sufficient to point out the views according to which this arrangement is founded.

Bodies which unite together in definite proportions belong to two distinct classes, distinguished from each other by the name of *Acids* and *Alkalies* or *Bases*. All minerals consist essentially of these two classes of bodies, either in an insulated state or united together. Hence, I divide the Mineral Kingdom into the two great classes of *Acids* and *Bases*. In the present imperfect state of our knowledge, I have thought it right to add a third class, entitled, *Neutral Bodies*, or bodies which neither possess acid nor alkaline properties. This class is only temporary, for I have no doubt that the bodies at present placed in it will hereafter find their arrangement, either among the *acids* or *bases*. But I placed the few bodies that belong to it in their present situation, because they exhibit no disposition to unite with, or at least, are never found united either to acids or bases, but simply with each other, or with a few other metals. The neutral bodies are *gold*, *platinum*, and *iridium*.

The class of acids is divided into fifteen genera, because fifteen acids or their bases exist in the mineral kingdoms. For the same reason the class of alkaline bodies is divided into 27 genera, and the class of neutrals into 3 genera.

I shall finish these introductory observations with a few observations on the most important characters by which minerals may be distinguished from each other. The three properties by far the most fixed and steady, are hardness, specific gravity, and crystalline shape. To these, therefore, we shall turn our attention in the first place.

1. *Hardness*. The hardness of minerals, no doubt, depends upon the nature of their constituents, or, at least, upon the way in which they are arranged. The ultimate atoms of bodies are, probably, all extremely hard. But their minuteness is such, that they never can become objects of our senses, except when aggregated together. The minutest particles of carbonate of lime (for example) which we can obtain, must contain both carbonic acid and lime, and probably many particles of each. But a particle of carbonic acid is a compound of three atoms, and a particle of lime of two atoms. Hence, a single integrant particle of carbonate of lime, must contain, as a minimum, 5 atoms of matter. The hardness of bodies depends chiefly upon what has been called the *attraction of aggregation*, or the force by which homogeneous bodies are attracted towards each other. This attraction seems to be in general, greatest between the particles of simple bodies. Thus, the diamond constitutes the hardest body in nature; quartz and sapphire consisting, the former of grains of silica, and the latter of particles of alumina aggregated together, are also very hard. But sulphur, arsenic, and antimony, though simple bodies, are far from hard. Those minerals which contain a considerable proportion of alumina, zirconia, yttria, and glucina, are usually hard; while lime, magnesia, barytes, and strontian, exist in comparatively soft minerals. Many of the silicates are hard.

We must carefully distinguish between *toughness* and *hardness*. By the former is meant difficult frangibility, or a resistance which the particles offer to be separated from each other. By *hardness*, is meant the property which one mineral has of scratching another, or the power which it has to resist the action of the file. When a mineral is capable of scratching another, we consider it as the harder of the two. Thus, quartz is capable of scratching felspar, while felspar is incapable of scratching quartz. Hence, we infer, that quartz is the harder of the two minerals.

It is difficult to convey an idea of the relative hardness of minerals by a long description. The method first put in practice by Kirwan, of using figures for that purpose, is more convenient than any other. He distinguished the relative hardness of minerals into 10 different degrees, that of the diamond the hardest mineral in nature being denoted by 10. Mohs has adopted the same plan, though he has neglected to mention the source whence he derived his first idea of it. But he has given us a mineral whose hardness is denoted by each of his figures. Every mineral is supposed to possess the hardness denoted by the figure, or a hardness intermediate between some two of the numbers, which, of course, will be denoted by a fraction. The following table will render the nomenclature of hardness sufficiently intelligible:—

1 denotes the hardness of Talc.
2 — — — Rocksalt, gypsum.
3 — — — Calcareous spar.
4 — — — Fluor spar.
5 — — — Apatite or phosphate of lime.
6 — — — Felspar or adularia.
7 — — — Rock crystal.
8 — — — Topaz.
9 — — — Corundum.
10 — — — Diamond.

These minerals are all easily procurable, and therefore may be kept on purpose, to serve as objects of comparison.

In trying the hardness of a mineral we should avoid applying a sharp pointed mineral to it for that purpose, otherwise we may sometimes be led to consider it as softer than it really is. A good way to judge of the comparative hardness of two minerals is to draw the file over each; if there be a difference in the hardness we will discover it by the way in which each will affect the file when drawn over it.

2. The specific gravity of minerals, or the weight of a given volume of each ought to depend upon the chemical composition, and the crystalline shape; for it is obvious that bodies composed of the same chemical constituents, arranged in the same way, must have the same specific gravity. This character is of importance, and often enables us to determine the species of a mineral, even when several of the other important characters are wanting; for, as the specific gravity depends upon the arrangement of the particles as well as the crystalline shape, it is obvious that the one may be considered as an index to the other.

The lightest body hitherto met with in the mineral kingdom, is the substance formerly known by the name of *mineral tallow*, and which Mr. Conybeare (probably without being aware that it had been long known) distinguished by the name of *Hatchetine*:[*] its specific gravity is 0·6078. The heaviest body hitherto met with in the mineral kingdom is the ore of iridium, which has a specific gravity of 19·5, or a little greater than pure hammered gold.

3. Minerals occur in the mineral kingdom in regular geometrical figures, the faces of which constitute planes inclined to each other at determinate angles, or at least deviating but little from each other, and constituting well defined crystals. This could hardly be the case unless the integrant particles of which each mineral is composed possessed a certain determinate shape. And unless we suppose farther that the aggregation is produced by these integrant particles always arranging themselves in one determinate way, we must suppose these particles possessed of a kind of polarity like magnets, so that certain poles attract each other, while others on the contrary repel. These mutual attractions and repulsions would undoubtedly cause them to be always aggregated together in the same way.

Were these suppositions well founded, one would expect that every mineral would always assume the very same crystalline shape; but this is very far from being the case: almost every crystallized mineral assumes different modifications of form, often so different, that they seem at first sight to have no

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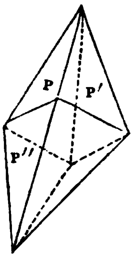
[*] Some mineralogists include *air* and the gaseous bodies among minerals. But it seems clear that the *aerial* as well as the *aqueous* fluids belonging to our globe ought to constitute classes quite distinct from those of minerals.

connexion whatever with each other. Thus calcareous spar is crystallized in *rhomboids* of various kinds, in pyramidal dodecahedrons, in six-sided prisms, four-sided prisms, three-sided prisms, and in many other forms. Fluor spar occurs in cubes, and in regular octahedrons.

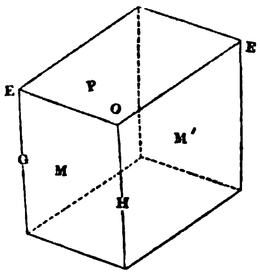
Hauy* first noted that in all such cases we can, by a cautious dissection of the crystal, extract from it a nucleus; and that this nucleus in the same mineral species has always exactly the same form. Thus, whatever be the shape of a crystal of calcareous spar, we can always extract from it an obtuse rhomboid whose faces are inclined to each other at angles of 105° 5′. Every cube of fluor spar by cautiously dissecting off the angles, yields for a nucleus a regular octahedron. The nucleus thus extracted has received the name of the *primary form* of the mineral, and characterizes the mineral species to which it belongs. Hauy showed how all the *secondary forms* (as the other forms are called,) may be deduced from the primary form by certain hypothetical laws of decrement, by means of which the connexion and dependence of all the secondary forms upon the primary forms may be mathematically deduced.



But there are certain minerals whose chemical composition is identical, that nevertheless have primary forms quite distinct from, and incompatible with each other. Thus, sulphur when found crystallized in a *native* state has the form of a double four-sided pyramid with a rhomboidal base; or it constitutes an oblique octahedron, as represented in the margin, the faces of which are thus inclined to each other,

P on P′ 106° 20′

P on P″ 143 25



When a large quantity of sulphur is melted in a crucible, and cooled slowly, pouring out the liquid portion after it has begun to congeal, pretty regular crystals will be found adhering to the inside of the vessel. These crystals have the figure represented in the margin, a right rhomboidal prism; now, this form is incom-

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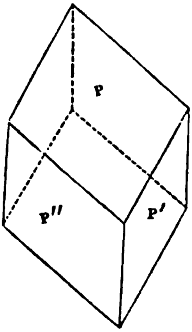
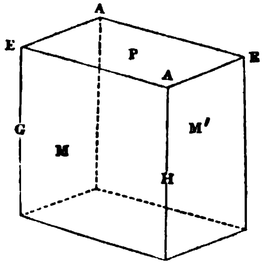
* The fact indeed had been discovered by Bergmann, or rather by Gahn, but they did not prosecute it.

patible with the former, or cannot be deduced from it by the usual laws of decrement.





Calcareous spar has for its primary form a rhombohedron, as represented on the margin, in which

P on P′ 105° 5′.

But the primary form of the arragonite is a right rhombic prism, in which

M on M′ 116° 10′.

Yet, as far as can be determined by chemical analysis, the constituents of both are exactly the same. The two forms, however, are incompatible with each other, and the minerals differ not merely in shape, but also in their specific gravity and hardness.

Common iron pyrites has a cube for its primary form, but the primary form of white or cockscomb pyrites is a right rhomboidal prism, M on M′ 106°. Yet the constitution of both is the same, namely, 2 atoms of sulphur, and 1 atom of iron.

The minerals called *idocrase*, and *grossularite* or *green garnet*, are composed of the same constituents, namely,

1 atom silicate of alumina.
1 atom silicate of lime.

Yet the primary form of the idocrase is a right square prism, and that of the grossularite a rhomboidal dodecahedron.

From these examples we see that mere identity in chemical composition is not always sufficient to constitute identity of species. It would not do, therefore, in constituting mineral species, to be guided entirely by chemical composition. We must take into consideration the other characters; namely, crystalline form, specific gravity, and hardness; and when these differ materially, it is obvious, that notwithstanding identity in composition, we must constitute minerals so differing into different species.

It would be still more dangerous to rely upon crystalline form alone, in constructing mineral species; for nothing is more common than to find two minerals having the same crystalline form, and yet differing from each other in almost every other particular. Thus, *galena*, *iron pyrites* and *analcime* have each a cube for its primary form; yet the first is a sulphuret of lead, the second a bisulphuret of iron, and the third a compound of 3 atoms bisilicate of alumina, 1 atom bisilicate of soda, and 2 atoms water. Spinell and sal ammoniac have each the regular octahedron for the primary form, though the former is composed of alumina and magnesia, and the latter of muriatic acid and ammonia.

These facts are so well known that even the most zealous crystallographers are obliged, in forming species, to have recourse to chemical analysis, and to acknowledge that the mineral kingdom cannot be accurately arranged into species without having recourse to the assistance of the chemist.

I shall devote the remaining part of this introduction to the explanation of the system of crystallography adopted by Mohs, partly because it is now pretty generally adopted in Germany, and partly to enable the English reader to consult Haidinger's translation of Mohs's Mineralogy, which contains a great deal of most valuable information respecting crystals.

Crystals assume the following forms:

1. *Rhombohedron* or *rhomboid*, composed of six equal and similar rhombic faces, parallel two and two.

2. *Pyramid*, by which is meant two equal pyramids applied base to base. The pyramids are,

(1.) Four-sided, constituting octahedrons.

(2.) Six-sided, constituting pyramidal dodecahedrons.

(3.) Eight-sided, constituting a crystal with sixteen triangular faces.

3. The *tetrahedron*.

4. The *hexahedron* or *cube*.

5. The *dodecahedron*.

(1.) With triangular faces. A low three-sided pyramid raised on each face of the tetrahedron.

(2.) The monogrammic tetragonal dodecahedron, composed of rhombs like the garnet crystal.

(3.) The digrammic tetragonal dodecahedron, it consists of twelve trapeziums, and has the aspect of the tetrahedron.

(4.) The pentagonal dodecahedron, contained under twelve equal and similar pentagons. Of this form there are two kinds.

The first the hexahedral pentagonal dodecahedron, each face of which is a pentagon containing four equal sides, and two pairs of equal angles. The single angle is opposite to the single side.

The second the tetrahedral pentagonal dodecahedron. The faces have angles all unequal, but they have two pairs of equal sides.

6. The *icosatetrahedron*, a solid bounded by twenty-four faces. There are three kinds of icosatetrahedrons.

(1.) *Trigonal*, when the faces are triangles. Of these figures there are three kinds.

a. Tetrahedral trigonal icosatetrahedron. It may be considered as a tetrahedron upon every face of which a six-sided pyramid is raised.

b. Hexahedral trigonal icosatetrahedron. It may be considered as a cube on every face of which a low four-sided pyramid is raised.

c. Octahedral trigonal icosatetrahedron. It may be considered as an octahedron on each face of which a three-sided pyramid is raised.

(2.) *Tetragonal* when the faces are equal and similar quadrilaterals. There are two kinds of them.

a. Digrammic tetragonal icosatetrahedron. This is the form well known as that belonging to the *leucite* and the *analcime.* The faces by one of their diagonals can be divided into two isosceles triangles. It may be considered as a cube, on every face of which a four-sided pyramid of a peculiar kind is raised.

b. Trigrammic tetragonal icosahedron. The faces cannot be divided into isosceles triangles by a diagonal. It may be considered as an octahedron, on the faces of which a peculiar triangular pyramid is raised.

(3.) *Pentagonal.* The faces are pentagons with unequal angles but two pairs of equal sides.

7. The tetraconta octahedron. This figure has 48 equal and similar faces. The diamond exhibits an example of it. We may consider it as an octahedron, on each face of which a low six-sided pyramid is raised.

There is a remarkable connexion among several simple forms, depending not only on the kind, but on the dimensions of these simple forms.

Every mineral affects certain forms and avoids others. Now, the secondary forms are derived from the fundamental by *derivations.* There are four processes of derivation.

1. Tangent planes are placed upon certain edges of the given

form, and enlarged till they limit the space entirely. By this process, either simple or compound forms may be obtained.

2. The axis of the fundamental form is elongated indefinitely, but equally, both ways. Straight lines are drawn from the lateral angles to the terminal points of the axis, and planes laid upon every contiguous pair of them. The derived form is contained under these planes.

3. Planes are laid on the terminal edges of the given form. The derived form is contained under these planes.

4. The fourth process of derivation depends on the situation of a moveable plane tangent to the uppermost point of a vertical rhombohedral axis.

If a process of derivation yields a form of the same kind as the given form, the same process may be applied to this as to the given form, and so on. Thus an assemblage of similar forms is produced, called a *series.* A constant ratio exists between every two contiguous members of such a series. This is called the law of the series.

The limits of the series of those forms which contain one axis are *planes* and *prisms.* The former, when the axis becomes infinitely short; the latter, when it becomes infinitely long.

The form which serves as the base of the derivation is called the *fundamental form.* The fundamental forms adopted by Mohs, as the foundation of his method, are the four following:

1. Scalene four-sided pyramid.
2. Isosceles four-sided pyramid.
3. Rhombohedron.
4. Hexahedron.

As an example of the mode of derivation, we shall take the first of these fundamental forms, the scalene four-sided pyramid.

By applying tangent planes to the edges, and extending these planes till they intersect, (performing this process twice,) we obtain a more obtuse pyramid, with a base similar to the fundamental form.

If the derived pyramid be more obtuse than the fundamental, the axis of the fundamental form is to that of the new form as $\frac{1}{2} : 1$; if more acute, as $2 : 1$.

If the derivations be continued, a series of scalene four-sided pyramids, with similar bases, will arise, whose axes will increase and decrease like the powers of the number 2.

P represents the axis of the fundamental form; P—1, P—2,

$P-3$, &c., the decreasing axes; $P+1$, $P+2$, $P+3$, &c., the increasing axes.

The limits of the series are an oblique four-sided prism, whose base is equal and similar to that of the fundamental form, and a plane perpendicular to the axis. The sign of the former is $P+\infty$; of the latter, $P-\infty$. For the first takes place when the axis becomes infinitely long, and the second when it becomes infinitely short.

$\breve{P}$ and $\bar{P}$ refer to the short and long horizontal diagonals of the fundamental form.

$(\breve{P}+n)^m$ and $(\bar{P}+n)^m$ indicate two derivative prisms, (by the second law of derivation,) the first having the short axis, the last the long axis, the same as in the fundamental form. *m* denotes the number of derivations. It is always positive, and greater than 1; commonly it is 3, 4, or 5.

$\breve{P}+n$ indicates the derived member of the series from which the pyramid is obtained.

If m be supposed equal, the bases of all $(\breve{P}+n)$ and $(\bar{P}+n)$ are equal and similar to each other.

$(\bar{P}r+n)^m$ and $(\acute{P}r+n)^m$ are expressions for other four-sided pyramids.

$Pr+n$, $\breve{P}r+n$, $\bar{P}r+n$, also denote horizontal prisms.

Horizontal prisms are formed by supposing one of the horizontal diagonals of the base to become infinite in length, while the other remains. The mark above P shows which of the diagonals becomes infinite.

In four-sided isosceles triangular pyramids, the limits, when the diagonal becomes infinite, are two kinds of four-sided prisms, the one rectangular, the other oblique. This second prism is denoted thus $[P+\infty]$, putting the symbol between brackets.

From every member of the series several scalene eight-sided pyramids may be derived.

From the rhombohedron, by the first method of derivation, a series of more obtuse rhombohedrons is derived. They are designated by R, $R+n$.

The limits of this series are on the one hand a plane perpendicular to the axis, denoted by $R-\infty$; and on the other, a six-sided prism, denoted by $R+\infty$.

By the second method we derive from the rhombohedron a series of scalene six-sided pyramids. Their limits on the one side are unequiangular twelve-sided prisms, and on the other, plane figures, equal and similar to the horizontal projection of the fundamental form.

A moveable plane passing through the axis of a hexahedron by assuming different positions, gives origin to the octahedron, dodecahedron, trigonal icositetrahedron, hexahedron, digrammic tetragonal icositetrahedron, hexahedral trigonal icositetrahedron, and tetraconta-octahedron.

The half of the octahedron is the tetrahedron. The signs of the two tetrahedrons, into which the octahedron is divisible, are $\frac{O}{2}$ and $-\frac{O}{2}$.

The half of the hexahedral trigonal icositetrahedron is the hexahedral pentagonal dodecahedron. The crystallographical signs for these two halves are $\frac{An}{2}$, and $-\frac{An}{2}$.

The half of the octahedral trigonal icositetrahedron is the digrammic tetragonal dodecahedron. The signs for these two halves are $\frac{Bn}{2}$, and $-\frac{Bn}{2}$.

The half of the digrammic tetragonal icositetrahedron is the trigonal dodecahedron. The sign of these two halves is $\frac{Cn}{2}$, and $-\frac{Cn}{2}$.

The halves of the tetraconta-tetrahedron are,

1st. The tetrahedral trigonal icosatetrahedron, the signs of which are $\frac{Tn}{2i}$, and $-\frac{Tn}{2i}$.

2d. The trigrammic tetragonal icosatetrahedron, the signs of which are $\frac{Tn}{2ii}$, and $-\frac{Tn}{2ii}$.

3d. The pentagonal icosatetrahedron, the signs of which are $r\frac{Tn}{2}$, and $l\frac{Tn}{2}$.

The fourths of the tetraconta octahedron are the tetrahedral pentagonal dodecahedrons. For the mode of designating these fourths we refer the reader to Haidinger's edition of Mohs's Mineralogy, i. 144.

There ought to be as many systems of crystallization as there are fundamental forms; but to the four systems derived from the fundamental forms, Mohs has added two others, making the systems six. These are,

1. The rhombohedral system. Fundamental form, the rhombohedron. It is composed of rhombohedrons, six-sided pyramids, and six-sided and twelve-sided prisms.

2. The pyramidal system. Fundamental form the isosceles four-sided pyramid. It consists of isosceles four-sided pyramids, and of scalene eight-sided pyramids; besides rectangular four-sided prisms, and eight-sided prisms, with alternately equal angles.

3. The prismatic system. Fundamental form the scalene four-sided pyramid.

4. The tessular system. Fundamental form the hexahedron. To this belongs the octahedron, rhomboidal dodecahedron, isacontatetrahedron, &c.

5. The hemiprismatic system. In this several of the forms contained in it, and bearing to each other the general relations of those in the prismatic system, appear with only half the number of their faces, or in which these faces show differences in their angles, referring to an axis which is inclined in a plane perpendicular upon the base, and passing through one of its diagonals. The signs are the same as for the prismatic system, only each is divided by 2.

6. Tetarto-prismatic system. The forms which constitute this system, the scalene four-sided pyramids, show only one-fourth, and the prisms, both horizontal and vertical, only one-half the number of their faces, or these faces are distinguished from each other by their angles, which refer to an axis inclined in a plane perpendicular upon the base, and passing through neither of its diagonals.

Two or more simple forms united together constitute a *combination*. These combinations are of great importance in the study of crystals. They are called *binary*, *triple*, &c., according to the number of simple forms combined.

The combined forms must be derived from one and the same fundamental form. They must be in such positions with respect to each other, as are peculiar to the systems to which they belong.

The edges in which the faces of two different forms contained in a combination meet, are termed edges of combination.

Such is a very short sketch of the principles upon which the crystallography of Professor Mohs is founded; sufficient it is presumed to enable the reader to understand the language employed by him in his descriptions. For a fuller view of the subject we refer to the work itself.

A few observations may be proper upon some of the other characters of minerals employed in the following descriptions, besides *hardness*, *specific gravity*, *and crystalline shape*.

4. *Cleavage* is confined to those minerals which have a crystalline structure. It means indications of the faces of the primary crystal, or at least of some of them. There are some

minerals which possess cleavage so perfectly, that when struck with a hammer, they at once exhibit the crystalline faces by splitting into fragments, having each the crystalline shape of the mineral. This is remarkably the case with *calcareous spar*, which breaks naturally into rhomboids; and with *galena* which breaks naturally into small cubes. In other minerals we do not obtain a cleavage by breaking them with a hammer; but we often succeed by means of a chissel, or when we hold the mineral (if transparent) in a strong light, we frequently see the natural joints.

Sometimes minerals cleave only in one direction, as mica; sometimes in two, and sometimes in three. It is obvious, that three cleavages are requisite to determine the crystalline shape of a mineral.

5. *Fracture* means the irregular surface which appears when a mineral is broken, so that the surfaces do not constitute a cleavage. The kinds of fracture are determined according to the quality of its faces. When it exhibits cavities something like the inside of a shell, it is said to be *conchoidal*. The terms *even*, *uneven*, *splintery*, will be understood without any explanation.

6. *Lustre* refers to the quantity of light which minerals are capable of reflecting. Two things are to be considered; namely, the kind and the intensity of lustre.

The kinds are five:

(1.) Metallic, or that which metals possess.

(2.) Adamantine, or that of the diamond.

(3.) Resinous, or that which a body exhibits when besmeared with oil or fat.

(4.) Vitreous, or that of glass.

(5.) Pearly, or that of pearl, or mother of pearl.

The intensity is divided into five degrees; namely,

(1.) Splendent, when the degree of lustre is the highest, so that the mineral, if opaque, possesses the properties of a mirror.

(2.) *Shining*. A strong lustre, but not presenting a distinct image, as in the former case.

(3.) *Glistening*. When the mineral reflects light in a still more disorderly manner. Although no image appears, yet it reflects light in pretty well defined patches.

(4.) *Glimmering*. When the mineral does not reflect defined patches of light, but a mass of undefined light is spread over the glimmering surface.

(5.) *Dull.* When the mineral possesses no lustre at all.

7. *Transparency* indicates the quantity of light which passes through minerals. It is of five different degrees.

(1.) *Transparent.* When objects can be seen distinctly through the mineral.

(2.) *Semi-transparent.* When an object is visible through the mineral, but its shape cannot be distinctly made out.

(3.) *Translucent.* When light passes through the mineral, but objects cannot be seen through it.

(4.) *Translucent on the edges.* When light passes only through the thin edges of a mineral, while the interior remains perfectly dark.

(5.) *Opaque.* When no light at all passes through a mineral.

8. *Double refraction.* A black line drawn on paper appears double when viewed through transparent calcareous spar, in all positions except one. In that one position, the one line will be observed to overlap the other. In the position at right angles to that, the separation of the two lines is the greatest possible. The overlapping takes place in what is called the *principal section* of the crystal, and the greatest separation in a plane very nearly coinciding with the *equator of double refraction*, which is a plane at right angles to the crystallographic axis of the rhomboid.

If we cut off the summits of the rhomboid, and polish the new faces, we shall find that a pencil of light transmitted through these new faces is not divided into two. The line along which there is no double image is named the *axis of double refraction*, or the *optic axis.*

All minerals which belong to the *rhombohedral* and *pyramidal systems* of crystallization have only one axis of double refraction, and that coincident with the axis of symmetry of the crystal; while all minerals belonging to the *prismatic* system, and its subordinates, have two axes of double refraction; and all belonging to the *tessular* system have either three axes in equilibrio, or are otherwise so constituted, in reference to this property, that they do not display any double refraction at all. This interesting fact was discovered by Sir David Brewster.

The other terms employed in the subsequent descriptions will be understood without any farther explanation.

ARRANGEMENT AND DESCRIPTION

OF

MINERALS.

MINERALS, if we arrange them according to their constituents, may be divided into three classes; namely,

Class I. Acid bases.
Class II. Alkaline bases.
Class III. Neutral bases.

The first class comprehends those bodies which become acids when combined with oxygen; the second those which become alkalies when united to the same substances; and the third those bodies which are never found in nature united to oxygen, but only united to other bases, whether acid or alkaline.

The following table, exhibiting the names and constituents of the minerals described in the following treatise will be of some utility. The composition is represented in the usual way, by symbols; and that these symbols, consisting of the first or more letters of the Latin names of the substances, may be understood, an explanation of them is inserted below.*

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* Explanation of Symbols used in the following Table, exhibiting the composition of Minerals :—

Gold	Au	Boracic acid	$\dot{\text{B}}$
Silver	Ag	Barytes	Br
Arsenic	As	Bismuth	Bs
Arsenious acid	$\dot{\text{A}}\text{s}$	Carbon	C
Arsenic acid	$\bar{\text{A}}\text{s}$	Carbonic acid	$\dot{\text{C}}$
Ammonia	Am	Chromium	Ch
Alumina	Al	Oxide of chromium	Çh
Boron	B	Chromic acid	$\dot{\text{C}}\text{h}$

TABLE EXHIBITING THE ARRANGEMENT AND CHEMICAL CONSTITUTION OF MINERALS.

Class I. ACID BASES.

Genus I. Carbon.

Species
1. **Diamond, C.**
2. **Graphite.**

Columbium	Cl	Nitric acid	Ṅt
Columbic acid	Ċl	Phosphorus	Ph
Lime	Cal	Phosphoric acid	Ṗh
Cerium	Cr	Lead	Pl
Protoxide of do.	C̲r	Palladium	Pal
Peroxide of do.	C̄r	Platinum	Plt
Cobalt	Ċb	Rhodium	R
Oxide of cobalt	c̣b	Silica	S
Copper	Ċp	Sulphur	Sl
Red oxide of do.	C̲p	Sulphuric acid	Ṡl
Black oxide of do.	C̣p	Selenium	Sel
Chlorine	Chl	Selenic acid	Ṡel
Iron	F	Antimony	St
Protoxide of iron	f̲	Protoxide of do.	s̲t
Peroxide of iron	f̣	Deutoxide of do.	ṣt
Fluoric acid	Ḟl	Tin	Sta
Glucina	G	Oxide of tin	Ṣta
Mercury	H	Strontian	Str
Iridium	I	Tellurium	Tl
Potash	K	Tungsten	Tn
Lithia	L	Tungstic acid	Ṫn
Mellitic acid	Ṁel	Titanium	Tt
Molybdenum	Ml	Titanic acid	Ṫt
Molybdic acid	Ṁl	Thorina	Th
Magnesia	Mg	Vanadium	Vn
Manganese	Mn	Vanadic acid	V̇n
Protoxide of do.	m̲n	Uranium	Ur
Sesquioxide of do.	ṃn	Protox of uranium	U̲r
Binoxide of do.	ṃṇ	Peroxide of do.	ụr
Muriatic acid	M	Zinc	Z
Soda	N	Oxide of zinc	Ẓ
Nickel	Nk	Zirconia	Zr
Oxide of nickel	ṇk	Yttria	Y

Species
3. Anthracite.
4. Pitcoal.
5. Asphalt.
6. Elastic bitumen.
7. Retinasphaltum.
8. Scheererite.
9. Mineral tallow.
10. Amber.
11. Highgate resin.

Genus II. BORON.

Sp.
1. Boracic acid, $\bar{B}$.

Genus III. SILICON.

Sp.
1. Quartz, S.
2. Kilpatrick quartz, $18S+Aq$.
3. Chalcedony.
4. Flint.
5. Opal.
6. Jasper.
7. Basanite.

Genus IV. PHOSPHORUS.

V. SULPHUR.

Sp.
1. Native sulphur.

Genus VI. SELENIUM.

VII. TELLURIUM.

Sp.
1. Native tellurium, 11TlF?

Genus VIII. ARSENIC.

Sp.
1. Native arsenic, As.
2. Arsenious acid, $\dot{A}s$.
3. Arsenic acid, $\bar{A}s$.

Species
4. Sulphide of arsenic, $AsSl$.
5. Sesquisulphide of do., $AsSl^{1\frac{1}{2}}$.

Genus IX. Antimony.

Sp.
1. Native antimony, St.
2. Arseniet of antimony, As^2St.
3. Protoxide of antimony, $\underset{\cdot}{S}t$.
4. Sesquisulphide of do., $StSl^{1\frac{1}{2}}$.
5. Red antimony, $2StSl^{1\frac{1}{2}}+\underset{\cdot}{S}l$.

Genus X. Chromium.

XI. Molybdenum.

Sp.
1. Bisulphide of molybd., $MlSl^2$.

Genus XII. Tungsten.

XIII. Columbium.

XIV. Titanium.

Sp.
1. Native titanium, Tt.
2. Protoxide of do., $\underset{\cdot}{T}t$.
3. Titanic acid, $\dot{T}t$.

Genus XV. Vanadium.

Class II. ALKALINE BASES.

Genus I. Ammonia.

Sp.
1. Sal ammoniac, $Am\,\dot{M}$.
2. Sulphate of ammonia, $Am\,\dot{S}l$.

Genus II. Potassium.

Sp.
1. Nitrate of potash, $K\dot{N}t$.

Genus III. SODIUM.

Species

1. Carbonate of soda, $N\dot{C}$.
2. Sesquicarbonate of do., $N\dot{C}^{1\frac{1}{2}}$.
3. Nitrate of soda, $N\dot{N}t$.
4. Hydrous sulphate of do., $N\dot{S}l+10Aq$.
5. Anhydrous sulphate of do., $N\dot{S}l$.
6. Borax, $N\dot{B}^2$.
7. Common salt, NChl.

Genus IV. LITHIUM.

V. BARIUM.

Sp.

1. Carbonate of barytes, $Br\dot{C}$.
2. Sulphate of do., $Br\dot{S}$.
3. Calcareo-sulphate of do., $Cal\dot{S}+2\frac{1}{2}Br\dot{S}$.
4. Baryto-calcite, $Cal\dot{S}+1\frac{1}{2}Br\dot{S}$.
5. Sulphato-carbonate of barytes, $Br\dot{S}+2Br\dot{C}$.

Genus VI. STRONTIUM.

Sp.

1. Green carbonate of strontian, $10Str\dot{C}+Cal\dot{C}$.
2. Brown carbonate of do., $7Str\dot{C}+Cal\dot{C}$.
3. Sulphate of strontian, $Str\dot{S}l$.
4. Baryto-sulphate of do., $7Str\dot{S}+3Br\dot{S}l$.
5. Calcareo-sulphate of do., $7Str\dot{S}+2Cal\dot{S}l$.
6. Stromnite, $4Str\dot{C}+Br\dot{S}l+\frac{1}{4}Cal\dot{C}$.

Genus VII. CALCIUM.

Sp.

1. Calcareous spar, $Cal\dot{C}$.
2. Arragonite, $Cal\dot{C}$.
3. Subsesquicarbonate of lime, $Cal^{1\frac{1}{2}}\dot{C}+Aq$.
4. Hydrous sulphate of lime, $Cal\dot{S}l+2Aq$.
5. Anhydrous sulphate of do., $Cal\dot{S}$.
6. Siliceous sulphate of do., $3Cal\dot{S}l+S$.
7. Subsesquiphosphate of do., $6Cal^{1\frac{1}{2}}Ph+CalChl$.
8. Fluor spar, $Cal\dot{F}l$.
9. Sesquisilicate of lime, $CalS^{1\frac{1}{2}}$.
10. Bisilicate of lime, $CalS^2$.
11. Wollastonite, $4CalS^2+NS^3$.

Species

12. Tersilicate of lime, $\mathrm{CalS^3}$.
13. Dysclasite, $\mathrm{5CalS^4+CalS^2+9Aq}$.
14. Sesquihydrous arseniate of do., $\mathrm{Cal\bar{A}s+1\frac{1}{2}Aq}$.
15. Bisesquihydrous arseniate of do., $\mathrm{Cal\dot{A}s+2\frac{1}{2}Aq}$.
16. Tungstate of lime, $\mathrm{Cal\dot{T}n}$.
17. Glauberite, $\mathrm{Cal\dot{S}l+N\dot{S}l}$.
18. Calcareo-carbonate of barytes, $\mathrm{Cal\dot{C}+Br\dot{C}}$.
19. Bicalcareo-carbonate of barytes, $\mathrm{2Cal\dot{C}+Br\dot{C}}$.
20. Baryto-fluate of lime, $\mathrm{3CalFl+Br\dot{S}}$.
21. Xanthite, $\mathrm{6CalS+5AlS}$.
22. Borosilicate of lime, $\mathrm{3CalS^3+Cal\dot{B}^2+2\frac{1}{2}Aq}$.
23. Botryolite, $\mathrm{4CalS^2+CalB^2+2\frac{1}{2}Aq}$.
24. Colophonite, $\mathrm{CalS+\underline{f}S}$.
25. Ilvaite, $\mathrm{CalS+3\underline{f}S}$.
26. Hedenbergite, $\mathrm{CalS^2+\underline{f}S^2}$.
27. Ligurite, $\mathrm{2\dot{C}alS^3+AlS}$.
28. Sphene, $\mathrm{CalS^3+Cal\dot{T}t}$.
29. Raphilite, $\mathrm{CalS^3+(\frac{2}{3}Al+\frac{1}{3}\underline{f})S^2+(\frac{1}{2}K+\frac{1}{2}Mg)S^2}$.
30. Polyadelphite, $\mathrm{5CalS+4(\frac{5}{6}\underline{f}+\frac{1}{6}\underline{mn})S+2MgS+AlS}$.

Genus VIII. MAGNESIUM.

Sp.

1. Hydrate of magnesia, $\mathrm{Mg+Aq}$.
2. Carbonate of do., $\mathrm{Mg\dot{C}}$.
3. Hydro-carbonate of do., $\mathrm{5Mg\dot{C}^2+MgAq^{1\frac{1}{2}}}$.
4. Sulphate of magnesia, $\mathrm{Mg\dot{S}l+7Aq}$.
5. Reissite, $\mathrm{16N\dot{S}l+9Mg\dot{S}l}$.
6. Bloedite, $\mathrm{3NChl+4N\dot{S}l+5Mg\dot{S}l}$.
7. Biborate of magnesia, $\mathrm{Mg\dot{B}^2}$.
8. Hydrous boracite, $\mathrm{Cal\dot{B}^2+Mg\dot{B}^2+5\frac{1}{2}Aq}$.
9. Chrysolite, MgS.
10. Hemolite, $\mathrm{5MgS+11MgAq^2+Mgf}$.
11. Common serpentine, $\mathrm{MgS+1\frac{1}{2}Aq}$.
12. $\left\{\begin{array}{l}\text{Nephrite,}\\ \text{Precious serpentine,}\end{array}\right\}\mathrm{MgS^{1\frac{1}{2}}+1Aq}$.
13. Picrosmine, $\mathrm{MgS^2+\frac{1}{2}Aq}$.
14. Schiller spar, $\mathrm{MgS^2+1Aq}$.
15. Tersilicate of magnesia, $\mathrm{MgS^3+\frac{1}{3}Aq}$.
16. Hydrous tersilicate of do., $\mathrm{MgS^3+AlS^3+4Aq}$.
17. Magnesite, $\mathrm{MgS^3+2Aq}$.
18. Quincite, $\mathrm{4MgS^3\pm fS^3+8\frac{1}{2}Aq}$.
19. Ferro-carbonate of magnesia, $\mathrm{9Mg\dot{C}+Cal\dot{C}}$.

Species
20. Calcareo-carbonate of do., $\mathrm{Mg\dot{C}+Cal\dot{C}}$, &c.
21. Wagnerite, $\mathrm{Mg^{2}\dot{P}h}$.
22. Chondrodite, $\mathrm{6MgS+Mg\dot{F}l}$.
23. Potash-bisilicate of magnesia, $\mathrm{13MgS^{2}+KS^{2}}$.
24. Venetian talc, $\mathrm{MgS^{2}+MgS^{3}+\tfrac{1}{2}Aq}$.
25. White augite, $\mathrm{MgS^{2}+CalS^{2}}$.
26. Pyroxene, $\mathrm{CalS^{2}+(\tfrac{2}{3}Mg+\tfrac{1}{3}f)S^{2}}$.
27. Jeffersonite, $\mathrm{4CalS^{3}++3mnS^{3}+2fS^{3}}$.
28. Amphibole, $\mathrm{CalS^{3}+3MgS^{2}}$.
29. Norwegian tremolite, $\mathrm{2CalS^{3}+MgS^{3}}$.
30. Retinalite, $\mathrm{3MgS^{2}+2NS+8\tfrac{1}{2}Aq}$.
31. Hyperstene, $\mathrm{2MgS^{2}+3\underline{f}S^{2}}$.
32. Humboldtilite, $\mathrm{3CalS^{2}+MgS^{2}}$.
33. Hyalosiderite, $\mathrm{2MgS+\underline{f}^{2}S}$.
34. Anthophyllite, $\mathrm{3MgS^{2}+\underline{f}S^{2}}$.
35. Mellilite, $\mathrm{3MgS+2CalS+\underline{f}S^{2}}$.
36. Mountain cork, $\mathrm{CalS^{2}+MgS^{2}+\underline{f}S^{2}}$.
37. Hydrous anthophyllite, $\mathrm{4MgS^{3}+\underline{f}S^{3}+KS^{3}+7\tfrac{1}{2}Aq}$.

Genus IX. ALUMINUM.

I. *Pure or combined with Bases.*

Sp.
1. Sapphire, Al.
2. Spinell, $\mathrm{MgAl^{6}}$.
3. Ceylanite, $\mathrm{2MgAl^{4}+\underline{f}S}$.
4. Automalite or Gahnite, $\mathrm{ZAl^{4}}$.
5. Sapphirine, $\mathrm{MgAl^{4}}$.
6. Candite, $\mathrm{8MgAl^{2}+5\underline{f}Al^{2}}$.
7. Dysluite, $\mathrm{5\underline{f}Al+2ZAl+1\underline{mn}Al}$.

II. *Simple Salts of Alumina.*

Sp.
1. Gibbsite or hydrate, AlAq.
2. Bihydrate of alumina, $\mathrm{AlAq.^{2}}$
3. Diaspore or dihydrate of do., $\mathrm{Al^{2}Aq}$.
4. Mellate of do., $\mathrm{AlMel+4Aq}$.
5. Aluminite, $\mathrm{Al^{2}\dot{S}l+9Aq}$.
6. Sulphate of alumina, $\mathrm{Al\dot{S}l+6Aq}$.
7. Fluellite, $\mathrm{Al\dot{F}l}$?
8. Tourquois, $\mathrm{Al^{3}\dot{P}h+2\tfrac{1}{2}Aq}$.
9. Andalusite, $\mathrm{Al^{2}S}$.

Species

10. Hydrous trisilicate of alumine, $\mathrm{Al^3S+5Aq}$.
11. Bucholzite, AlS.
12. Gilbertite, $\mathrm{7AlS+(\frac{4\cdot75}{10}Cal+\frac{3}{10}Mg+\frac{2\cdot25}{10}f)S^2+1\frac{1}{2}Aq}$.
13. Hydrous bucholzite, $\mathrm{5Al\dot{S}+1Aq}$.
14. Halloylite, $\mathrm{2Al\dot{S}+Al\dot{S}^2+4Aq}$.
15. Pholerite, $\mathrm{1\frac{1}{2}AlS+Aq}$.
16. Worthite, $\mathrm{5AlS+Al\bar{A}q}$.
17. Cyanite, $\mathrm{Al^{1\frac{1}{2}}S}$.
18. Allophane, $\mathrm{2AlS+Al^2S+10Aq}$.
19. Tuesite, $\mathrm{3AlS+2AlS^{1\frac{1}{2}}+3Aq}$.
20. Nacrite, $\mathrm{AlS^2}$.
21. Fullers' earth, $\mathrm{AlS^2+2Aq}$.
22. Davidsonite, $\mathrm{AlS^{2\frac{1}{2}}}$.
23. Lenzinite, $\mathrm{AlS+1Aq}$.
24. Quatersilicate of Alumina, $\mathrm{AlS^4}$.

III. *Double anhydrous aluminous Salts.*

Sp.

1. Cryolite, $\mathrm{Al\dot{F}l+N\dot{F}l}$.
2. Topaz, $\mathrm{3AlS+Al\dot{F}l}$.
3. Pycnite, $\mathrm{6AlS+Al\dot{F}l^2}$.
4. Ambligonite, $\mathrm{2Al^2\dot{P}h+L^2\dot{P}h}$.
5. Fibrolite, $\mathrm{2AlS+Al^2S}$.
6. Nepheline, $\mathrm{3AlS+NS}$.
7. Sodalite, $\mathrm{2AlS+NS}$.
8. Idocrase, $\mathrm{AlS+CalS}$.
9. Grossularite, $\mathrm{AlS+CalS}$.
10. Melanite, $\mathrm{AlS+(\frac{23}{46}Mg+\frac{9}{46}\underline{f}+\frac{8}{46}Cal+\frac{6}{46}mn)S}$.
11. Garnet, $\mathrm{AlS+fS}$ and $\mathrm{CalS+\underline{f}S}$.
12. Essonite, $\mathrm{\underline{f}S+4CalS+4AlS}$.
13. Brown manganese garnet, $\mathrm{CalS+AlS+\underline{f}S+\underline{mn}S}$.
14. Pyrope, $\mathrm{10AlS+5(\frac{10}{23}Mg+\frac{8}{23}Cal+\frac{5}{23}\underset{.}{C}hr)S+3(\frac{3}{4}\underline{f}+\frac{1}{4}\underline{mn})S^2}$.
15. Zoisite, $\mathrm{2AlS+CalS}$.
16. Meionite or scapolite, $\mathrm{2AlS+CalS}$.
17. Prehnite, $\mathrm{2AlS+CalS^{1\frac{1}{2}}+\frac{1}{2}Aq}$.
18. Anhydrous scolezite, $\mathrm{3AlS+CalS^3}$.
19. Iolite, $\mathrm{9AlS+3MgS^2+fS}$.
20. Hydrous iolite, $\mathrm{3AlS+1(\frac{3}{4}Mg+\frac{1}{4}f)S^2+2Aq}$.
21. Staurotide, $\mathrm{4AlS+f^6S}$.
22. Gehlenite, $\mathrm{3Al^{1\frac{1}{2}}S+3(\frac{8}{9}Cal+\frac{1}{9}f)^{1\frac{1}{2}}S+Aq}$.
23. Trollite, $\mathrm{2AlS^2+1\frac{8}{11}Mg+\frac{2}{11}K+\frac{1}{11}f)S^2+\frac{1}{2}Aq}$.
24. Fahlunite, $\mathrm{3AlS+1\frac{6}{10}Mg+\frac{3}{10}f+\frac{1}{10}mn)S^2+2Aq}$.

Species
25. Anhydrous fahlunite, $3\mathrm{AlS}+\mathrm{fS}^{2}+1(\frac{2}{3}\mathrm{Mg}+\frac{1}{3}\mathrm{Cal})\mathrm{S}^{2})$.
26. Leucite, $3\mathrm{AlS}^{2}+\mathrm{KS}^{2}$.
27. Pipe Stone, $2\mathrm{AlS}^{2}+(\frac{40}{49}\mathrm{N}+\frac{8}{49}\mathrm{Cal}+\frac{1}{49}\mathrm{Mg})\mathrm{S}^{2}+\mathrm{Aq}$.
28. Murchisonite, $3\mathrm{AlS}^{3\frac{1}{2}}+\mathrm{kS}^{3\frac{1}{2}}$.
29. Gabronite, $3\mathrm{AlS}^{2}+(\mathrm{K,N})\mathrm{S}^{2}$.
30. Icespar, $6\mathrm{AlS}^{2\frac{1}{2}}+\mathrm{KS}^{2\frac{1}{2}}$.
31. Felspar, $3\mathrm{AlS}^{3}+\mathrm{KS}^{3}$.
32. Glassy felspar, $4\mathrm{AlS}^{3}+(\frac{5}{9}\mathrm{K}+\frac{4}{9}\mathrm{N})\mathrm{S}^{3}$.
33. Albite, $3\mathrm{AlS}^{3}+\mathrm{NS}^{3}$.
34. Anorthite, $7\mathrm{AlS}+2\mathrm{CalS}+\mathrm{MgS}$.
35. Labradorite, $3\mathrm{AlS}^{2}+(\frac{2}{3}\mathrm{Cal}+\frac{1}{3}\mathrm{N})\mathrm{S}$.
36. Kaolin, $4(\mathrm{Al}+\mathrm{f})\mathrm{S}+(\mathrm{Cal}+\mathrm{K})\mathrm{S}$.
37. Leelite, $\mathrm{AlS}^{7}+\mathrm{fS}^{7}+\mathrm{KS}^{7}$.
38. Spodumene, $4\mathrm{AlS}^{2}+\mathrm{LS}^{2}$.
39. Petalite, $2\mathrm{AlS}^{4}+\mathrm{LS}^{4}$.

IV. *Double hydrous aluminous Salts soluble in water.*

Sp.
1. Ammonia alum $3\mathrm{Al}\dot{\mathrm{S}}\mathrm{l}+\mathrm{Am}\dot{\mathrm{S}}\mathrm{l}+25\mathrm{Aq}$.
2. Potash alum, $3\mathrm{Al}\dot{\mathrm{S}}\mathrm{l}+\mathrm{K}\dot{\mathrm{S}}\mathrm{l}+25\mathrm{Aq}$.
3. Soda alum, $3\mathrm{Al}\dot{\mathrm{S}}\mathrm{l}+\mathrm{N}\dot{\mathrm{S}}\mathrm{l}+20\mathrm{Aq}$.

V. *Double hydrous aluminous Sulphates and Phosphates insoluble in water.*

Sp.
1. Alumstone, $3\mathrm{Al}^{3}\dot{\mathrm{S}}\mathrm{l}+\mathrm{K}\dot{\mathrm{S}}\mathrm{l}+8\mathrm{Aq}$.
2. Wavellite, $18\mathrm{Al}^{2}\dot{\mathrm{P}}\mathrm{h}+\mathrm{Al}\dot{\mathrm{F}}\mathrm{l}^{2}+29\mathrm{Aq}$.
3. Lazulite, $4\mathrm{Al}^{2}\dot{\mathrm{P}}\mathrm{h}+\mathrm{Mg}^{2}\dot{\mathrm{P}}\mathrm{h}+1\frac{1}{2}\mathrm{Aq}$.
4. Blue spar, $3\mathrm{Al}^{2}\dot{\mathrm{P}}\mathrm{h}+\mathrm{Mg}^{2}\dot{\mathrm{P}}\mathrm{h}$.

VI. *Double hydrous aluminous Silicates, or Zeolites.*

Sp.
1. Stellite, $4\mathrm{CalS}^{2}+\mathrm{MgS}^{2}+\mathrm{AlS}+2\frac{1}{2}\mathrm{Aq}$.
2. Thomsonite, $3\mathrm{AlS}+\mathrm{CalS}+2\frac{1}{2}\mathrm{Aq}$.
3. Natrolite, $3\mathrm{AlS}+\mathrm{NS}^{3}+2\mathrm{Aq}$.
4. Mesolite, $3\mathrm{AlS}+(\mathrm{Cal,N})\mathrm{S}^{3}+3\mathrm{Aq}$.
5. Scolezite, $3\mathrm{AlS}+\mathrm{CalS}^{3}+3\mathrm{Aq}$.
6. Zeuxite, $3\mathrm{AlS}+\mathrm{f}^{2}\mathrm{S}+\mathrm{Aq}$.
7. Ittnerite, $3\mathrm{AlS}+(\frac{2}{3}\mathrm{N}+\frac{1}{3}\mathrm{Cal})\mathrm{S}+2\mathrm{Aq}$.
8. Plinthite, $3\mathrm{AlS}+2(\frac{7}{8}\mathrm{f}+\frac{1}{8}\mathrm{Cal})\mathrm{S}+6\mathrm{Aq}$.
9. Bonsdorfite, $3\mathrm{AlS}+(\frac{3}{4}\mathrm{Mg}+\frac{1}{4}\mathrm{f})\mathrm{S}^{2}+2\mathrm{Aq}$.
10. Chalilite, $4(\frac{7}{8}\mathrm{Al}+\frac{1}{8}\mathrm{f})\mathrm{S}+(\frac{2}{3}\mathrm{Cal}+\frac{1}{3}\mathrm{N})\mathrm{S}+4\mathrm{Aq}$.

Species

11. Karpholite, $7AlS+3(\frac{17}{19}mn+\frac{2}{19}f)S^{1\frac{1}{2}}+6Aq.$
12. Antrimolite, $5AlS+(\frac{3}{4}Cal+\frac{1}{4}K)S^{3}+5Aq.$
13. Glottalite, $AlS^{1\frac{1}{2}}+CalS+3Aq.$
14. Harringtonite, $3AlS^{1\frac{1}{2}}+(\frac{2}{3}Cal+\frac{1}{3}N)S+2Aq.$
15. Soapstone, $AlS^{1\frac{1}{2}}+2MgS^{1\frac{1}{2}}+4Aq.$
16. Killinite, $6\frac{1}{2}AlS^{1\frac{1}{2}}+(\frac{1}{2}K+\frac{1}{2}f)S^{2}+4Aq.$
17. Lomonite, $3AlS^{2}+CalS^{2}+5Aq.$
18. Chabazite, $3AlS^{2}+CalS^{3}+6Aq.$
19. Levyine, $3AlS^{2}+(\frac{10}{11}Cal+\frac{1}{11}Mg)S^{2}+6\frac{1}{2}Aq.$
20. Analcime, $3AlS^{2}+NS^{2}+2Aq.$
21. Lehuntite, $3AlS^{2}+(\frac{8}{9}N+\frac{1}{9}Cal)S^{2}+3Aq.$
22. Cluthalite, $4(\frac{19}{20}Al+\frac{1}{20}Mg)S^{2}+(\frac{1}{2}N+\frac{1}{2}f)S^{2}+3Aq.$
23. Hydrolite, $2AlS^{3}+(\frac{1}{2}f+\frac{1}{2}K)S+9Aq.$
24. Erinite, $6AlS^{2}+fS^{4}+16Aq.$
25. Pyrophyllite, $8AlS^{2}+MgS^{2}+3Aq.$
26. Agalmatolite, $13AlS^{2}+KS+4Aq.$
27. Stilbite, $3AlS^{3}+CalS^{3}+6Aq.$
28. Heulandite, $4AlS^{3}+CalS^{3}+6Aq.$
29. Brewsterite, $3AlS^{3}+(\frac{1}{3}Br+\frac{2}{3}Str)S^{3}+6\frac{1}{2}Aq.$
30. Harmotome, $4AlS^{3}+BrS^{3}+6Aq.$
31. Phillipsite, $4AlS^{2}+(Cal,K)S^{2}+6Aq.$
32. Morvenite, $5AlS^{4}+CalS^{4}+11Aq.$
33. Apophyllite, $7CalS^{3}+KS^{3}+15Aq.$
34. Rhodalite, $3AlS^{4}+\underline{f}S^{4}+16Aq.$
35. Neurolite, $5AlS^{4}+(\frac{2}{3}Cal+\frac{1}{3}Mg)S^{4}+2\frac{1}{2}Aq.$
36. Comptonite, $8AlS+2CalS^{2}+NS+9Aq.$
37. Hexagonal talc, $5AlS+4(\frac{5}{6}Mg+\frac{1}{6}Cal)^{2}S+4f^{2}S+7Aq.$
38. Chlorite, $Al^{1\frac{1}{2}}S+(\frac{5}{12}Mg+\frac{7}{12}f)^{1\frac{1}{2}}S+Aq.$
39. Brown chlorite, $7AlS^{2}+3\frac{1}{2}\underline{f}S+KS^{2}+MgS^{2}+2Aq.$

VII. *Triple aluminous Salts.*

Sp.

1. Mica, $15AlS+1\frac{1}{2}KS^{3}+fS^{3}.$
   Black Mica, $6AlS+6MgS+4fS^{2}+KS.$
   Lepidolite, $6AlS+LS+KS.$
2. Elœolite, $3AlS+(\frac{1}{6}K+\frac{5}{6}N)S.$
3. Epidote, $4AlS+3CalS+2fS$?
4. Axinite, $AlS+(\frac{39}{100}Cal+\frac{35}{100}f+\frac{26}{100}mn)S^{2}.$
5. Tourmalin,
6. Bytownite, $5AlS+3(\frac{11}{12}Cal+\frac{1}{12}Mg)S^{2}+3(\frac{2}{3}N+\frac{1}{3}f)S^{2}.$
7. Vermiculite, $AlS^{2}+2MgS^{2}+fS^{2}+3Aq.$
8. Lithomarge, $7AlS^{2}+KS^{2}+3Aq.$

Species
9. Latrobite, $5AlS+(\frac{2}{3}Cal+\frac{1}{3}K)S$
10. Withamite, $3AlS^2+2fS^2+CalS^2+Aq$.
11. Isapyre, $3AlS^2+2fS^2+2CalS$.
12. Kirwanite, $AlS^2+fS+CalS+Aq$.
13. Scorilite, $3AlS^2+CalS^2+fS^3$.
14. Sordawalite, $3AlS^2+2fS^2+2MgS+2Aq$.
15. Couzeranite, $6AlS^2+4CalS+(\frac{1}{2}K+\frac{1}{2}N)S$.

VIII. *Quadruple aluminous Salts.*

Sp.
1. Gieseckite, $10AlS+1\frac{1}{3}KS^4+(\frac{1}{6}mn+\frac{2}{6}Mg+\frac{3}{6}f)S^2+3Aq$.
2. Nutallite, $3AlS+2(Cal,f,k)S$.
3. Phyllite, $9AlS+3fS+3MgS+KS+4Aq$.
4. Huronite, $13AlS+8CalS^2+4fS^2+2MgS^2+11Aq$.
5. Erlanite, $3AlS^2+CalS^2+MgS^2+(\frac{1}{3}N+\frac{2}{3}f)S$.
6. Pinite, $8\frac{1}{2}AlS^2+KS^2+2(\frac{9}{20}f+\frac{11}{20}Mg)S+Aq$.
7. Glauconite, $3fS^{2\frac{1}{4}}+2(\frac{7}{11}Al+\frac{4}{11}K)S^{2\frac{1}{4}}+MgS^{2\frac{1}{4}}+5Aq$.
8. Mountain leather, $10AlS^3+7CalS^3+3fS^3+2MgS^2+40Aq$.
9. Pearl stone, $6AlS^5+fS^4+CalS^4+KS^4+4Aq$.
10. Saussurite, $7AlS^7+5CalS^7+2fS^7+5MgS^6$.
11. Pitchstone, $13\frac{1}{2}AlS^5+4NS^4+3CalS^4+2fS^4$.
12. Obsidian, $3AlS^9+2NS^9+2fS^9+CalS^9$.

Genus X. GLUCINUM.

Sp.
1. Phenakite, GS^2.
2. Euclase, $GS+2AlS$.
3. Emerald, GS^3+2Als^3.
4. Chrysoberyl, $5\frac{1}{2}GAl^6+fAl$.

Genus XI. YTTRIUM.

Sp.
1. Phosphate of yttria, $Y^{1\frac{1}{3}}\dot{P}h$.
2. Yttrotantalite,
    1. Black, $5Y^2\dot{C}l+f^2\dot{C}l+4\frac{1}{2}Cal^3\dot{T}n$.
    2. Yellow, $9Y^3\dot{C}l+(Cal,Ur.f)^3\dot{C}l$.
    3. Brownish black, $7Y^4\dot{C}l+(Cal,Ur,f)^4\dot{C}l$.
3. Fergusonite, $4\frac{1}{2}Y^5\dot{C}l+(Cr,Zr,Ur,f)^5\dot{C}l$.
4. Gadolinite, $2YS+(G,Cr)S$.
5. Orthite, $12\frac{1}{2}AlS+6CrS+5\frac{1}{2}fS+4\frac{1}{3}CalS+1\frac{1}{2}mnS+YS+9Aq$.
6. Pyrorthite, $2\frac{1}{2}CrS+2Al^3S+1\frac{1}{2}f^3S+Y^3S+\frac{1}{2}Cal^3S+\frac{1}{3}mn^3S$.

Genus XII. CERIUM.

Species

1. Carbonate of cerium.
2. Cerite, $CrS+Aq$.
3. Thulite, $3CrS^2+3CalS^2+1\frac{1}{2}KS^2$.
4. Fluate of cerium, $\underline{C}r\dot{F}l+\underset{\cdot}{C}r\dot{F}l$.
5. Subsesquifluate of do., $\underset{\cdot}{C}r^{1\frac{1}{2}}\dot{F}l+\frac{1}{2}Aq$.
6. Yttrocerite, $7Cal\dot{F}l+\underset{\cdot}{C}r\dot{F}l+Y\dot{F}l$.
7. Allanite, $2fS+2CrS+CalS+\frac{3}{4}AlS$.
8. Pyrochlore.

Genus XIII. ZIRCONIUM.

Sp.

1. Zircon, ZrS.
2. Sillimanite, $3AlS+ZrS$.
3. Æschynite, $5Zr\dot{T}t+2Cr\dot{T}t+Cal\dot{T}t^2+\frac{1}{2}f\dot{T}t$.
4. Eudyalite, $3\frac{1}{2}NS^2+3CalS^2+3ZrS^3+1\frac{1}{2}fS^3+\frac{1}{2}mnS3$.
5. Polymignite, $3Zr\dot{T}t+f\dot{T}t+2Y^2\dot{T}t+Cal^2\dot{T}t+\frac{1}{3}Cr^2\dot{T}t+\frac{2}{3}mn^2\dot{T}t$.

Genus XIV. THORIUM.

Sp.

1. Thorite, $2ThS+(Cal,f,mn,\ \&c.)\ S+1\frac{1}{4}Aq$.

Genus. XV. IRON.

I. *Uncombined, or united to a Simple Substance.*

Sp.

1. Native iron, F.
2. Meteoric iron, $F^{10}Nk$.
3. Magnetic iron ore, $\underline{f}\underset{\cdot}{f}^2$.
4. Specular iron ore, $\underset{\cdot}{f}$.
5. Crucite, $2Al\underset{\cdot}{f}^3+Cal\underset{\cdot}{f}^3$.
6. Manganesian iron ore, $\underset{\cdot}{f}^3\underset{\cdot}{m}n$.
7. Franklinite, $\underline{m}n\underset{\cdot}{f}^2+Z\underset{\cdot}{f}^2$.
8. Dihydrated peroxide, $\underset{\cdot}{f}^2Aq$.
9. Hydrated peroxide, $\underset{\cdot}{f}Aq$.
10. Sulphuret of iron.

$$1.\ \begin{cases}180\ \text{Sulphuret.}\\ 1\ \text{Bisulphuret.}\end{cases}$$

$$2.\ \begin{cases}5\ \text{Sulphuret.}\\ 1\ \text{Bisulphuret.}\end{cases}$$

Species

3. $\left\{\begin{array}{l}\text{2 Sulphuret.}\\ \text{1 Bisulphuret.}\end{array}\right.$

11. Bisulphuret of iron, FSl^2.
12. Radiated pyrites, FSl^2.
13. Sesquiarseniet of iron, $FAs^{1\frac{1}{2}}$.

II. *Oxygen Salts of Iron.*

1. *Simple Oxygen Salts.*

Sp.

1. Carbonate of iron, $\underline{f}\dot{C}$.
2. Junkerite, $\underline{f}\dot{C}$.
3. Bisulphated peroxide of do., $\underset{\cdot}{f}\dot{S}l^2+5Aq$.
4. Sulphated peroxide of do., $\underset{\cdot}{f}\dot{S}l+5Aq$.
5. Mullicite, $\underline{f}^2\dot{P}h+4Aq$.
6. Subsesquiphosphate of iron, $\underline{f}^{1\frac{1}{2}}\dot{P}h+2\frac{1}{2}Aq$.
7. Vivianite, $\underline{f}^{1\frac{1}{2}}\dot{P}h+3\frac{1}{2}Aq$.
8. Diarsenite of iron, $\underset{\cdot}{f}^2\bar{A}s+6Aq$.
9. Subsesqui-arseniate of iron, $\underset{\cdot}{f}^{1\frac{1}{2}}\dot{A}s+3\frac{1}{3}Aq$.
10. Arseniate of iron, $\underline{f}\dot{A}s+2\underset{\cdot}{f}\dot{A}s+6Aq$.
11. Hydrousdisilicate of do., $\underline{f}^2S+\frac{3}{4}Aq$.
12. Chamoisite, $\underline{f}^2S+2Aq$.
13. Anhydrous silicate of iron, $\underline{f}S$.
14. Chronstedtite, $\underline{f}S+Aq$.
15. Hedenbergite, $\underline{f}S^{2\frac{1}{2}}+2Aq$.
16. Chloropal, $\underline{f}S^5+2Aq$.
17. Titaniate of iron, $\underline{f}\dot{T}t$.
18. Iserine, $\underline{f}\dot{T}t$.
19. Subsesquititaniate of iron, $\underset{\cdot}{f}^{1\frac{1}{2}}\dot{T}t$.
20. Crichtonite.
21: Nigrin, $\underset{\cdot}{f}\,Tt^5$.
22. Oxalate of iron, $\underset{\cdot}{f}\dot{O}$?

2. *Double Oxygen Salts.*

Sp.

1. Hydrous carbonate of iron, $8\underline{f}\dot{C}+9\underset{\cdot}{f}Aq$.
2. Magnesia-carbonate of do., $2\underline{f}\dot{C}+Mg\dot{C}$.
3. Manganeso-diphosphate of do., $\underline{f}^2\dot{P}h+\underline{mn}^2\dot{P}h$.
4. Alumina sulphate, $3\underline{f}\dot{S}+Al\dot{S}$.
5. Hetopizite, $2\underline{f}\dot{P}h+\underline{mn}^2\dot{P}h+Aq$.
6. Carbono-phosphate of iron, $6\underline{f}\dot{C}+\underline{f}^2\dot{P}h+3\underline{f}\underset{\cdot}{f}^5$.
7. Scorodite, $4\underline{f}^{1\frac{1}{2}}\dot{A}s+(\underline{mn},Cal,Mg)^{1\frac{1}{2}}\dot{A}s$.

Species
8. Cacoxenite, $\mathrm{AlS}+\underline{\mathrm{f}}^{2}\dot{\mathrm{Ph}}+6\mathrm{Aq}$.
9. Sulpho-arseniate of iron, $2\underline{\mathrm{f}}\dot{\mathrm{As}}+\underline{\mathrm{f}}^{1\frac{1}{2}}\dot{\mathrm{Sl}}+12\frac{1}{2}\mathrm{Aq}$.
10. Thraulite, $\underline{\mathrm{f}}\mathrm{S}^{1\frac{1}{2}}+2\underline{\mathrm{f}}\mathrm{S}^{1\frac{1}{2}}+5\mathrm{Aq}$.
11. Achmite, $4\underline{\mathrm{f}}\mathrm{S}^{2}+2\mathrm{NS}^{3}+(\frac{1}{6}\mathrm{Al}+\frac{1}{6}\mathrm{Mg}+\frac{1}{6}\mathrm{Cal}+\frac{3}{6}\mathrm{mn})\mathrm{S}^{2}$.
12. Krokidolite, $4\underline{\mathrm{f}}\mathrm{S}^{3}+\mathrm{NS}^{1\frac{1}{2}}+2\frac{1}{2}\mathrm{Aq}$.
13. Chromiron ore, $\underline{\mathrm{f}}\bar{\mathrm{Ch}}+\mathrm{Al}\bar{\mathrm{Ch}}$.
14. Arfvedsonite, $4\underline{\mathrm{f}}\mathrm{S}^{3}+\underline{\mathrm{mn}}\mathrm{S}^{3}$.
15. Knebelite, $\underline{\mathrm{f}}\mathrm{S}+\underline{\mathrm{mn}}\mathrm{S}$.
16. Columbite, $\underline{\mathrm{f}}\dot{\mathrm{Cl}}+\underline{\mathrm{mn}}\dot{\mathrm{Cl}}$.
17. Wolfram, $3\underline{\mathrm{f}}\dot{\mathrm{Tn}}+\underline{\mathrm{mn}}\dot{\mathrm{Tn}}$.
18. Ilmenite, $\underline{\mathrm{f}}\dot{\mathrm{Tt}}+\underset{\cdot}{\mathrm{f}}\dot{\mathrm{Tt}}$.
19. Titaniferous iron ore, $^{4}\dot{\mathrm{Tt}}+\underline{\mathrm{f}}^{4}\dot{\mathrm{Tt}}$. &c

3. *Triple Oxygen Salts.*

Sp.
1. Ankerite, $8\overset{\cdot}{\mathrm{Cal}}\mathrm{C}+5\mathrm{Mg}\dot{\mathrm{C}}+3\underline{\mathrm{f}}\dot{\mathrm{C}}$.
2. Pyrosmalite, $7\underline{\mathrm{f}}\mathrm{S}^{1\frac{1}{2}}+5\underline{\mathrm{mn}}\mathrm{S}^{1\frac{1}{2}}+\frac{1}{2}\mathrm{FChl}^{1\frac{1}{2}}+3\mathrm{Aq}$.
3. Commingtonite, $3\underline{\mathrm{f}}\mathrm{S}^{3}+1\frac{1}{3}\mathrm{NS}^{3}+\underline{\mathrm{mn}}\mathrm{S}^{3}+1\frac{1}{2}\mathrm{Aq}$.
4. Nontronite, $7\frac{1}{2}\underline{\mathrm{f}}\mathrm{S}^{3}+2\mathrm{AlS}^{2}+\mathrm{MgS}+20\mathrm{Aq}$.
5. Volkonskoite, $4\mathrm{ChS}^{3}+2\mathrm{MgS}^{3}+\underset{\cdot}{\mathrm{f}}\bar{\mathrm{Ch}}+14\mathrm{Aq}$.
6. Polylite, $9(\underline{\mathrm{f}},\underline{\mathrm{mn}})\mathrm{S}+4\mathrm{AlS}+3\frac{1}{3}\mathrm{CalS}^{2}$.

III. *Sulphur Salts of Iron.*

Sp.
1. Arsenical pyrites, $\mathrm{FAS}+\mathrm{FSl}+\mathrm{ASl}$.
2. Berthierite, $1\frac{1}{2}\mathrm{StSl}^{1\frac{1}{2}}+\mathrm{FSl}$.

Genus XVI. MANGANESE.

I. *Combined with Simple Bodies.*

Sp.
1. Hausmannite, $\underline{\mathrm{mn}}\underset{\cdot}{\mathrm{mn}}^{2}$.
2. Braunite, $\underset{\cdot}{\mathrm{mn}}$.
3. Manganite, $\underset{\cdot}{\mathrm{mn}}^{2}\mathrm{Aq}$.
4. Pyrolusite, $\underset{\cdot\cdot}{\mathrm{mn}}$.
5. Hydrous binoxide, $6\underset{\cdot\cdot}{\mathrm{mn}}+2\underset{\cdot}{\mathrm{mn}}+14\mathrm{Aq}$.
6. Hydrous sesquibinoxide, $3\underset{\cdot}{\mathrm{mn}}+2\underset{\cdot\cdot}{\mathrm{mn}}+5\mathrm{Aq}$.
7. Varvacite, $2\underset{\cdot\cdot}{\mathrm{mn}}+2\underset{\cdot}{\mathrm{mn}}+\mathrm{Aq}$.
8. Psilomelanite, $2\underset{\cdot\cdot}{\mathrm{mn}}^{6}\mathrm{Br}+5\underset{\cdot}{\mathrm{mn}}\mathrm{Aq}$.
9. Newkirkite, $3\underset{\cdot\cdot}{\mathrm{mn}}\mathrm{Aq}+2\underset{\cdot}{\mathrm{mn}}\underset{\cdot}{\mathrm{f}}^{2}$.
10. Sulphuret, $16\mathrm{MnSl}+\mathrm{MnSl}^{2}$.
11. Arseniet, MnAs.

II. *Oxygen Salts of Manganese.*

1. *Simple Oxygen Salts.*

Species
1. Carbonate of manganese, $\underline{m}n\dot{C}$.
2. Disilicate of do., $\underset{\cdot}{m}n^2S$.
3. Silicate of do., $\underline{m}nS$.
4. Sesquisilicate of do., $8\underline{m}n\underline{S}^{1\frac{1}{2}}+\underline{f}S^5$.
5. Bisilicate of do., $\underline{m}nS^2$.

2. *Double Oxygen Salts.*

Sp.
1. Huraulite, $6\underline{m}n\dot{P}h+2\underline{f}^2\dot{P}h+13Aq$.
2. Bustamite, $2\underline{m}nS^2+CalS^2$.
3. Ferruginous silicate of m., $3\underline{m}nS+\underline{\ }S^{1\frac{1}{2}}+2Aq$.
4. Carbosilicate of do., $\underline{m}n\dot{C}+4\underline{m}nS^2$.
5. Babingtonite.

3. *Triple Oxygen Salts.*

Sp.
1. Helvine $\underline{f}S^2+GS^2+6\underline{m}nS$.

Genus XVII. NICKEL.

I. *Combined with Simple Bodies.*

Sp.
1. Sulphuret of nickel, $NkSl$.
2. Arseniet of do., $NkAs$.
3. Subsequiarseniet of do., $Nk^{1\frac{1}{2}}As$.
4. Binarseniet of do., $NkAs^2$.
5. Antimoniet of nickel, $NkSt$.

II. *Oxygen Salts.*

Sp.
1. Diarseniate of nickel, $nk^2\dot{A}s+4Aq$.

III. *Sulphur Salts.*

Sp.
1. Sulpho-arsenite of nickel, As^2Sl+Nk^2Sl.
2. Sulpho-antimonite of do., $NkSt+NkSl$.

Genus XVIII. COBALT.

I. *Combined with Simple Bodies.*

Species
1. Sulphuret of cobalt, $CbSl^{1\frac{1}{2}}$.
2. Sesquiarseniet of do., $CbAs^{1\frac{1}{2}}$.
3. Binarseniet of do., $6\frac{1}{2}CbAs^2+FAs^2$.
4. Terarseniet of do., $9CbAs^3+4FAs^3$.
5. Cobalt ochre.

II. *Oxygen Salts.*

Sp.
1. Diarseniate of cobalt, $\underset{\cdot}{C}b^2\dot{A}s+4Aq$.
2. Disulphate of cobalt, $\underset{\cdot}{C}b^2\dot{S}l+9Aq$.

III. *Sulphur Salts.*

Sp.
1. Sulpho-arsenite of cobalt, $As^2Sl+\underset{\cdot}{C}b^2Sl$.

Genus XIX. ZINC.

I. *United to Simple Bodies.*

Sp.
1. Blende, ZSl.
2. Voltzinc, $4\frac{1}{2}ZSl+\underset{\cdot}{Z}$.
3. Seleniet of zinc, $3\frac{1}{2}ZSel^2+H^2Sl$.
4. Red zinc, $\underset{\cdot}{Z}^7\underset{\cdot}{mn}$.

II. *Oxygen Salts.*

Sp.
1. Anhydrous carbonate of zinc, $\underset{\cdot}{Z}\dot{C}$.
2. Hydrous dicarbonate of do., $\underset{\cdot}{Z}^2\dot{C}+2Aq$.
3. Anhydrous silicate of do., $\underset{\cdot}{z}S$.
4. Hydrous silicate of do., $\underset{\cdot}{z}S+\frac{1}{2}Aq$.
5. Sulphate of zinc, $\underset{\cdot}{z}\dot{S}l+9Aq$.
6. Hopeite.

III. *Sulphur Salts.*

Sp.
1. Marmatite, $7ZSL+3FSL$.

Genus XX. Lead.

I. *Native, or united to Simple Bodies.*

Species
1. Native lead, Pl.
2. Protoxide of lead, $\underline{p}l$.
3. Sesquioxide of lead, pl.
4. Sulphuret of lead, $Pl\dot{S}l$.
5. Supersulphuret of do., $Pl^7 Sl^8$.
6. Seleniet of lead, $PlSel$.
7. Bitelluret of do., $PlTl^2$.

II. *Oxygen Salts of Lead.*

1. *Simple Oxygen Salts.*

Sp.
1. Carbonate of lead, $\underline{p}l\dot{C}$.
2. Sulphate of lead, $\underline{p}l\dot{S}l$.
3. Chromate of lead, $\underline{p}l\dot{C}b$.
4. Melanochroite, $\underline{p}l^{1\frac{1}{2}}\dot{C}h$.
5. Tungstate of lead, $\underline{p}l\dot{T}n$.
6. Molybdate of lead, $\underline{p}l\dot{M}l$.
7. Trismolybdate of do., $\underline{p}l^3\dot{M}l$.

2. *Double Oxygen Salts.*

Sp.
1. Oxido-chloride of lead, $7\underline{p}l+3PlChl$.
2. Cupreo-sulphate of do., $\underline{p}l\dot{S}l+\underset{.}{c}p+Aq$.
3. Sulphato-carbonate of do., $\underline{p}l\dot{C}+\underline{p}l\dot{S}l$.
4. Sulphato-tricarbonate of do., $3\underline{p}l\dot{C}+\underline{p}l\dot{S}l$.
5. Chloro-carbonate of do., $\underline{p}l\dot{C}+PlChl$.
6. Phosphate of lead, $PlChl+4Cal^{1\frac{1}{2}}\dot{P}h+11\underline{p}l^{1\frac{1}{2}}\dot{P}h$.
7. Vanadiate of lead, $PlChl+6\underline{p}l^3\dot{V}n$.
8. Arseniate of lead, $10\underset{.}{p}l^{1\frac{1}{2}}\dot{A}s+PlChl$.
9. Cuprochromate of do., $2\underset{.}{p}l\dot{C}h+\underset{.}{c}p$.
10. Sexaluminate of do., $\underset{.}{p}lAl^6+6Aq$.

3. *Triple Oxygen Salts.*

Sp.
1. Cupreous sulphato-carbonate, $7\frac{1}{2}\underset{.}{p}l\dot{S}l+5\underset{.}{p}l\dot{C}+4\underset{.}{c}p\dot{C}$.

Species
2. Hediphan, $4Cal^{1\frac{1}{2}}\dot{P}h+2Cal^{1\frac{1}{2}}\dot{A}s+5\underset{\cdot}{p}l^{1\frac{1}{2}}\dot{A}s+PlChl$.

III. *Sulphur Salts.*

Sp.
1. Zinkenite, $2StSl^{1\frac{1}{2}}+PlSl$.
2. Plagionite, $3StSl^{1\frac{1}{2}}+2PlSl$.
3. Jamesonite, $4StSl^{1\frac{1}{2}}+3PlSl$.
4. Feather ore, $StSl^{1\frac{1}{2}}+PlSl$.
5. Nagyag of tellurium ore, $6AuTl^6+7Pl^6+StSl$.

Genus XXI. TIN.

Sp.
1. Peroxide of tin, Sta^3S.
2. Cupreous sulphuret of do., $FSl^2+2CpSl+StaSl^4$.

Genus XXII. BISMUTH.

I. *Native, or combined with Simple Bodies.*

Sp.
1. Native bismuth, Bs.
2. Sulphuret of bismuth, $BsSl$.
3. Ferruginous arseniet of do., $3BsAs+FAs$.
4. Arsenic glance, $As^{12}Bl$.
5. Telluret of bismuth.
6. Oxide of bismuth, $7\frac{1}{2}\underset{\cdot}{b}s+\underline{f}\dot{C}+2\frac{1}{2}Aq$.

II. *Oxygen Salts.*

Sp.
1. Carbonate of bismuth.
2. Silicate of bismuth, $\underset{\cdot}{b}sS^{1\frac{1}{2}}$.

III. *Sulphur Salts.*

Sp.
1. Needle ore of bismuth, $5Bs^2Sl+3Cp^2\dot{S}l+2Pl^2Sl$.

Genus XXIII. COPPER.

I. *Native, or combined with Simple Bodies.*

Sp.
1. Native copper, Cp.
2. Red oxide of copper, $\underline{c}p$.
3. Black oxide of do., $\underset{\cdot}{c}p$.

Species
4. Disulphuret of do., Cp^2Sl.
5. Seleniet of copper.
6. Arseniet of do.

II. *Oxygen Salts.*

1. *Simple Oxygen Salts.*

Sp.
1. Anhydrous dicarbonate of copper, $\underset{\cdot}{c}p^2\dot{C}$.
2. Hydrous dicarbonate of do., $\underset{\cdot}{c}p^2\dot{C}+Aq$.
3. Sulphate of copper, $\underset{\cdot}{c}p\dot{S}l+5Aq$.
4. Brochantite.
5. Tetrasulphate of copper, $\underset{\cdot}{c}p^4\dot{S}l+4\frac{2}{3}Aq$.
6. Hydrous diphosphate of copper, $\underset{\cdot}{c}p^2\dot{P}h+Aq$.
7. Pelokonite.
8. Hydrous sub-bisesquiphosphate of copper, $\underset{\cdot}{c}p^{2\frac{1}{2}}\dot{P}h+3Aq$.
9. Hydrous sesquisilicate of do., $\underset{\cdot}{c}pS^{1\frac{1}{2}}+Aq$.
10. Bisilicate of copper, $\underset{\cdot}{c}pS^2+2Aq$.
11. Hydrous sub-bisesquiarseniate of do., $cp^{2\frac{1}{2}}\dot{A}s+Aq$.
12. Diarseniate of copper, $\underset{\cdot}{c}p^2\dot{A}s+4Aq$.
13. Prismatic oliven ore, $\underset{\cdot}{c}p^2\dot{A}s+\frac{1}{2}Aq$.
14. Acicular oliven ore, $\underset{\cdot}{c}p^2\dot{A}s+2Aq$.
15. Copper mica, $\underset{\cdot}{c}p^2\dot{A}s+3Aq$.
16. Octahedral arseniate of copper, $\underset{\cdot}{c}p^2\dot{A}s+5\frac{1}{2}Aq$.
17. Copper schaum, $\underset{\cdot}{c}p^{2\frac{1}{2}}\dot{A}s+4\frac{1}{2}Aq$.

2. *Double Oxygen Salts.*

Sp.
1. Hydro-carbonate of copper, $\underset{\cdot}{c}p\dot{C}+\underset{\cdot}{c}pAq$.
2. Silico-carbonate of do., $\underset{\cdot}{c}p\dot{C}+\underset{\cdot}{c}pS^2+Aq$.

III. *Chlorine Salts of Copper.*

Sp.
1. Hexmuriate of copper, $Cp^6Chl+6Aq$.

IV. *Sulphur Salts.*

Sp.
1. Variegated copper ore, $2Cp^2Sl+FSl$.
2. Copper pyrites, $FSl+CpSl$.
3. Bournonite, $StSl+PlSl+CpSl$.
4. Grey copper ore, $\left.\begin{matrix}St\\As\end{matrix}\right\}Sl+3CpSl$.

Species
5. Tenantite, $AsSl+4\frac{1}{2}CpSl$.

v. *Selenium Salts.*

Sp.
1. Eukairite, $3Cp^2Sel+AgSel$.

Genus XXIV. MERCURY.

Sp.
1. Native mercury, H.
2. Native amalgam, H^2Ag & H^5Ag.
3. Sulphuret of mercury, HSl.
4. Dichloride of do., H^2Chl.
5. Chloride of do., $HChl$.

Genus XXV. SILVER.

I. *Native, or combined with Simple Bodies.*

Sp.
1. Native silver, $Ag^{24}Cp$.
2. Antimoniet of silver, Ag^4St & Ag^3St.
3. Arseniet of silver.
4. Bitelluret of silver, $AgTl^2$.
5. Flexible sulphuret of do.
6. Sulphuret of silver, $4AgSl+AgSl^2$.
7. Sternbergite, $4FSl+AgSl^2$.
8. Seleniet of silver, $12AgSel+PlSel$.
9. Chloride of silver, $AgChl$.
10. Iodide of silver.

II. *Oxygen Salts.*

Sp.
1. Carbonate of silver.

III. *Sulphur Salts.*

Sp.
1. Sulpho-cuprite of silver, $AgSl+2Cp^2Sl$.
2. Brittle silver glance, $StSl^2+3AgSl$.
3. Dark red silver ore, $StSl^{1\frac{1}{2}}+1\frac{1}{2}AgSl$.
4. Miargirite, $11StSl^{1\frac{1}{2}}+6AgSl^{1\frac{1}{2}}$
5. Light red silver ore, $AsSl^{1\frac{1}{2}}+1\frac{1}{2}AgSl$.
6. Polybasite, $\left.\begin{matrix}St\\As\end{matrix}\right\}Sl+5\left.\begin{matrix}Ag\\Cp\end{matrix}\right\}Sl$.

Genus XXVI. URANIUM.

Species
1. Pitch ore.
2. Sulphated protoxide.
3. Sulphated peroxide.
4. Uranite, $2\underset{\cdot}{u}\dot{P}h+Cal^{1\frac{1}{4}}\dot{P}h+12Aq$.
5. Chalcolite, $2\underset{\cdot}{u}\dot{P}h+\underset{\cdot}{c}p^{1\frac{1}{4}}\dot{P}h+11Aq$.

Genus XXVII. PALLADIUM.

Sp.
1. Native palladium, Pal.
2. Seleniet of palladium.

Class III. NEUTRAL BASES.

Genus I. GOLD.

Species
1. Native gold, Au^2Ag to $Au^{56}Ag$.
2. White ore of tellurium, $7AuTl^5+5PlTl^5$.
3. Graphic ore of tellurium, $3\frac{1}{3}AuTl^5+AgTl^5$.

Genus II. PLATINUM.

Sp.
1. Native platinum, $5Plt^2F+RCp$.

Genus III. IRIDIUM.

Sp.
1. Native iridium, I^2Os.

CLASS I.

ACID BASES.

THERE are 15 acid bases, which exist in the mineral kingdom, namely:

1 Carbon,
2 Boron,
3 Silicon,
4 Phosphorus,
5 Sulphur,
6 Selenium,
7 Tellurium,
8 Arsenic,
9 Antimony,
10 Chromium,
11 Molybdenum,
12 Tungsten,
13 Columbium,
14 Titanium,
15 Vanadium.

Hence, this first class is divided into 15 genera, a genus being allotted for each base.

GENUS I.—CARBON.

Carbon exists in the mineral kingdom pure, when it is distinguished by the name of *diamond;* and nearly pure when it bears the name of *plumbago* and *anthracite*, according to its colour and situation. It occurs also combined with oxygen, constituting *carbonic acid.* This acid forms an essential constituent of 24 different minerals. The bases with which the acid is united are necessarily alkaline. Hence, these 24 species will appear in the second class under the respective alkaline bases to which they belong.

The other minerals consisting essentially of carbon, have it combined with hydrogen, and sometimes oxygen, into various bituminous or resinous substances, constituting *common pit coal*, *asphalt*, *elastic bitumen*, *scheererite*, *retinasphaltum*, *mineral tallow*, *amber*, and *Highgate resin.* Hence, this genus contains 11 different species of minerals, several of which are of great importance.

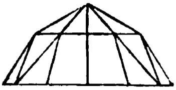
Species 1. *Diamond.*

The diamond has been known and prized for its beauty and rarity from the remotest ages. It was called *adamas* and *adamantos* by the Greeks, doubtless in consequence of its hardness. Pliny describes several species, and enumerates several fanciful properties belonging to them; but only one of these, the Indian diamond, coincides with the mineral to which we at present give that name.*

The diamond almost always occurs crystallized. It is seldom completely transparent. Its colours are usually white or grey. But diamonds are occasionally met with of a blue, red, brown, yellow, green, and I have seen them partly of a black colour. Of these colours, the blue and the black are the rarest. It exhibits a most beautiful play of colours when exposed to the direct rays of the sun or of a candle, especially when cut. The lustre is splendent and of a peculiar kind, to which the name of *diamond lustre*, or *adamantine lustre*, has been given. It refracts only singly; but its refractive power considerably exceeds that of most other minerals of nearly the same specific gravity.

It is *harder* than any other substance in nature, and capable, of course, of scratching every other mineral. Yet it is not difficult to break it by a blow. In consequence of this superior hardness, it can only be rubbed down or polished by means of diamond powder. The ancients were ignorant of this method of cutting diamonds, and of course were unable to polish them or cut them into facets; but employed them such as they occur in nature. In the year 1456, a citizen of Bruges, called Louis Berquen, thought of polishing them by rubbing them one against another. He collected the powder which was thus rubbed off, and spreading it by means of a greasy matter on the circumference of a wheel, this wheel being put in motion diamonds were applied to it, which by this contrivance were cut into facets, and at the same time polished. Such was the origin of the method at present employed to cut diamonds. It was highly appreciated by Charles, duke of Burgundy, who rewarded Berquen handsomely for his invention.†

Diamonds for ornamental purposes are cut into two shapes; namely, *rose diamonds* and *brilliants*. Rose diamonds have nearly a hemispherical form, and the hemisphere is cut into 24 triangular planes. Of course there are 7 prominent solid angles upon the hemisphere where six of the little triangles meet. This shape is represented by the figure in the margin. One of these constitutes the apex, and



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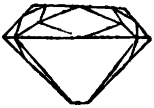
* Plinii Hist. Nat. lib. xxxviii. c. 4.

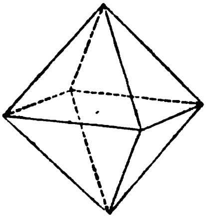
† Hauy; Traité de Mineralogie, iv. 438.

the other six surround it at the distance of one of the triangular faces. It is not so easy to convey an idea of what is called a *brilliant.* Some conception may be formed by supposing a natural diamond to be a regular octahedron, consisting of two four-sided pyramids with square bases applied base to base. Half the upper pyramid is cut off, and all the corners and edges converted into triangular faces. The figure of the brilliant is represented in the margin.



The specific gravity of the diamond varies somewhat in different specimens. I found that of a very fine transparent colourless diamond, in the Hunterian museum, weighing 10·825 grains, to be 3·5295. Mr. Wilson Lowry, who had in his possession a beautiful collection of crystallized diamonds, found the specific gravity 3·488. Hauy states the specific gravity of the diamond to be 3·55.* Mohs makes it 3·520.†

The structure of the diamond is straight foliated with a fourfold cleavage, parallel to the faces of the regular octahedron, which constitutes the primary form of its crystals. It occurs also frequently in cubes and in rhomboidal dodecahedrons. Indeed it is well known, that these forms are easily deducible from each other. Not unfrequently three faces may be seen, constituting a very low three-sided pyramid on each face of the primary octahedron; thus making a 24-sided figure, to which Hauy has given the name of *binaire.*



Very frequently the faces of the diamond are curved instead of being planes, as is usual with the faces of crystals. Occasionally it approaches a spherical figure, the surface being composed of 48 faces; every one of the faces of the primary octahedron being covered by a very low six-sided pyramid, three of the faces of these pyramids which are contiguous to the three angles of the octahedral face are most distinct. The other three are barely visible, and when they disappear, the diamond of course has only 24 faces, constituting the binaire of Hauy.

When the diamond is rubbed it becomes positively electric; and this happens even when it has not been cut, and though it be not insulated.

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* Mineralogie, iv. 19.

† Mohs's Mineralogy, ii. 306.

When exposed to the sun and then brought suddenly into a dark place, it phosphoresces sensibly, and this evolution of light continues for some time.

When the diamond is kept at a red heat in contact with air, it gradually burns away without leaving any residue, being wholly converted into carbonic acid gas.

Hitherto, the diamond has been found only in the torrid zone. The ancients drew all their diamonds from India. It occurs in alluvial soil in the provinces of Golconda and Visapoor, Bengal, and in the island of Borneo. It is still found in these situations, though not in such abundance as formerly. About the year 1740, diamonds were discovered in Brazil. Great quantities of them have been collected in the district of Serro dofrio, and in other places. They are obtained as in India, by washing the alluvial soil. The original repository of this precious stone is unknown; unless we consider the kind of iron ore in which it is occasionally found embedded in Brazil as of that nature.* A report has been current, that diamonds, of late years, have been discovered in the mining district of the Uralian mountains. But this report stands in need of confirmation. We are informed also, that M. Peluzzo bought three diamonds from a native of Algiers; which had been found in the sand of the river Gumil, in the province of Constantine, in Africa.†

The largest diamond known to exist, (if we except that belonging to the king of Portugal, thought by many to be only a topaz) weighed in its original state 900 carats, or 2769·3 grains.‡ By cutting, it was reduced to 279·9 carats, or 861 grains. It has the form and the size of half a hen's egg. It is mentioned by Tavernier, as in possession of the Great Mogul, and was found in the mine of Colone in 1550. What has become of this diamond of late years is unknown.

The oriental diamond purchased by the Empress Catharine II. of Russia, claims the next place. It is without flaw or fault of any kind, and weighs 193 carats, or 593·86 gr. Its form is that of a flattened ovoid, and its size that of a pigeon's

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* Some account of the constitution of that portion of Brazil which yields diamonds, will be found in Humboldt's *Essai Geognostique sur le Gisement des Roches*, p. 89.

† Poggendorff's Annalen, xxxii. 480.

‡ A carat is equal to 3·077 grains.

egg. It is said to have been in possession of Nadir Shah. But more lately it had become one of the eyes of a Braminical idol, and was stolen by a French Grenadier, who disposed of it at a very low price. After passing through several hands, it was purchased by Catharine, for about £90,000, in ready money, and an annuity of £4000 more.

The Pitt, or Regent diamond, is said to have been found in Malacca. It was purchased by Mr. Pitt, an English gentleman, who was governor of Bencoolen in Sumatra. It was sold by him to the regent Duke of Orleans, for £130,000, by whom it was placed among the crown jewels of France. It is cut in the form of a brilliant, and is not only without blemish, but considered as the most beautiful diamond hitherto found. It weighs 136·25 carats, or 419¼ grains. Its value, as estimated by a commission of jewellers in 1791, is twelve millions of livres or half a million sterling.

The greater number of diamonds are very small, and so full of flaws, as to be useless for the purposes of the jeweller. They are reduced to powder, and employed in the cutting and polishing of those diamonds that are sufficiently perfect for the purpose. Such minute and imperfect diamonds sell at a very low price. I was once offered my choice out of a large cargo, at the rate of three shillings each. Those diamonds which weigh a carat or more, and which are transparent and free from flaws, sell at a high price, which increases as the square of the weight. According to Mr. Jeffries, who was a jeweller in London, and published a treatise on diamonds and pearls about the middle of the last century, an unwrought diamond weighing 1 carat, if free from flaws, is worth two pounds sterling. If we multiply the square of the weight (in carats) by two, the product represents the value of the uncut diamond. Thus, the diamond in the Hunterian museum, which weighs 10·825 grains, or 3·518 carats, is worth £24 : 15s.

If the diamond has been cut and polished, he reckons its value when it weighs one carat, to be eight pounds sterling. And the square of the number of carats constituting the weight multiplied by 8, gives the value of polished and cut diamonds in pounds sterling. According to this mode of valuing, the Pitt diamond, which weighs 136¼ carats would be worth 148,512 pounds sterling. But large diamonds are so rare, that they are valued at a much greater price than that which would result from multiplying the square of their weight in carats by 8.*

Sp. 2. *Plumbago*or *Graphite.*

This mineral is distinguished in common language by the name of *black lead.* It constitutes the ingredient of which writing pencils are usually made. Plumbago was long confounded with *molybdena:* indeed the two minerals were not accurately distinguished, till Scheele determined the properties of each in 1779.†

The colour of plumbago is steel grey, and it has the metallic lustre. The streak is splendent and metallic.

Its hardness is 1, for it is easily scratched by gypsum, but scarcely by talc. It is sectile, has a greasy feel, and writes readily upon paper. The thin laminæ are highly flexible. Opaque.

The specific gravity varies from 2·25 to 2·32.‡

Its texture is foliated; though from the occasional small size of the plates, this cannot always be observed. In Greenland, and in the neighbourhood of Philadelphia, it has been met with crystallized in six-sided prisms. But nothing is known respecting the angles of these crystals.§

When plumbago is boiled in nitro-muriatic acid, a portion of oxide of iron is dissolved. When mixed with ten times its weight of saltpetre, and heated to redness, it deflagrates with violence, and leaves a brown coloured residue, which varies in different specimens both in quantity and composition; showing that it is merely foreign matter not chemically combined with the plumbago, but simply mixed mechanically with it. In Gahn's and Hjelm's trials, it amounted to ten per cent. and was peroxide of iron or ochre of iron, as Scheele expresses himself.|| A fine specimen examined by Allen and Pepys, left only 5 per cent.¶ A specimen from Borrowdale, analyzed

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* Some account of the price of diamonds in India, will be found in Brewster's Journal, vii. 134.

† Pliny employs molybdena and plumbago as synonymes for a plant. (Hist. Nat. lib. xxvi. c. 13.) He uses *molybdena* also for *litharge,* and describes it as the same with *galena.*

‡ Schräder; Annals of Philosophy, i. 299.

§ Hauy; Traité de Mineralogie, iv. 85; 2d edition.

|| Scheele's Essays, p. 246.

¶ Nicholson's Jour. xix. 233.

by Schräder, left 14·75 per cent. This residue had a brown colour, and was composed of

Protoxide of iron,	5·8
Silica,	3·5
Alumina,	2·3
Oxide of titanium,	3·15
	14·75[*]

Professor Vanuxem analyzed three specimens of plumbago,[†] and found their constituents as follows:

Carbon,	88·37	61·27	94·4	62·8
Water,	1·23	5·83	0·6	——
Silica,	5·10	10·10	2·6	21·6
Alumina,	1·00	3·20	0·0	9·3
Lime,	——	——	——	0·2
Oxide of iron and manganese,	3·60	20·00	1·4	5·4
	99·30	99·9	99·0	99·3[‡]

The first two of these specimens were from Borrowdale, in Cumberland, the third, from Bustletown, Pennsylvania.

If we abstract these foreign bodies, plumbago may be considered as consisting of carbon, seemingly from the experiments of Davy, not quite free from hydrogen.

Plumbago is found usually in primary or transition rocks. At Borrowdale, in Cumberland, which yields the finest plumbago known, it occurs in nests in a greenstone rock, which constitutes a bed in clay slate, together with felspar porphyry, and hornstone porphyry. In Glenstrathfarrar, in Inverness-shire, it constitutes nests in gneiss. At Arendal, in Norway, it is found in a quartz rock. In the United States of America, it is met with in various rocks, but all primary; sometimes in granular foliated limestone, sometimes in felspar, and sometimes in mica slate.

A mineral resembling plumbago, and applied to many similar purposes, is found in Ayrshire in the coal beds. There is a mine of it about four miles from New Cumnock, belonging to the Marquis of Bute. The plumbago occurs in

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[*] Annals of Philosophy, i. 209.

[†] Ibid. (2d series) ii. 107.

[‡] This column gives the constituents of Ceylon graphite, as analyzed by Princep. Ann. des Mines, (3d series) v. 523.

the sixth bed from the surface, the bed immediately above and immediately below, consists of greenstone. The plumbago is mixed with anthracite or glance coal, and constitutes a bed from 3 to 6 feet thick. It is occasionally mixed with greenstone.

Another mine of plumbago exists on the banks of the Ayr river, about 8 miles east from the town of Ayr, near the place where the celebrated hones, known by the name of *water of Ayr stones* are found. The plumbago in this mine, however, is far from being pure, and indeed is rather entitled to the name of *anthracite* than of *plumbago.* It is not fit for pencils, but is used in the manufactory of black-lead crucibles, for polishing cast iron grates, and to obviate friction.

Sp. 3. *Anthracite.*

Glance coal and Columnar coal of Werner, Kilkenny coal, Blind coal, Culm.

This is a species of coal distinguished from common coal by its higher specific gravity, its semimetallic lustre, and by its burning without emitting smoke; though, when it contains moisture, (as is frequently the case) it emits a low yellow flame.

The colour is black; the lustre splendent and semimetallic. Sometimes beautifully iridescent. It is opaque, and breaks usually with a conchoidal fracture. Hardness about 2. In general it is rather harder than common coal; though this is not always the case.

Specific gravity of the Pennsylvania coal, which belongs to this species, from 1·52 to 1·55; that of Rhode island 1·75.* I found that of Kilkenny coal 1·4354. Mohs states the specific gravity of the columnar coal from Meissner, to be 1.400, and that of the glance coal from Schönfield, in Saxony, 1·482.

I have never seen it under any regular form. But Hauy states that it has been met with in the coal mines of Berg, on the right banks of the Rhine, in imperfect acute octahedrons. He considers the primary form to be that of the regular six-sided prism.

By friction when insulated, it acquires negative electricity.

Anthracite when pure consists almost entirely of carbon, in that black state in which it exists in charcoal. Kilkenny coal

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* Silliman's Jour. x. 333.

leaves, when burnt, 4 per cent. of ashes. Two varieties of anthracite, that of Lehigh, in Pennsylvania, and that of Rhode island, were analyzed by Mr. Vanuxem,* who found the constituents as follows:

	Lehigh coal.	Rhode island coal.
Carbon,	90·1	90·03
Water,	6·6	4·90
Silica,	1·2	2·14
Alumina,	1·1	——
Oxides of iron and manganese,	0·2	2·50
	99·2	99·57

Anthracite occurs occasionally in primary rocks. Thus Ramond found specimens of it in gneiss, on the table land of Troumou in the upper Pyrenees. It is much more abundant in transition rocks. The Lehigh coal in Pennsylvania, extends in length 100 miles, partly along the Susquehannah river, till it is lost at Peter's mountain, a few miles above Harrisburgh. The mean thickness of this bed of anthracite, is from 12 to 15 feet, though in some places it amounts to from 30 to 40 feet. It alternates with clay slate, mica slate, and a micaceous sandstone.† And Mr. Maclure informs us, that the whole of that part of the country is transition.‡ A very extensive tract of anthracite occurs also in Rhode island. This coal has of late years been brought into common use in America. Anthracite occurs also in the common coal measures. This is probably the case with the Kilkenny coal in Ireland. It is certainly the case with the Welsh *culm*, so extensively used in the iron works in South Wales. Many other localities of it in the common coal beds might be pointed out, both in Great Britain and on the continent.

Sp. 4. *Bituminous Mineral Coal.*

Brown coal, black coal, slate coal, moorcoal, jet, &c.

This very important mineral occurs in the earth, in beds usually alternating with slate clay and sandstone, and is employed very abundantly in this country as an article of fuel. A great number of different kinds have been described, but it will be sufficient if we notice the following sub-species, which constitute the common varieties in this country.

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* Annals of Philosophy, (2d series) xi. 105.

† See a description by Mr. Cist in Silliman's Jour. iv. 1. ‡ Ibid.

I. *Caking Coal.*

When this coal is heated, it breaks into a great number of small pieces. When the heat is raised to a certain point the coal melts, and all the fragments become united together in one solid mass. It is to this property that the name of *caking coal* is owing.

The colour is velvet black, or in some places greyish black. Lustre shining, resinous. The principal fracture is straight, slaty; the cross fracture partly small grained uneven, when the lustre is only *glistening;* partly small conchoidal, when the lustre is *shining.* It is not uncommon to find in it thin seams, exactly similar to wood charcoal.

It is soft, and very easily frangible. The fragments have more or less of a cubic shape. Soils the fingers; specific gravity 1·269. It catches fire very readily, and burns with a lively yellow flame; but in consequence of its caking property it requires to be frequently stirred to admit the free ingress of air, otherwise it is extinguished. It is a lasting coal, and gives out much heat; but it requires care to manage it well in a common fire.

The best Newcastle caking coal contains 1½ per cent. of earthy matter. The combustible portion is a compound of carbon, hydrogen, azote and oxygen, in the following proportions:

33 atoms carbon, = 24·75
11 atoms hydrogen, = 1·375
3 atoms azote, = 5·25
1½ atoms oxygen, = 1·5

32·875*

The principal beds in the Newcastle coal field consist of this kind of coal. It constitutes the sixth bed (reckoning from the surface) of the Glasgow coal field. The coal at Hurlet, about 5 miles south-west from Glasgow, is a caking coal. It occurs also at Bannockburn, and in various places in Fifeshire.

II. *Splint Coal.*

This coal constitutes the fifth of the Glasgow beds, or the lowest bed at present wrought.

It is thin, varying from thirty inches to three feet. It occurs also occasionally in the other Glasgow beds, particularly

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* Annals of Philosophy, xiv. 91.

the second. It is the most valuable of the Glasgow coal, and always sells at a higher price than the *cherry* or *soft coal.*[*]

The colour is black, with a slight shade of brown. The lustre is between glimmering and glistening; resinous; lustre of the streak between glistening and shining. Thin layers of cherry coal often pervade splint coal; they are easily distinguished by their superior lustre.

The principal fracture is imperfect, curve slaty; cross fracture fine grained uneven and splintery.

Soft, but difficultly frangible; much more so than any other species of coal. Hence the reason why the term *hard coal* is often applied to it. The specific gravity is 1·290.

It requires more heat to kindle it than either caking or cherry coal; but when once thoroughly lighted it constitutes a lasting and clear fire, which gives out much heat.

The best splint coal which I have met with contains about 9·5 per cent. of earthy matter. The combustible portion is a compound of carbon, hydrogen, azote and oxygen, in the following proportions:

28 atoms carbon,	21·00
14 atoms hydrogen,	1·75
1 atom azote,	1·75
3½ atoms oxygen,	3·5
	28·00[†]

III. *Cherry Coal.*

This constitutes the greater part of the four uppermost Glasgow coal beds, especially the third and fourth beds. The Staffordshire coal seems to be similar in its nature.

Colour velvet black, with a slight intermixture of grey; the lustre is sometimes splendent, sometimes shining. When the lustre is shining, the coal has exactly the appearance of caking coal; but is easily distinguished as it wants the property of softening and caking when heated. The lustre is resinous.

Principal fracture straight, slaty. The different slates or plates differ in their lustre; some of them are splendent, others only shining. The surface is smooth; when the lustre is splendent the surface is specular, but when only

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[*] The difference is about one shilling per waggon, of 24 Cwt.

[†] Annals of Philosophy, xiv. 92.

shining, the surface is merely even. Cross fracture usually flat conchoidal and specular splendent. In some places it has occasionally the aspect of wood charcoal.

Its hardness is about the same as that of caking and splint coal. But it is very easily frangible. Hence there is a good deal of waste in mining it, and as it does not cake, the fragments can be used only for furnaces. Near Birmingham, the loss in mining, including the pillars, amounts to two-thirds of the whole.

The fragments are rectangular, and approach the cubic form. The specific gravity is 1.265.

When exposed to heat it readily catches fire, and burns with a clear yellow flame, giving out a great deal of heat. It burns away much faster than either caking or splint coal.

When burnt it leaves about ten per cent. of ashes. The combustible portion is a compound of carbon, hydrogen, azote, and oxygen in the following proportions:

34 atoms carbon, = 25·5
34 atoms hydrogen, = 4·25
2 atoms azote, = 3·5
1 atom oxygen, = 1·0
34·25*

As this is the most beautiful, it is at the same time the most abundant species of mineral coal. It has got the name *cherry*, from the colliers, in consequence of its lustre and beauty.

IV. *Cannel Coal.*

This species of coal is said to have got its name because when kindled it burns with a clear flame, like a candle. It abounds at Lesmahago, about twenty miles from Glasgow. It is found in different parts of Ayrshire, where it is made into inkhorns, snuff boxes, and other similar ornaments. It abounds, as is well known, at Wigan, in Lancashire; there is a mine of it in Lord Anglesea's park at Beaudesert near Coventry. What is called *jet*, is merely a variety of cannel coal.

The colour is dark greyish black, sometimes brownish black; the lustre is glistening, resinous; it takes a good polish; the fracture is usually large and flat conchoidal. In the great this kind of coal is frequently slaty.

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* Annals of Philosophy, xiv. 93.

In some varieties the fragments approach the cubic shape, in others they are wedge-shaped, or even quite irregular.

Soft; sectile; does not soil the fingers; rather difficultly frangible; specific gravity 1·272.

When applied to the flame of a candle it catches fire and burns with a clear yellow flame, without melting. On this account it is frequently employed to give light, as a substitute for candles. If a large piece be put on the fire, it splits into foliæ, and if the flat side of these foliæ be laid over the fire, the pieces fly off with a crackling noise, and are, many of them, driven to a considerable distance. Hence the reason why the term *parrot* coal is applied to this variety in Scotland.

This coal at an average contains about 11 per cent. of earthy matter. The combustible portion is composed of carbon, hydrogen, and azote, in the following proportions:

11 atoms carbon, = 8·25
22 atoms hydrogen, = 2·75
1 atom azote, = 1·75

12·75[*]

v. *Wood Coal.*

As a variety of mineral coal, we ought to mention *wood coal*, or *brown coal*, as it has been termed by Werner, which occurs usually in the newest formations; it has all the appearance of wood, and obviously consists of trees that have been softened, probably by moisture, and then squeezed flat by pressure. The deposite at Bovey, in Devonshire, constitutes one of the best examples of this kind of coal. Its colour is brown or grey, differing a good deal in the shade; the texture of the wood is preserved, and it burns exactly as wood does; so that there cannot be the least doubt about its origin. Indeed, the common opinion is, that mineral coal in general owes its origin to vegetable matter; but the occurrence of anthracite in primary rocks constitutes a difficulty in the adoption of this theory in every other respect so plausible.

Sp. 5. *Asphalt.*

Black mineral resin of Mohs; bitumen, petroleum, naphtha, &c.

This substance occurs in considerable quantity on the

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[*] Annals of Philosophy, xiv. 94.

shores of the Dead Sea, and on the surface of a lake in Trinidad. There is a thick bed of it in Albania, from which the Greek fire, so celebrated in the middle ages, was principally formed.

When solid, it has a black colour, but is frequently also brownish and reddish. The streak is usually unchanged; but sometimes lighter than the colour of the asphalt.

Hardness, 2. Friable; sectile; lustre resinous; fracture conchoidal, more or less perfect. The specific gravity varies from 1·073 to 1·160. Klaproth states it as high as 1·205.

When heated it melts, gives out a bituminous smell, and colourless naphtha may be distilled from it. Neither acids nor alkalies are capable of acting on it; but it dissolves in naphtha, and in the fixed and volatile oils.

Naphtha, which issues occasionally from the earth in various countries, especially Persia, is a colourless transparent liquid, very volatile, and about $\frac{5}{4}$ths of the weight of water. It is very combustible, and appears to be a compound of carbon and hydrogen in equal atoms, seemingly six atoms of each. When naphtha is exposed to the air, its colour deepens, and its consistency increases, and it gradually assumes the form of *petroleum*, a brown bituminous oily looking matter, which occasionally floats on the surface of springs issuing from coal beds. When the petroleum is heated, it gives out naphtha, and leaves a quantity of asphalt. Pit coal, when distilled, yields also naphtha. Hence naphtha seems to be the part of a series of substances which graduate into each other, and the last of the series is pit coal.*

Sp. 6. *Elastic Bitumen.*

Mineral caoutchouc of Kirwan.

This mineral was first discovered in the forsaken lead mine of Odin, which is situated near the base of Mamtor, to the north of Castletown, in Derbyshire. It was first noticed by Dr. Lister, in 1673.† He called it a subterraneous fungus, and is uncertain whether it belongs to the vegetable or mineral kingdom. It was first accurately described by Mr. Hatchett.‡ In 1816, it was discovered by M. Olivier of Angers, in the

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* From the late experiments of Reichenbach, naphtha appears to be a very complex substance; and Dr. Christison and Dr. Gregory have shown that two distinct species of natural naphtha occur.

† Phil. Trans. viii. p. 6179.

‡ Linnæan Trans. iv. 146.

coal mine of Montrelais, at the depth of 230 feet. Haussmann states that it has been observed also at Neufchatel, and in the island of Zante.*

Its colour is blackish brown of various shades.

Internally it is shining and glistening; lustre resinous; fracture conchoidal; translucent on the edges; very soft; sectile; soft and elastic, flexible. The specific gravity of the Derbyshire variety, as determined by Hatchett, varies from 0·9053 to 1·233; that of the French is lighter than water.

It catches fire readily, and burns with a lively yellow flame, giving out a bituminous odour. The English and French varieties were subjected to analysis by M. Henry, junior.† The results were as follows:—

	English variety.	French variety.
Carbon,	0·5225	0·5826
Hydrogen,	0·0746	0·0489
Azote,	0·0015	0·0010
Oxygen,	0·4011	0·3675
	1·0000	1·0000

This corresponds with

35 atoms carbon,	= 26·25
3 atoms hydrogen,	= 0·375
2 atoms oxygen,	= 2·000
	28·625

for the English variety; and

41 Carbon,	= 30·75
2 Hydrogen,	= 0·25
2 Oxygen,	= 2·00
	33

for the French variety.

It is obvious that these numbers can be considered only as rude approximations to the truth.

Sp. 7. *Retinasphaltum.*

This mineral was first observed accompanying Bovey coal in Devonshire, and was noticed by Dr. Milles.‡ Its nature was afterwards more accurately determined by Mr. Hatchett.§ It was found afterwards by M. Voight in a bed of bituminous

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* Handbuch, iii. 273.

† Ann. des Mines, xii. 269.

‡ Phil. Trans. li. 536.

§ Ibid. 1804, p. 401.

vegetable earth near Helbra, in the county of Mansfield;[*] and soon after it was discovered in the neighbourhood of Halle, in a bed of brown coal, and subjected to a chemical examination by Bucholz.[†]

The colour is pale brown ochraceous yellow. The fracture is imperfectly conchoidal. It appears earthy externally; but when broken exhibits a slight resinous lustre; very soft and easily frangible. It is usually, when first dug up, elastic flexible; but loses this property on exposure to the air.

Its specific gravity, as determined by Hatchett, was 1·135. The variety described by Voight is said to be very light, sometimes even swimming in water. Bucholz states the specific gravity of the retinasphalt found near Halle, to be nearly the same as that stated by Hatchett.

When heated it melts, smokes much, and burns with a bright flame, giving out a fragrant odour. The melted mass, when cold, is black, very brittle, and breaks with a glossy fracture. The Bovey retinasphalt, according to the analysis of Hatchett, is composed of

Resin, . . .	55
Asphalt, . . .	41
Earthy matter, . .	3
	99[‡]

According to Bucholz, the retinasphalt from Halle is composed of

Resin soluble in alcohol, .	91
Resin insoluble in alcohol, .	9
	100[§]

Sp. 8. *Scheererite.*[||]

Prismatic resinous naphthaline of Koenlein.

This substance was observed in the year 1822, in the beds of brown coal at Uznach in Switzerland. These beds are from 2 to 6 feet thick, and belong to a very recent formation.[¶]

The colour of the mineral is white, or sometimes greenish or yellowish, like talc. It has the form of small needle-shaped

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[*] Jour des Mines, xv. 77.

[†] Schweigger's Jour. i. 290.

[‡] Phil. Trans. 1804, p. 404.

[§] Schweigger's Jour. i. 293.

[||] This name was given by Stromeyer, from M. Scheerer, who, it seems, first observed the mineral.

[¶] Poggendorf's Annalen der Physick, xii. 336.

crystals, and is deposited in hollows in the brown coal; lustre resinous.

Soft; translucent; very easily frangible; without taste or smell, even when rubbed.

Specific gravity, according to Macaire Princep, 0·65, that of water being 1.

Stains paper like oil.

It melts, according to Macaire Princep, when heated to 111°, and boils at the temperature of 197½°.

It dissolves very slowly in alcohol; ether is a better solvent, and so is warm oil of turpentine. It does not combine with alkalies. It dissolves slowly in dilute sulphuric acid, and communicates a red colour to the liquid. When heat is applied, the solution becomes first brown and then black, and charcoal is at last deposited. It is soluble in the fat oils.

Catches fire easily, and burns with a pale flame, giving out much smoke.

According to the analysis of M. Macaire Princep, it is composed of

$$\left.\begin{array}{lll}\text{Carbon,} & 73, \text{ or } 1 \text{ atom} \\ \text{Hydrogen,} & 24, \text{ or } 2 \text{ atoms}\end{array}\right\} \text{nearly.}^{*}$$

It is obvious from its properties and constitution that Scheererite is quite a different substance from naphthaline.

Sp. 9. *Mineral Tallow.*

Hatchettine of Conybeare—Bergfet.

This substance is noticed by Mr. Kirwan in his Mineralogy (vol. ii. p. 47,) but it has not found a place in modern systems of mineralogy.†

It was first found by some peasants on the coast of Finland, in the year 1736. Afterwards a similar substance occurred in one of the Swedish lakes, and M. Hermann, a physician in Strasburg, discovered a similar substance in the water of a fountain near that city. There is a fine specimen of it in the Hunterian Museum at Glasgow, which was found near Inverary, in the County of Argyle. I have another specimen in my possession, which was found in a moss near Oban, in the same county. The Hatchettine of Conybeare seems to

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* Poggendorf's Annalen der Physick, xv. 294.

† Phillips indeed gives an account of it under the name of *Hatchettine Mineralogy*, p. 374. Magellan also notices it from Kirwan, in his English edition of Cronstedt's Mineralogy.

be a variety of the same substance. It was found by him in 1820, in the ironstone of Merthyr Tydvil, in South Wales.[*]

It is white, and has nearly the consistency of spermaceti; but does not exhibit any appearance of crystallization; soft; fracture even; tasteless; lustre resinous or waxy. It melts when heated to 118°, and boils at 290°.

Its specific gravity is not easily determined, because it is difficult to free it from air. After standing under the vacuum of an air pump for 24 hours, the specific gravity was 0·8035. After fusion the specific gravity was 0·983. This I consider as the true gravity, because by fusion the air bubbles were expelled, and the cavities in it filled up. It is partly but not completely soluble in alcohol. It does not form a soap, nor combine with soda.

The Hatchettine is not quite so firm as the mountain tallow. Its colour is greenish yellow, the texture is slightly flaky, and it is not opaque as mountain tallow is, but slightly translucent. It melts according to Conybeare at 170°, and is lighter than water. In its chemical properties it agrees with mountain tallow.

The analogy between mountain tallow and Scheererite, is very considerable. Probably they will ultimately be found only varieties of the same substance.

Sp. 10. *Amber.*

This mineral has been known since the commencement of history, and was employed by the ancients as a medicine, and worn by them as an ornament. Theophrastus, who lived three hundred years before the Christian era, mentions it as a stony body, by which probably he meant, that like stones it was dug out of the earth.

Amber is cast ashore on the north coast of Germany, from the Baltic, and on the east coast of England, from the German ocean. It is dug up in considerable quantities in North Prussia, from which the great supply of amber comes. It is found there in beds of bituminous wood, from which it is disengaged by the action of the waves, and in the mines it is deposited in considerable quantity below the bituminous wood. It has been observed, also, in a similar position in Sicily, Spain, France, Greenland, China, &c.

Insects and other organic bodies are frequently found

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[*] Annals of Philosophy, (2d series,) i. 136.

engaged in it. From this, it has been concluded, that it was originally exuded from trees in a liquid state, and that it gradually became solid by exposure to the air.

It occurs in irregular forms, grains and spheroidal masses; fracture conchoidal; surface uneven and rough. It has never been observed in crystals.

Its colour is yellow, passing into red, brown, and white, streak white; often transparent, sometimes only translucent.

Hardness 2 or 2·5. Specific gravity of yellow amber as determined by Mohs 1·081.

When rubbed, it becomes negatively electric. When rubbed, pounded, or burnt, it gives out an agreeable odour.

When heated, it swells and burns; when distilled, it yields *succinic acid.*

Amber is capable of being turned on the lathe and polished. It then possesses great beauty, and is occasionally employed as an ornament.

It contains at least five different substances, namely, 1., a volatile oil, to which it owes its aromatic smell. It exists in small quantity. Doubtless it was originally abundant, and gave fluidity to the amber. 2. A yellow resin easily soluble in alcohol, ether, and alkalies. 3. A resin soluble in hot alcohol, and precipitating in a white powder as the solution cools. 4. Succinic acid. 5. A substance insoluble in alcohol, ether, and alkalies, similar to a substance found in lac.

Sp. 11. *Highgate resin.*

Fossil copal of Aiken.

This mineral was discovered about the year 1812, during an attempt to pass a tunnel through Highgate Hill, on the north side of London. It was in small pieces without any regular shape. The colour was muddy yellowish brown; semitransparent; lustre resinous; brittle; hardness 2·5; specific gravity 1·046.

When heated it melts into a limpid fluid, and gives out a resinous and aromatic odour. Takes fire at the flame of a candle, and burns all away without leaving any residue. Insoluble in potash ley and acetic acid. Soluble in ether, and partially in alcohol.

Genus II. BORON.

[redacted], which constitutes the base of boracic acid, is a black substance, somewhat like charcoal, which has never been met with in the mineral kingdom. But the combination of boron and oxygen, known by the name of boracic acid, occurs in that kingdom, and constitutes the only species belonging to this genus at present known.

Sp. 1. *Boracic Acid.*

Sassolin of Reuss.

This acid is rare in the mineral kingdom. It has been observed in the craters of certain volcanoes, particularly in that of Vulcano, one of the Lipari islands, where it was first observed by Mr. Smithson Tennant, and afterwards by Dr. Holland. It was first observed as a deposit from the hot springs at Sasso, a city in Sienna, Italy.* It exists also abundantly in the Lagoni, in Tuscany, and considerable quantities of it are imported into this country to be converted into borax for the use of the potteries.

The boracic acid from Vulcano is in small scales, translucent, having a pearly lustre, and a white colour, except when tinged yellow by an accidental mixture of sulphur.

It is very light, and the scales adhere to the fingers. Its taste is slightly saline, and it is soluble in water, by which it may be separated from all admixture of sulphur. The proportion of sulphur, as Stromeyer has shown, varies from 5 to 20 per cent., proving that it is not chemically combined, but only mechanically mixed.

When put into the flame of a candle, it at first tinges it green; but when the water of crystallization is completely dissipated the green tinge disappears. Stromeyer has shown that this boracic acid is pure, and that it retains its water of crystallization.†

The variety called *sassolin* occurs in stalactites having a white colour, here and there spotted with Isabella yellow. It has a smooth and soapy feel, and is composed of small scales.

Vulcanic boracic acid is pure, if we except the occasional admixture of sulphur. Sassolin was found by Klaproth to contain the following substances:—

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* Hence the name *Sassolin*.

† Untersuchungen, p. 280.

Hydrous boracic acid, . . .	81·33
Sulphate of manganese with some iron,	10·50
Sulphate of lime, . . .	2·83
Silica, ...	2·66
Carbonate of lime, . . .	1·66
Alumina, ...	0·66
Peroxide of iron, . . .	0·33
	99·97*

The foreign bodies are obviously mechanical mixtures.

Boracic acid is very seldom found in the mineral kingdom combined with bases. Only three species containing it are at present known to exist. These are,

1. Borax or biborate of soda.
2. Boracite, or biborate of magnesia.
3. Tourmalin, which contains biborate of lithia combined with two silicates.

Genus III. Silicon.

Silicon, which constitutes the base of silica, has never yet been met with in the mineral kingdom, but the combination of it with oxygen, called *silica*, is exceedingly abundant, and presents itself under so many forms, that it has been subdivided into no fewer than eight different species. Of these we shall now give a description.

Sp. 1. *Quartz.*

Rock crystal, amethyst, cantalite, dragonite, iron flint, prase, rose quartz, milk quartz, siderite.

Quartz constitutes one of the most abundant of minerals, being one of the constituents of granite, gneiss, mica slate, and sandstone.

Its colour when pure, is white; but it is often coloured *violet*, when it is called *amethyst; red*, when it is called *rose quartz; green*, when it is called *prase; yellowish green*, when it is called *cantalite; yellow*, when it is called *Indian topaz*, or *cairngorum stone.* It occurs, also, *blue*, when it is called siderite; *smoke-grey*, *brown*, and *black*, or *blackish brown*. When transparent and colourless, it is called *rock crystal.*

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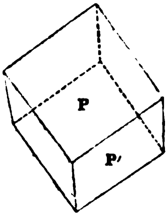
* Beitrage, iii. 97.

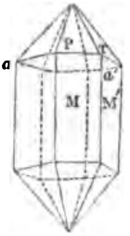
The fracture is small conchoidal. Cleavages may be discovered parallel to the faces of a triangular dodecahedron, composed of two six-sided pyramids applied base to base; but quartz cannot be said to have a foliated structure.

It occurs very frequently crystallized, and the most common form is a six-sided prism terminated by six-sided pyramids. The primary form is a rhombohedron deviating but a few degrees from a cube.



P on P′ 94° 15′

This primary form is sometimes met with; but by far the most common form is a regular six-sided prism terminated by six-sided pyramids.



M on M′ 120°.
M on P 141° 40′.
P on T 133° 48′.

When the intervening prism is wanting, the crystal becomes a dodecahedron composed of two six-sided pyramids applied base to base. The two adjacent faces of each pyramid are inclined to each other at angles 76° 40′.

Sometimes the angles *a*, a′ are replaced by small rhombs. Sometimes the face M is much broader than the two contiguous faces of the prism M′. Sometimes all the edges of the pyramids are replaced by tangent planes. The relative size of the faces varies exceedingly.

Lustre splendent and vitreous in the crystallized specimens. Sometimes the lustre inclines to resinous. Sometimes it is only shining or glimmering.

Crystals often transparent, sometimes only translucent. The amorphous specimens sometimes opaque, or only translucent on the edges.

Refracts doubly.

Hardness 7. Specific gravity of a snow-white crystal 2·690.* Hauy gives the specific gravity 2·6701.† According to Brisson, it is 2·654. Beudant found the specific gravity to vary from 2·6413 to 2·6541.‡

Before the blowpipe it undergoes no change per se; but with carbonate of soda, it fuses with brisk effervescence into a transparent glass.

* Mohs, ii. 334. † Hauy, ii. 229.
‡ Ann. des Mines (2d series), v. 275.

When pure, it is composed of nothing but silica. Traces of alumina, oxide of iron, or oxide of manganese, are found often in apparently pure specimens.

Quartz crystals occur most commonly in cavities in granite. The finest specimens are found in Dauphiné, the Alps of Saltzburg, the Tyrol, Switzerland, Piedmont, and Savoy. They occur, also, in the islands of Madagascar and Ceylon. The cairngorum pebbles are found near the source of the Dee, at the head of Aberdeenshire, in the highest mountainous tract in Scotland. But deeper yellow, and more beautiful transparent specimens of rock crystal are brought from Brazil. Rose quartz occurs at Rabenstein, near Zwiesel, in Bavaria and in Siberia. It is found, also, in the United States of America. The milk-white varieties are from Norway, Spain, France, &c.

What is called *prase*, is quartz tinged green by *epidote*. It occurs at Breitenbrunn, in the mining district of Schwartzenburgh, in Saxony.

Sp. 2. *Kilpatrick Quartz.*

In the amygdaloid, which constitutes a considerable portion of the Kilpatrick hills, terminating near Dumbarton on the north side of the Clyde, a kind of quartz occurs, which seems entitled to rank as a separate species.

It is white and translucent, and constitutes spheres about the size of a hazel nut, mixed abundantly with stilbite and calcareous spar. I have not seen it in situ, but it seems from its appearance to occur in cavities, or rifts in the rock.

These spheres constitute an aggregation of crystals, the forms of which cannot be made out, but the exterior termination of each, when examined under a microscope, appears to be a four-sided pyramid. So that each of the spheres is studded with small microscopic four-sided pyramids.

The hardness is 7, the same as that of rock crystal. But the specific gravity is only 2·525.

Its constituents were found to be

Silica, . .	96·2
Water, . .	3·0
	99·2

The water contained traces of sulphuric acid.

This constitutes very nearly

18 atoms silica, . .	36
1 atom water, . .	1·125
	37·125

The presence of water, the smaller specific gravity, and the different shape of the crystals, seem to warrant the propriety of constituting this kind of quartz into a peculiar species.

Sp. 3. *Calcedony.*

Bloodstone, carnelian, Egyptian pebble, heliotrope, sardonyx, onyx, mocha stone, haytorite.

Calcedony seems to bear the same relation to rock crystal that common stalactite does to calcareous spar. It occurs most commonly in the cavities of amygdaloidal rocks; though sometimes, also, it constitutes veins.

Its colour is most commonly grey, of various shades and degrees of intensity. Blue, green, brown, and yellow, are not uncommon colours. It is also said to have been observed of a brownish black colour. In some of the varieties various colours appear together either in stripes or spots. Sometimes thin layers of different colours alternate with each other.

The fracture is even and fine grained. In some cases a fibrous fracture may be perceived.

Most commonly calcedony is amorphous; but it is sometimes found crystallized in small rhombohedrons, having the same angles as the primary crystal of quartz. This shows that the difference between calcedony and quartz lies merely in the way in which the particles have been united together. Those of calcedony have been deposited from a liquid, and have in general solidified too rapidly to assume a regular form, while quartz has always crystallized either regularly or irregularly. The variety called Haytorite, exhibits pseudomorphous crystals, which Mr. Levy has shown to be analogous to those of Humboldtite, a mineral which is probably a variety of datholite.*

The lustre is dull, or only glimmering. The hardness is the same as that of quartz.

It is generally semitransparent, or at least translucent. The lightest kinds more, and the darkest less so. Some of the deepest coloured specimens are only slightly translucent.

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* Phil. Mag. (2d series), i. 38. Phillips' Mineralogy, p. 379.

I found the specific gravity of a very pure specimen 2·600. Two specimens were found by Hoffman, the first 2·583, the second 2·620.* According to Brisson, the specific gravity varies from 2·583 to 2·664.

Before the blowpipe, it behaves exactly as quartz does.

Calcedony, when pure, consists of silica with a small quantity of water, which seems not enough to be chemically combined. For example, Wöhler found Haytorite composed of

Silica,	98·5
Peroxide of iron,	0·2
Water,	0·5
	99·2†

If the water in this specimen be chemically combined, it would be a compound of

114 atoms silica,	228
1 atom water,	1·125
	229·125

Now this, to say the least of it, is rather an improbable combination.

The term *calcedony* is generally applied by dealers to the grey-coloured varieties. Those that have a red colour, are called *carnelian*.

Alternate layers of brown and opaque white calcedony constitute the *onyx*. When the colour is a deep brownish red, or by transmitted light blood-red, the stone is termed *sard*. Alternate layers of sard and milk-white calcedony constitute *sardonyx*.

Plasma has a dullish green colour with yellow and whitish dots, and a glistening lustre. It has not been analyzed; but is considered at present as a variety of calcedony.

Heliotrope has a deep green colour, and blood-red spots are ientrspersed through it. From this latter circumstance it has got the name of *bloodstone*.

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* Handbuch, ii. 111.

† Poggendorf's Annalen, xii. 136. I found a calcedony constituting sphericles in a felspar porphyry from the Morne mountains, Ireland, having a specific gravity of 2·641 composed of

Silica,	95·15
Alumina, with a little peroxide of iron,	1·95
Lime,	2·25
Water,	1
	100·35

Chrysoprase has an apple-green colour, and in other respects approaches calcedony. Its specific gravity is stated in some mineralogical systems to be 3.25, on the authority of Klaproth. But Klaproth, in the paper in which he relates his analysis of chrysoprase, says nothing about its specific gravity.[*] Hoffmann found the specific gravity to be 2·608.[†] It contains 96·16 per cent. of silica, 1 per cent. of oxide of nickel, with a very little lime, magnesia, alumina, and oxide of iron.[‡]

Mocha stone is calcedony, containing dendrites, usually of a black or brown colour; but sometimes green, and bearing considerable resemblance to certain mosses.

Agate is a compound mineral, consisting of alternate layers of calcedony and quartz, jasper, heliotrope, or opal. Calcedony is usually the basis. The crystals of quartz, or amethyst, which it contains, are commonly in the centre; showing, when it occurs, that it has been formed by depositions of siliceous matter within the cavity. After the first layers of calcedony have been deposited, the silica in the fluid still remaining in the central portion shoots into quartz crystals, which are more or less regular.

Sp. 4. *Flint.*

Pyromachus, pierre à fusil, feuerstein.

This mineral occurs in great abundance in common chalk, in which it is deposited in tuberose masses, and in pretty regular layers, each in an insulated state. It is found also occasionally in amygdaloid, being sometimes a constituent of agate. It is said also to occur in veins both in primary and transition rocks.

The colour is usually grey, of various shades and degrees of intensity. Black, brown, yellow, and red, are the colours intermixed with grey in this mineral.

Its fracture is perfect and large conchoidal. It is never crystallized. But when cavities occur in it, they are sometimes lined with small quartz crystals having the usual form.

Lustre glistening or glimmering.

It is translucent; the blackish varieties only on the edges.

Hardness 7, or even 7·25. It is very fragile; being exceedingly easily broken by a blow.

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[*] Beitrage, ii. 127. [†] Handbuch, ii. 99. [‡] Klaproth, Ibid.

Its specific gravity, as determined by Hoffman, is from 2.575 to 2·594.*

When two pieces of flint are rubbed against each other in the dark, a good deal of light is given out with a peculiar smell. It breaks into wedge-shaped fragments. It gives abundant sparks with steel, and therefore is commonly fixed on musket locks, to kindle gunpowder by striking against the pan of the piece.

Before the blowpipe it behaves like quartz.

It is essentially composed of silica, with a little combined water. A specimen analyzed by Klaproth contained

Silica, . .	98·0
Alumina, . .	0·25
Oxide of iron, .	0·25
Water, . .	1·5
	100†

If we admit the alumina and oxide of iron to be accidental ingredients, flint will be a compound of

37 atoms silica, . .	74
1 atom water, . .	1·125
	75·125

Sp. 5. *Opal.*

Cacholong, gyrasol, hydrophane, semiopal, wood opal, opal jasper.

The term *opal* is usually applied to minerals having a certain degree of transparency, but rendered somewhat opaque by a different colour floating, as it were, within the stone. This colour is usually milk-white, constituting what is called the *common opal.* But it is yellow, brown, red, and even green, of different shades. What is called the *precious opal,* is also most commonly milk white; but when held in a proper direction with respect to the light, it displays a beautiful play of colours, blue, green, yellow, and red. Most commonly several of them appear together. When the play of colours exhibits only the red, the stone is called *fire* opal; when the texture is fibrous, the mineral is known by the name of *wood* opal.‡

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* Handbuch, ii. 84.

† Beitrage, i. 46.

‡ The *opalus* of the ancients (see Plinii Hist. Nat. lib. 37. c. 36.) seems the same as our opal.

The fracture of the opal is perfect conchoidal. In what is called *semiopal*, it is flat conchoidal.

None of the varieties of opal have been observed in crystals.

The lustre is splendent and vitreous. In the *mother-of-pearl* opal it is pearly, and in the semiopal, the lustre is resinous and only glistening.

It is most commonly semitransparent or translucent. The *fire* opal is transparent, and the mother-of-pearl opal opaque.

It is rather softer than quartz. Perhaps the hardness may be nearly represented by 6·75.

The specific gravity varies from 2·015 to 2·21.

It is infusible before the blowpipe.

The precious opal has not been analyzed. The common opal, by Klaproth's analysis, is silica, united to 5 per cent. of water, and 1 per cent. of peroxide of iron. Or, considering the iron as accidental, it is a compound of

10 atoms silica, .	20
1 atom water, .	1·125
	21·125

Whether the water be really in chemical combination with the silica, is not known; but that it is so is not improbable.

The precious opal is found chiefly at Czscherwenitza, near Kaschau in Upper Hungary, where it occurs in veins in a clay porphyry, considered as having been ejected from a volcano long since extinct. The other sub-species have been found in veins in primary rocks and in amygdaloid, where they are associated with calcedony. It is stated also in books to occur in beds, but no locality is given.

Sp. 6. *Jasper*.

Sinople, ribbon jasper, Egyptian jasper.

This mineral is easily distinguished from the other species of quartz already described, by its opacity and by the darkness of its colours.

It is a hard mineral, having a conchoidal fracture and a pretty deep colour, either brown, yellow, or red. The lustre is inconsiderable, and most commonly resinous. The specific gravity is about 2·6.

The brown-coloured mineral which occurs so abundantly in rolled pebbles in the deserts of Egypt, is called *Egyptian jasper*. When stripes of green, yellow and red, occur on the same mineral, it is called *striped jasper*. The *jasper agate* is reddish white. Several colours generally appear on the same mineral.

Jasper has not been examined by modern chemists; but it seems to consist of silica united to a small quantity of peroxide of iron. If any confidence can be put in Kirwan's analysis of common jasper, it consists of

Silica, . . .	75
Peroxide of iron, . .	13
Alumina, . .	0·5
Lime, . . .	0·2
	88·8*

Were we to consider the silica and peroxide of iron to be in the ratios in which they exist in jasper, it would be a compound of $14\frac{1}{8}$ atoms of silica, and 1 atom of peroxide of iron. But the analysis requires repetition.

Jasper occurs in veins in primary and transition rocks. It is found also in nodules, and associated with calcedony in amygdaloid.

Sp. 7. *Basanite.*

Lydian stone, touchstone, flinty slate.

This mineral is usually met with in beds in grey rocks and trap rocks.

Its most common colour is grey; ash grey, smoke grey, and pearl grey, are the most frequent. Sometimes it is bluish grey. Shades of yellow, brown, and red, are not uncommon. Frequently it presents zoned, striped, or undulating delineations. When greyish black or velvet black, it is called *Lydian stone* or *basanite.* The other colours belong to *Flinty slate.*

The fracture of flinty slate is slaty, that of basanite, even.

It never occurs crystallized.

Lustre glimmering. Frequently traversed in various directions by quartz veins, which have a stronger lustre.

Lydian stone is opaque; but flinty slate is translucent on the edges.

Hardness 7. Very tough.

The specific gravity of Lydian stone, according to Hoffmann, is 2·585, and that of flinty slate from 2·613 to 2·644.†

This species has not been analyzed, but it is obvious from

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* So stated by Phillips, Mineralogy, p. 19. I do not know where this analysis was published.

‡ Handbuch, ii. 77.

its characters that it consists chiefly of silica. Humboldt has rendered it probable, that Lydian stone owes its black colour to charcoal.

Perhaps this substance should rather be considered as a rock than a simple mineral. If so, it should not find a place in the system.

Besides the species above described, there are some other varieties or sub-species of quartz which have been noticed by mineralogists. The most important of these are the following:

HYALITE or *Muller glass.* It occurs at Frankfort on the Maine, lining the cavities of basalt. It has been observed also in America, Italy, and Hungary.

It has a glassy lustre, is brittle but as hard as quartz. Its specific gravity is stated at 2·4. According to Bucholz, it is composed of

Silica, . . .	92
Water, . . .	6·3
Alumina, trace, . .	—
	98·3

This is nearly 8 atoms silica to 1 atom water.

BURR STONE. This mineral occurs in the tertiary formations in the neighbourhood of Paris, and has been long famous for the excellent mill stones which it forms. It is met with also in England. I have a specimen from Holken.

Its colour is yellowish white, its texture compact, its fracture even, and its hardness and its behaviour under the blowpipe is the same as that of quartz. It contains small cavities which are tinged yellow, obviously by iron. Specific gravity 2·511.

For an account of NECTIC QUARTZ we refer to Hauy, Mineralogy, ii. 266. For the *flexible sandstone* of South America, we refer to Jameson's Mineralogy or Hoffmann's Handbuch, ii. 47.

For an account of *gelatinous silica*, we refer to the Annales des Mines, xiii. 321.

For other varieties, Jameson or Phillips may be consulted.

Silica possesses the characters of an acid. It enters into definite combinations with lime, magnesia, alumina, glucina, yttria, cerium, zirconia, thorina, iron, manganese, zinc, and copper. Like all weak acids it unites with bases in several proportions. Hence, the number of silicates in the mineral kingdom is very great, constituting no fewer than 206 different species of minerals. These different species will come under our review when treating of the genera included under the 2d class of our division, namely, *alkaline bases.*

GENUS IV.—PHOSPHORUS.

Phosphorus has so great a disposition to unite with oxygen that it is never found in the mineral kingdom in an isolated state. As it has a strong affinity for the greater number of the metals, we might have expected that metallic phosphurets would occur; but hitherto no such compounds have been observed. Phosphoric acid, in which the phosphorus is united to oxygen, is rather common in the mineral kingdom, never in an isolated state but always in combination with a base. These combinations, called *phosphates*, will be described among the minerals arranged under the 2d class of our arrangement.

The phosphates at present known to exist in the mineral kingdom, amount to about 12. Their names are as follow:

1 Apatite or subsesquiphosphate of lime,
2 Turquois or trisphosphate of alumina,
3 Wavellite or hydrousdiphosphate of alumina,
4 Phosphate of yttria,
5 Diphosphate of iron,
6 Subsesquiphosphate of iron,
7 Phosphate of iron,
8 Huraulite or ferro-phosphate of manganese,
9 Chloro-phosphate of lead,
10 Hydrous diphosphate of copper,
11 Bihydrous diphosphate of copper,
12 Uranite or calcareo-phosphate of uranium,
13 Chalcoliteor cupreo-phosphate of uranium.

GENUS V.—SULPHUR.

Sulphur has not the same strong tendency to unite with oxygen that phosphorus has. Hence, it is found native in considerable abundance. Its disposition to unite with bases is greater than that of phosphorus. Hence it is found in the mineral kingdom united both with acid and alkaline bases. With the former of these it constitutes acids, to which the name of *sulphides* has been given. With the latter it forms alkalies or bases, distinguished by the name of *sulphurets.*

Sulphur is also found in the mineral kingdom united to oxygen, and constituting sulphuric acid. This acid has so great a tendency to unite with bases, that it rarely occurs in an isolated state. Certain lakes in the islands of Java and Borneo are said to be impregnated with this acid in a free state; but no example of this kind has been met with any where else, except in Persia, where there is an earth so strongly impregnated with this acid, that it is used by the natives as an acidulous seasoner of food.

Sp. 1. *Native Sulphur.*

Brimstone.

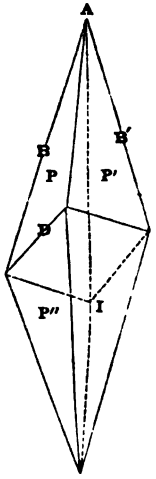
Sulphur has a greenish yellow colour. The crystals are sometimes transparent, but sometimes only translucent. It refracts doubly so strongly that the image appears double even when viewed through two parallel faces.

The hardness of sulphur is 2·5. Its specific gravity is very nearly 2. Breithaupt found that of a yellow transparent specimen 2·071. Brisson states the specific gravity at 2·033.

The primary form of the crystal of sulphur is an octahedron, composed of two four-sided pyramids, with a rhomboidal base, the dimensions of which are as follow:—

P on P′	106°20′	according to Brooke.
	106 30	according to Phillips.
	106 16·5	according to Kupffer.
P on P″	143°25′	according to Brooke.
	143 25	according to Phillips.
	143 26·8	according to Kupffer.

Sometimes the face P extends in breadth so as to make the point A assume the form of a wedge. Sometimes the point A is replaced by a small rhomboidal face parallel to the common base of the pyramids. Sometimes the edges D are replaced by tangent planes, introducing an oblique prism between the two pyramids which constitute the octahedron. The angle which P on P″ makes with the adjoining face of the prism is 161° 42′·5.



Sometimes the angle I is replaced by a triangular face, which may also be considered as a tangent plane.

Sometimes the edges B, B′ are replaced by tangent planes. This converts the octahedron into a dodecahedron.

Sometimes the summits A are replaced by low four-sided pyramids.

Mitcherlich has shown that when sulphur is melted and cooled slowly it crystallizes in right rhomboidal prisms. But this form (which is incompatible with the pyramidal) has never been observed in the crystals of sulphur found native.

Sulphur occurs in beds in a blue clay formation, which constitutes a considerable portion of Sicily, occupying the central half of the south coast, and extending inwards two-thirds of the island, and eastward as far as the district of Mount Etna. This blue clay formation, Dr. Daubeny considers as more recent than chalk, and of the same age with the gypsum beds in the neighbourhood of Paris. It contains beds of gypsum and of rock salt. The quantity of sulphur in it must be enormous; for though Sicily has long supplied all Europe with this article, the supply was so far from diminishing that the price for a series of years rather sank than rose. Of late, indeed, there has been a considerable rise, but not owing to any deficiency of the supply, but advantage has been taken of the great increase of demand. The Sicilians purify their sulphur by collecting it in heaps, and setting fire to them on the surface; thus causing the purification of one portion by the combustion of another.*

In veins, sulphur occurs in Suabia, Spain, and Transylvania. It is deposited also from several springs, and in large quantities from volcanoes.

Only two acid combinations of sulphur (exclusive of sulphuric acid) occur in the mineral kingdom; namely,

Sesquisulphide of arsenic, or realgar.

Sesquisulphide of antimony.

And red antimony, in which the sesquisulphide of antimony is combined with deutoxide of antimony.

Fourteen sulphurets occur in the mineral kingdom, in which sulphur is united with an alkaline base. These are

1 Bisulphuret of molybdenum,
2 Sulphuret of iron,
3 Bisulphuret of iron,
4 White sulphuret of iron,
5 Sulphuret of manganese,
6 ———— nickel,
7 ———— lead,
8 Supersulphuret of lead,
9 Cupreous sulphuret of tin,
10 Sulphuret of bismuth,
11 Needle ore of bismuth,
12 Disulphuret of copper,
13 Sulphuret of mercury,
14 ———— silver.

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* Silliman's Jour. x. 242.

There are 17 sulphur salts formed by the combination of sulphides with sulphurets. These are

1 Nickel glance,
2 Sulpho-antimonide of nickel,
3 Sulpho-arsenide of cobalt,
4 Zinkenite,
5 Jamesonite,
6 Feather ore of antimony,
7 Variegated copper ore,
8 Copper pyrites,
9 Bournonite,
10 Grey copper ore,
11 Tennantite,
12 Cupreous sulphide of silver,
13 Silver glance,
14 Dark red silver ore,
15 Light red silver ore,
16 Myargirite,
17 Polybasite.

The sulphates, consisting of combinations of sulphuric acid with one or more bases, amount to 27.

All of these minerals will be described in the subsequent part of this treatise.

GENUS VI.—SELENIUM.

Selenium has not yet been met with in the mineral kingdom in an uncombined state. In the state of selenious or selenic acid it has not yet occurred in any mineral substance; but combined with a base in the state of seleniet, it has been met with, and four such species are known to exist; namely,

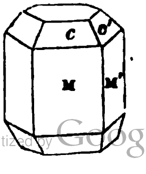
1 Seleniet of zinc,
2 Seleniet of lead,
3 Seleniet of copper,
4 Seleniet of silver.

GENUS VII.—TELLURIUM.

This rare metal has hitherto been found only in Transylvania, and in Norway. Various species of tellurium ore have been described, but only one of these belongs to this genus; namely,

Sp. 1. *Native Tellurium.*

The colour of this mineral is tin-white, and the lustre metallic. It has been found in crystals, which, according to Mr. William Phillips, are regular six-sided prisms. The figure in the margin represents the modification described by Mr. Phillips.



M on M′ 120°.

The edges at the base of the prism are replaced by the faces c, c′.

M on c or M′ on c′ 147° 36′.

It is obvious from this that the faces c, c' are not tangent planes, for the inclination of c on the base of the prism is only 122° 24'. These crystals are so small that the cleavage planes have not been ascertained.

This mineral is always opaque; it is brittle; its hardness is 2 to 2·5; its specific gravity, as determined by Mr. W. Phillips, from 5·7 to 6·1.

When exposed to the action of the blowpipe, it melts before ignition, and on the increase of the heat, burns with a bluish green flame, and is almost entirely volatilized in a dense white vapour, having the smell of horseradish.

According to the analysis of Klaproth, it is composed of

Tellurium . .	92·55
Iron . . .	7·20
Gold . . .	0·25
	100·00*

It is possible that this mineral may be a compound of 11 atoms tellurium, and 1 atom iron, but as the ore is mixed with a good deal of stony matter, it is more likely that the iron is only mechanically mixed.

Native tellurium has been hitherto found only in the mine of Maria Loretto at Facebay, near Zalathna, in Transylvania. It is very rare at present; but about 40 years ago it was met with in considerable quantity, and was melted to extract from it the little gold which it contains. It was in a sandstone, but whether in veins or beds is not quite certain.

There are three other species of tellurium ores, in each of which it is united with one or more metallic bases. These are

1 Foliated tellurium ore, or bitelluret of lead,
2 Graphic ore of tellurium, or argento-telluret of gold,
3 White tellurium ore, or plumbargento-telluret of gold.

These will come under our consideration in a subsequent part of this treatise.

GENUS VIII.—ARSENIC.

This poisonous metallic substance occurs pretty frequently in the mineral kingdom. It is found sometimes uncombined in the metallic state, and metallic arsenic is found united with

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* Beitrage, iii. 2.

other metallic bodies, constituting *arseniets*. It occurs likewise united with oxygen, constituting both *arsenious* and *arsenic* acids. The former of these is found in the mineral kingdom uncombined, but not the latter. Arsenic acid, however, enters into combination with various alkaline bases, constituting *arseniates*. Arsenic also is found united to sulphur in two different proportions, constituting two sulphur acids, which enter into various chemical combinations in the mineral kingdom. The species belonging to this genus are the five following:

1 Native arsenic,
2 Arsenious acid,
3 Arsenic acid,
4 Sulphide of arsenic,
5 Sesquisulphide of arsenic.

Sp. 1. *Native Arsenic.*

When metals occur in the earth in a state of purity, or nearly so, mineralogists distinguish them by prefixing the epithet *native*. When they are met with in combination with sulphur, or with some other bodies, they are said to be *mineralized*. By *native arsenic* then is meant arsenic in the metallic state, or nearly pure.

Its colour in the fresh fracture is nearly tin-white, but it speedily tarnishes and becomes greyish black.

The lustre is metallic. It occurs massive and in various accidental forms, but has never been observed in regular crystals. When sublimed, arsenic crystallizes in octahedrons, which Romé de Lisle considered as regular; but Hauy doubts whether the fibrous form of arsenic, after fusion, be compatible with that figure.

Hardness about 5; but it becomes softer on exposure to the air. When reduced to powder, it speedily becomes black.

The specific gravity of arsenic, when pure, is 5·672.* Native arsenic usually contains a small portion of some other metal, which increases its specific gravity somewhat. Brisson states it at 5·7249.† Breithaupt found a specimen of Saxon native arsenic as high as 5·923.‡

When heated it is volatilized in a white smoke having the smell of garlic. When heated nearly to redness it burns with a pale bluish white flame, giving out white fumes having the smell of garlic.

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* Harepath. Phil. Mag. lxiv. 322.

† As quoted by Hauy.

‡ Hoffman's Handbuch, iv. 208.

John analyzed two specimens of native arsenic from Joachimsthal, and found the constituents

Arsenic,	96	97
Antimony,	3	2
Oxide of iron and water,	1	1
	100	100[*]

If the first of these specimens was a chemical compound of arsenic and antimony, it must have consisted of

54 atoms arsenic,
1 atom antimony,

while the second would be a compound of

82 atoms arsenic,
1 atom antimony,

But it is much more probable that the antimony is either only mechanically mixed, or at least combined with only a portion of the arsenic.

Native arsenic occurs most commonly along with those metallic ores that contain arsenic as a constituent; as arsenical pyrites, orpiment, grey copper, white cobalt, grey antimony, arseniet of nickel. In this way it is found at Kongsberg in Norway, at Andreasberg in the Hartz, and St. Marie aux Mines in France.

Sp. 2. *Arsenious Acid.*

White Arsenic.

This is rather a rare mineral; but it is met with in small quantities along with native arsenic, arseniet of cobalt, and sulphate of arsenic. The principal localities are Andreasberg in the Hartz, Joachimsthal, and St. Marie aux Mines.

Its colour is snow-white; it is either in stalactitical crusts or in small capillary prisms. The internal lustre is shining, and either glassy or silky.

It may be obtained artificially, crystallized in regular octahedrons; but under this form it has not yet been met with in the mineral kingdom. The specific gravity when pure is 8·729.[†]

Before the blowpipe it is completely volatilized in a white smoke. When exposed to the internal flame it becomes black, and gives out a strong smell of garlic. It dissolves in

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[*] Chemische Untersuchungen, i. 289.

[†] Harepath. Phil. Mag. lxiv. 322.

hot water, and the solution strikes a yellow with water impregnated with sulphuretted hydrogen.

Sp. 3. *Arsenic Acid.*

The tendency of this acid to combine with bases is so great that in an isolated state it has not been met with in the mineral kingdom; but in combination with a base constituting an arseniate, it is by no means uncommon, no fewer than nineteen species being already known. These are,

1 4½ hydrous arseniate of lime,
2 Sesquihydrous arseniate of lime,
3 Diarseniate of iron,
4 Arseniate of iron,
5 Subsesquiarseniate of iron,
6 Scorodite,
7 Sulpho-arseniate of iron,
8 Diarseniate of nickel,
9 Diarseniate of cobalt,
10 Arseniate of lead,
11 Subsesquiarseniate of lead,
12 Diarseniate of copper,
13 Copper mica,
14 Prismatic oliven ore,
15 Acicular oliven ore,
16 Octahedral arseniate of copper,
17 Trisarseniate of copper,
18 Kapferschaum,
19 Ferruginous arseniate of copper.

These species will come under our consideration while treating of the various bases with which the arsenic acid is united.

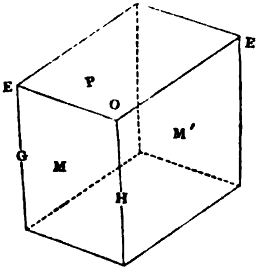
Sp. 4. *Sulphide of Arsenic.*

Realgar, red sulphuret of arsenic.

This mineral has a beautiful scarlet red colour, while its streak is orange yellow.

Its cross fracture is uneven, or sometimes imperfectly conchoidal; but it cleaves parallel to the planes of an oblique rhombic prism.

M on M′ 74° 15′, and the corresponding obtuse angle at the edge G 105° 45′. The terminal face P on M or M′ 104° 6′. The crystals of this substance hitherto met with have never the primary form. The solid angles E, E, are always replaced by small planes; the acute edges H of the prism are always replaced by two, and sometimes by three faces. In some crystals the obtuse edges G are also replaced by a tangent plane.



Hardness 1·5. It is brittle, and easily frangible. Its specific gravity, according to Brisson, is 3·384. Breithaupt found that of a crystallized specimen from Felsobanja 3·642.

Before the blowpipe it fuses easily, and burns with a blue flame, and is dissipated in fumes having the odour of garlic, and of sulphurous acid.

It is translucent, and the crystals are semitransparent. When rubbed, it acquires negative electricity.

Berzelius analyzed it and found it a compound of

Arsenic	4.68
Sulphur	2
	6·68

It is obvious from this that it is a sulphide, or a compound of 1 atom sulphur and 1 atom arsenic.

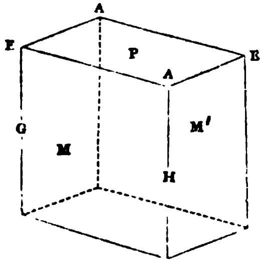
This mineral occurs along with native arsenic, and those metallic bodies such as cobalt and nickel, which are mineralized by arsenic. It is found at Andreasberg, in the Hartz, and beautiful crystals have been observed at Joachimsthal in Bohemia. It is said also to be found along with volcanic substances at Vesuvius, Solfatara, and Puzzola.

Sp. 5. *Sesquisulphide of Arsenic.*

Orpiment, yellow sulphuret of arsenic.

The colour is lemon yellow, and the streak has the same colour, but is rather paler.

The fracture is foliated, and the thin foliæ are flexible.



It occurs in very small crystals. Mr. W. Phillips has shown that the primary form is a right rhombic prism.

M on M′ 100°. The edge G 80°. Sometimes the edge H is replaced by a tangent plane, sometimes by two planes. The angles A, A, and likewise the angles E, E, are occasionally replaced by planes intersecting the base P parallel to its diagonals. It cleaves also parallel to the diagonal E, E.

The lustre of the cleavage faces is metallic, pearly; every where else resinous.

Semitransparent, or at least translucent. Hardness 1·5. Specific gravity, according to Haidinger, 3·480* Breithaupt

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* Mohs's Mineralogy, iii. 48.

found that of a foliated specimen from Lower Hungary 3·4.[*] Brisson states it at 3·445.[†]

The action of the blowpipe on it is the same as upon realgar.

From the analysis of Berzelius it is evident that this mineral is a compound of

1½ atom sulphur,	3
1 atom arsenic,	4·75
	7·75

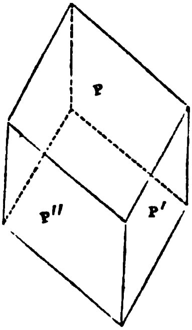
Orpiment occurs in the same situations as realgar; according to the Wernerians it is of rare occurrence in primary rocks, but much more frequent in the flœtz trap rocks. It is found in blue clay at Tasowa, near Neusohl, in Lower Hungary.[‡]

GENUS IX.—ANTIMONY.

This metal does not occur in nature in a great variety of forms. It is found native, though in that state it is rare; it is found united to arsenic and silver, constituting antimoniets of these metals. United to oxygen, it constitutes antimonious acid, and with sulphur sesquisulphide of antimony. The union of the two last species constitutes *red antimony.*

Sp. 1. *Native Antimony.*

This mineral was discovered by Anton Swab, in 1748, in the lead mine of Sala, in Westmanland.[§] Afterwards it was found at Allemont, in France, and in other places.



The colour is tin-white, often tarnished; the fracture is foliated, and it cleaves, according to Mr. Brooke, parallel to the planes of an obtuse rhomboid.

P on P' about 117° Brook
117° 15' Haidinger.

But the measurements of different fragments do not agree within more than two degrees. Hauy considers the primary form obtained by mechanical division, to be the regular octahedron.

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[*] Haussmann's Handbuch, iv. 222.

[†] Ibid.

[‡] Haidinger, Mohs's Mineralogy, iii. 49.

[§] Kong. Vetensk. Acad. Handl. 1748, p. 99.

The lustre is metallic, and when newly broken splendent.

Opaque; hardness 2·5 to 3. Specific gravity as determined by Klaproth, in a specimen from Catharine Neufang mine at Andreasberg in the Hartz, 6·720.*

Before the blowpipe it melts, and is volatilized in a white smoke. Its constituents, as determined by Klaproth, are

Antimony	98
Silver	1
Iron	0·25
	99·25†

There can be no doubt that the silver and iron are merely accidental ingredients.

Sp. 2. *Arseniet of Antimony.*

This species is doubtless scarce, as it is not described in any mineral system which I have seen. The specimen in my cabinet is from Allemont.

The colour is reddish grey; the texture fine granular; the lustre metallic; opaque; hardness 3·5; specific gravity 6·130.

Before the blowpipe it smokes, emitting the smell of arsenic, melts into a metallic globule, which catches fire, and burns all away, leaving white oxide of antimony on the charcoal. The constituents were found to be

Antimony	46·612
Arsenic	38·508
Loss	14·880
	100·000

Probably it is a compound of

2 atoms arsenic	7·5
1 atom antimony	8
	15·5

This estimate is founded on the supposition that the loss was arsenic. If the loss consists both of antimony and arsenic, then the mineral is a compound of

11 atoms arsenic
8 atoms antimony

But the first supposition is the most probable of the two.

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* Beitrage, iii. 170.

† Ibid.

Sp. 3. *Protoxide of Antimony.*

White antimony—antimony bloom.

This mineral occurs in small quantity, in veins traversing primary or grey-wacke rocks. It usually accompanies the ores of antimony, and is very frequently attended by quartz.

Colour white, most commonly with a shade of yellow.

The fracture cannot be observed, but it occurs in crystals which are usually very thin four-sided prisms, having very much the aspect of split straw. At Braunsdorf near Freiberg, it has been found in sulphuret of lead in pretty large six-sided prisms. According to Mr. Phillips it yields to mechanical division parallel to the sides of a rhombic prism of 137° 43′, and 42° 17′; but the principal cleavage is parallel to the shorter diagonal of the prism.*

The lustre is adamantine and shining. It is semitransparent, or at least translucent. Hardness 2·5 to 3; specific gravity 5·566.†

Before the blowpipe it melts easily, and is volatilized in a white vapour. Indeed it fuses when simply held in the flame of a candle.

It is protoxide of antimony mixed or combined with a little silica. A specimen from Braunsdorf analyzed by Vauquelin, was composed of

Oxide of antimony	86·
Ditto and iron	3·
Silica	8
	97‡

This approaches to 3 atoms silica
7 atoms oxide of antimony.

It may perhaps be a disilicate of antimony, or a compound of

1 atom silica . . .	2
2 atoms protoxide of antimony	19
	21

But this can only be determined by a new analysis, and the mineral is so scarce that it is not easy to procure a sufficient quantity for such a purpose.

It was first found at Przibram in Bohemia, and afterwards at Braunsdorf, in Saxony. It is found also at Malaczka, in Hungary, in Baden, in Nassau, and at Allemont in Dauphiny.§

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* Mineralogy, p. 331.

† Mohs' Mineralogy, ii. 152.

‡ Hauy, iv. 309.

§ Mohs, ii. 154.

Sp. 4. *Sesquisulphide of Antimony.*

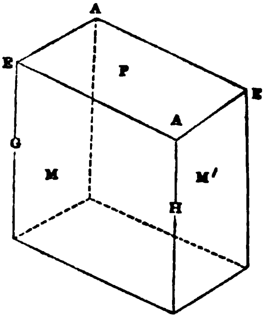
Grey antimony—crude antimony—sulphuret of antimony.

This species constitutes the great ore of antimony, from which all the antimony of commerce is extracted.

The colour is lead grey, inclining to steel grey. It has the metallic lustre, and is specular splendent, except when in minute capillary crystals, when it is nearly dull.

The primary form of the crystal is a right rhombic prism.

M on M′ 91° 30′, by Mr. Phillips' measurement. Mr. Brooke found M on M′ 90°, but observes that the secondary forms of the crystals show that it is not rectangular, but rhombhoidal. In many cases the acute edges G of the prism are replaced by tangent planes. In some the terminal faces P of the prism are surmounted by four-sided pyramids, the faces M, M′ making angles of 145° 30′, with the corresponding faces of the pyramid. These two modifications sometimes occur together.



When the crystals are large enough to observe the texture, the mineral is foliated. The thin plates are very flexible. Opaque; sectile; hardness 2. Specific gravity, as determined by Mohs 4·620;[*] according to Hauy, it is 4·516.[†]

When placed in the flame of a candle it melts. Before the blowpipe it is dissipated in a white vapour, which coats the charcoal, and gives out at the same time the smell of burning sulphur. I found its constituents to be

Antimony	73·77
Sulphur	26·23
	100·00

This amounts nearly to

1 atom antimony	8
1½ atom sulphur	3
	11

The mineral is therefore a sesquisulphide.

The compact varieties of this species occur most commonly in beds; but the crystallized and foliated varieties are con-

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[*] Mineralogy, iii. 24.

[†] Mineralogie, iv. 292.

fined to veins. In Great Britain it has been wrought only in Cornwall, where a pretty rich mine of it exists, Huel Boys, Endellion, near Padstow. There was another mine of it at Saltash on the borders of Devonshire, near Plymouth, which yielded considerable quantities of crude antimony about the year 1776. It is found at Glendinning, in Dumfries-shire; but I am not aware that the mine has ever been wrought. It occurs at Pösing, near Presburg, in Hungary, and in other localities of that country. It is found also in Saxony, and beautiful specimens are brought from the department of Puy-de-Dome, in France.

Sp. 5. *Red Antimony.*

This is rather a rare mineral. In small quantities it is often associated with sesquisulphide of antimony. It has been supposed by some that it owes its origin to a partial decomposition of the sesquisulphide of antimony.

Colour cherry red; the fracture, when observable, is foliated.

It most commonly occurs in delicate capillary crystals, which Mr. Phillips thinks have for their primary form a right square prism, having the edges commonly replaced by a tangent plane. Mohs considers the primary form as an octahedron, having a rhombic base.

Lustre shining, and approaching the adamantine; feebly translucent; sectile; the thin laminæ slightly flexible; hardness 1 to 1·5. Specific gravity, as determined by Klaproth, 4·090.[*] According to Mohs, it is from 4·5 to 4·6.[†]

Before the blowpipe it melts, and is volatilized, giving out a sulphureous odour. When plunged into nitric acid it becomes covered with a white coating.

From the late investigations of M. H. Rose, we learn that this mineral is a compound of

1 atom oxide of antimony . .	9·5
2 atoms sesquisulphide of antimony	22
	31·5

Red antimony is found at Braunsdorf, in Saxony, Allemont, in France, in Tuscany, and in Hungary and Transylvania. It has been met with in veins only.

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[*] Beitrage, iii. 179.

[†] Mineralogy, iii. 37.

GENUS X.—CHROMIUM.

Chromium in the metallic state has not yet been observed, either isolated or in combination with other bases. The green oxide of chromium, and chromic acid are not uncommon, and always in combination with a base.

Oxide of chromium exists in chrome iron ore, where it acts the part of an acid. The mineral being a compound of

$\left\{\begin{array}{l}\text{1 atom chromite of iron,}\\ \text{1 atom chromite of alumina.}\end{array}\right.$

Chromic acid united to oxide of lead constitutes several mineral species, namely,

Chromate of lead,
Dichromate of lead,
Cupreochromate of lead,
Chromo-phosphate of lead.

Of these, chrome iron ore is by far the most abundant, and the most valuable. These species will come under our review in a subsequent part of this work.

GENUS XI.—MOLYBDENUM.

Molybdenum has never been found native in the metallic state. It exists in the form of molybdic acid, combined with oxide of lead, and constituting *molybdate of lead*, a species which will come to be described under the genus *lead*.

Molybdenum exists also united to sulphur, constituting the only species belonging to this genus.

Sp. 1. *Bisulphide of Molybdenum.*

Molybdena—wasserblei—molybdenglanz.

The colour of this mineral is lead grey. It has the metallic lustre, is splendent, and the streak is unchanged.

The fracture is foliated; the plates are easily separated from each other, and when sufficiently thin, are flexible, but not elastic. The mineral is sectile, and almost malleable.

The crystal is the regular six-sided prism of unknown dimensions; but it always occurs very short. Schmeisser, in the second volume of his mineralogy, says, that he saw crystals of it in the possession of Mr. Raspe, which were six-sided prisms terminated on both ends by six-sided pyramids; but I am not aware of any such crystals at present existing in cabinets.

Opaque; hardness 1 to 1·5; specific gravity, as determined by Karsten, 4·569; by Brisson, 4·7385.

Before the blowpipe, it does not melt nor is reduced; but it emits fumes, which are deposited upon the charcoal, while at the same time a sulphureous odour is exhaled.

It was first analyzed by Bucholz, who found its constituents

2 atoms sulphur, . .	4
1 atom molybdenum, . .	6
	10[*]

It is found in small pieces, or in crystals, most frequently in granite or gneiss. Its oldest localities are Altenberg, in Saxony, and Schlaggenwald and Zinnwald, in Bohemia, where it accompanies tin ore. It is found in a similar situation in Cornwall, and abounds in the primary rocks of the United States of America. In Norway, it occurs imbedded in the zirconsyenite rock of the neighbourhood of Christiania.

GENUS XII.—TUNGSTEN.

Tungsten has not been observed in the metallic state in the mineral kingdom. It is always under the form of tungstic acid; and as this acid is constantly united to an alkaline base, the species of minerals containing it will come to be described under their respective bases. They are the following:—

1 Tungstate of lime,
2 Wolfram,
3 Sesquitungstate of lead.

GENUS XIII.—COLUMBIUM.

Columbium, like the preceding metal, occurs only in the state of peroxide, or columbic acid, which is always united to an alkaline base. The species hitherto met with are the following:—

1. Yttro-tantalite, under which name three species of minerals are included; namely,

(1.) Columbate of yttria,
(2.) Dicolumbate of yttria,
(3.) Triscolumbate of yttria.

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[*] Gehlen's Jour. iv. 60.

2. Fergusonite.
3. Columbite, or tantalite.

These species will be described in a subsequent part of this work.

GENUS XIV.—TITANIUM.

This metal in the metallic state has been observed only in the slag at the bottom of iron furnaces. It combines with two proportions of oxygen, constituting the protoxide of titanium and titanic acid. Both of which have been observed native, though the latter is never in a state of purity. Titanic acid combines with the oxide of iron in various proportions, and constitutes at least five different species, which will be described when we come to treat of the genus *Iron*. Here we have only to give an account of titanium and its two oxides.

Sp. 1. *Native Titanium*.

The existence of this metal in a state of purity in the slag of Merthyr Tydvil furnaces, in South Wales, was discovered by Dr. Wollaston in 1822.*

The colour is copper-red, and the titanium is usually under the form of small cubes with smooth surfaces.

Lustre splendent and metallic; hardness 7·5; opaque; specific gravity 5·3.

The crystals are infusible before the blowpipe: They are not sensibly acted on by acids. They may be oxidized when heated with a mixture of nitre, borax, and carbonate of soda. They are good conductors of electricity.

These crystals consist of titanium in the metallic state, and nearly pure. I found traces of iron in some of the cubes, but am not quite certain that the iron may not have been mechanically mixed. The cubes, however, had been repeatedly digested in muriatic acid.

This reduced titanium was found at the bottom of the furnaces at Merthyr Tydvil, when these furnaces were cleared out. It has been met with in other places. For example, Professor Walchner found it in the iron slag at Carlsruhe.† It was found also lately at the bottom of the furnace at Muirkirk, in Ayrshire.

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* Phil. Trans. 1823, p. 17.

† Schweigger's Jahrbuch, xvii. 118.

Sp. 2. *Protoxide of Titanium.*

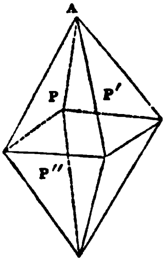
Anatase—octahedrite—oisanite.

This mineral was discovered by Count Bournon in 1783, near the town of Oisan, in the department of the Isere, and called by him *blue schorl.* Saussure afterwards described it, and gave it the name of *octahedrite*, while Hauy distinguished it by the name of *anatase.*

Its colour, when pure, seems to be indigo *blue;* but more commonly it appears, by reflected light, *clove brown* or *steel-grey:* by transmitted light it is greenish yellow, or blue. Its fracture is foliated, and the cleavage planes are parallel to the faces of an octahedron.

It has been only found crystallized. The primary form is an octahedron with a square base.

P on P′ 98°.
P on P″ 136° 12′



Sometimes the summit A is replaced by a small square parallel to the base of the pyramid. P or P′ makes with that face an angle of 111° 17′. Sometimes the summit A is replaced by a low four-sided pyramid, P making with the corresponding face of this small pyramid an angle of 131° 21′. Sometimes the small pyramid replacing A is eight-sided.

Lustre splendent and adamantine. It varies from semi-transparent to opaque; hardness 5·5 to 6; specific gravity, as determined by Hauy, 3·857,[*] by Mohs 3·826.[†]

Before the blowpipe, it exhibits the phenomena of oxide of titanium.[‡]

By the analysis of Vauquelin, it is pure oxide of titanium. From the colour, I am disposed to consider it as the protoxide of that metal. It is certainly not titanic acid, which when pure is white.

This mineral is rare. In Dauphiny, it occurs in veins in primary rocks along with albite, axinite, rock-crystal, and chlorite. Bournon says, that he possessed a crystal of it from Cornwall in granite. It has been found also in Norway by Von Buch; in Spain, and in Brazil.[§]

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[*] Mineralogie, iv. 344.

[†] Mineralogy, ii. 380.

[‡] Berzelius on the blowpipe, p, 140.

[§] Mohs, ii. 380.

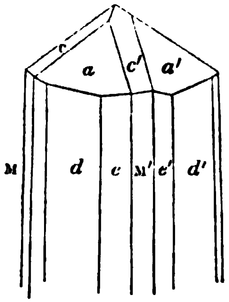
Sp. 3. *Titanic Acid.*

Crispite, gallizinite, rutile, sagenite, titanite.

This mineral usually occurs in veins passing through primary rocks. It has been met with in many different places. I have fine specimens from Glen Tilt, in Perthshire. St. Yrieiz, in France, is the most abundant locality; but the variety of situations in which it is found is so great, that it would be impossible to enumerate them all. Its peculiar nature was first pointed out by Klaproth in 1795.

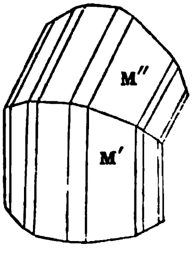
The usual colour is brownish-red, more inclined to brown when the specimen is opaque, and to red when it is transparent.

Most commonly crystallized. The fracture, when observable, is foliated, the cleavage being parallel to the lateral faces, and to the diagonals of a right square prism; which must therefore be considered as the primary form. In some crystals the lateral edges are replaced by tangent planes; in others, by two planes; and in some, both of these modifications occur together. The prism is frequently terminated by a four-sided or eight-sided pyramid. The figure in the margin exhibits at one view most of these modifications.



M on d, or M' on d', 132° 32'.
M' on e' 161° 40'.
M on c, or M' on c', 122° 45'.
a on d 132° 20'.
d on e 153° 33'.
a on a over summit 90°.
c on c ditto 109° 47'.
a on a' 123° 15'.
a on c 151° 42'.

The crystals are longitudinally striated. They often occur penetrating transparent quartz. Sometimes small needle-form crystals are met with intersecting each other like a net. It was this circumstance which induced Saussure to give the mineral the name of sagenite. Geniculated crystals frequently occur, consisting of twin crystals united together lengthways, and making an angle with each other, as represented in the margin.



M' on M'' 134° 52'.

Hardness 6·5 to 7; specific gravity as determined by Klaproth 4·18;[*] as determined by Mohs 4·249.[†] The last specific gravity was that of a dark-coloured variety from Ohlapian.

Before the blowpipe it is not altered. It dissolves in borax, forming a hyacinth red bead. It does not fuse with biphosphate of soda, though it communicates a pale red colour.

Klaproth considered it a pure titanic acid, but Rose has shown that it contains iron, and that it owes its colour to the presence of the oxide of that metal. We are not yet in possession of an exact analysis. Should the iron amount to an atomic proportion, titanic acid will require to be transferred to the genus *iron*, and described as a *titaniate* or *supertitaniate of iron*.

GENUS XV.—VANADIUM.

Vanadium has not hitherto been discovered in the metallic state. The minerals at present known contain it in the form of vanadic acid. Only one species has been hitherto met with; namely,

Vanadiate of Lead.

It will come to be described under the genus *lead*.

CLASS II.

ALKALINE BASES.

There are 27 alkaline bases which occur in the mineral kingdom. These are,

1 Ammonia,
2 Potassium,
3 Sodium,
4 Lithium,
5 Barium,
6 Strontium,
7 Calcium,
8 Magnesium,
9 Aluminum,
10 Glucinum,
11 Yttrium,
12 Cerium,
13 Zirconium,
14 Thorium,
15 Iron,
16 Manganese,
17 Nickel,
18 Cobalt,
19 Zinc,
20 Lead,
21 Tin,
22 Bismuth,
23 Copper,
24 Mercury,
25 Silver,
26 Uranium,
27 Palladium.

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[*] Beitrage, i. 234.

[†] Mineralogy, ii. 377.

Each of these bases constituting a genus, it is obvious that this second class comprehends under it no fewer than 27 genera of minerals.

GENUS I.—AMMONIA.

Though ammonia rather belongs to the animal than the mineral kingdom, yet there are a few ammoniacal salts occasionally met with, chiefly in the neighbourhood of volcanoes, which are usually enumerated as mineral species. These we shall notice in this place.

Sp. 1. *Sal Ammoniac.*

This salt occurs in the immediate vicinity of active volcanoes, and is formed by sublimation. Its best known localities are Vesuvius, Etna, Solfatara, &c. It is formed also during the combustion of pitcoal, and sublimes in the brick kilns in the neighbourhood of London, during the baking of the bricks.

Colour usually white; often inclining to grey or yellow.

Occurs in powder, in fibrous masses, in crusts, and in regular crystals, which have most commonly the form of what is called the *leucite crystal;* that is, a crystal approaching the spherical form, and bounded by 24 trapezoidal faces. The nature of this crystal will be explained under the species *leucite.* The primary form of this salt is a cube, and the leucite crystal is formed when each angle of the cube is replaced by three planes, and when these planes increase so much as to obliterate the original faces of the cube.

Lustre vitreous; hardness 1·5 to 2; very sectile; specific gravity 1·528; taste saline and pungent; sublimes when heated; soluble in water.

The sal ammoniac from Vesuvius was found by Klaproth composed of

Pure sal ammoniac . .	99·5
Common salt . .	0·5
	100

That from Bucharia consisted of

Sal ammoniac . .	97·5
Sulphate of ammonia .	2·5
	100·0[*]

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[*] Beitrage, iii. 89.

Sp. 2. *Sulphate of Ammonia.*

Mascagnine.

This salt is met with in the neighbourhood of Etna and Vesuvius, &c.

Colour yellowish grey, lemon yellow.

Occurs in mealy crusts and stalactites.

Translucent; lustre vitreous, after solution in water and crystallization; taste pungent and bitter; soluble in water.

It has not been subjected to analysis, but is probably nearly pure sulphate of ammonia.

GENUS II.—POTASSIUM.

Potassium has so strong an affinity for oxygen that its existence in the metallic state, at least within reach of the atmosphere, is out of the question. Combined with oxygen in the state of potash it is not an uncommon constituent of minerals; but only a single species occurs, in which it constitutes the only alkaline ingredient united to an acid.

Sp. 1. *Nitrate of Potash.*

Saltpetre, nitre.

This salt occurs in small needle form crystals on the surface of the earth, on walls, rocks, &c., in many parts of the world; in none more abundantly than in India, whence we are supplied with all the nitre which we require.

Colour white; taste cooling and bitter; when thrown on burning coals it deflagrates with great splendour; specific gravity 1·933.

The primary form of saltpetre, according to Hauy, is an octahedron with a rectangular base, but it crystallizes commonly in six-sided prisms, which are striated longitudinally. When pure it is a compound of

1 atom nitric acid . .	6·75
1 atom potash . . .	6
	12·75

But it almost always contains a mixture of chloride of potassium, common salt, sulphate of potash, and not unfrequently nitrate of lime. These foreign salts sometimes amount to 25 per cent. of the nitre; but in fine samples from India I have found no more than 5 per cent. of impurity. In these fine samples the calcareous salts are altogether wanting.

There are 26 species of minerals in which potash occurs as one of the bases. These will be described under the genus *aluminum*, as they all contain a considerable proportion of alumina as a constituent. We shall merely give a list of their names:

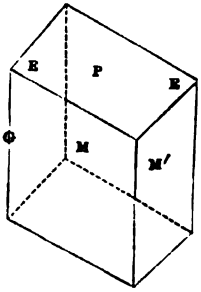
1 Ice spar,
2 Killinite,
3 Leucite,
4 Gabronite,
5 Felspar,
6 Kaolin,
7 Leelite,
8 Lepidolite,
9 Rhomboidal mica,
10 Brown scaly mica,
11 Anthophyllite,
12 Hydrous ditto,
13 Gieseckite,
14 Diploite,
15 Pinite,
16 Glauconite,
17 Marchesonite,
18 Nutallite,
19 Phyllite,
20 Pearl stone,
21 Antrimolite,
22 Ittnerite,
23 Hydrolite,
24 Agalmatolite,
25 Morvenite,
26 Apophyllite.

GENUS III.—SODIUM.

Sodium, like potassium, occurs in the mineral kingdom only in the state of soda, constituting the base of various salts. Those in which it exists simply united to an acid belong to this genus. But the various minerals in which soda is associated with other bases will be described when we come to treat of those bases that constitute the greater proportion of the compound. The simple soda salts belonging to this genus are seven in number.

Sp. 1. *Carbonate of Soda.*

From the observations of Klaproth, it appears that the common crystallized carbonate of soda occurs at Debrezin, in Hungary, and Montenuovo, near Naples.*



It is usually effloresced, and in powder, from the loss of its water of crystallization, but it is easily crystallized artificially. The primary form is an oblique rhombic prism.

P on M or M′ 108°43′.
M on M 76° 12.

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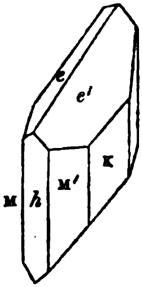
* Beitrage, iii. 83.

But the most common modification of the crystal is that represented in the figure in the margin, in which the edges G are replaced by tangent planes *h*, and the solid angles E, E are replaced by two planes.

Its taste is alkaline, but much less acrid than the carbonate of potash. When exposed to the air it effloresces.



Sp. 2. *Sesquicarbonate of Soda.*

Natron, trona, borech, urao.

This mineral occurs in great abundance in the province of Suckena, which belongs to Tripoli, in Africa, and lies at the distance of 28 days journey from the town of Tripoli, or two days journey from Fezzan. The mineral is found at the foot of a mountain, and forms a crust, varying from the thickness of an inch to that of the back of a knife.[*]

It is in crystals adhering together, and constituting parallel or oblique four-sided prisms. It is often in fibrous masses, seemingly consisting of a congeries of minute crystals.

Lustre vitreous glistening; translucent; colour grey, or yellowish-white; taste alkaline, but mild; soluble in water; not altered by exposure to the atmosphere.

A specimen of the African natron, analyzed by Klaproth, was a compound of

Carbonic acid,	38
Soda,	37
Water,	22·5
Sulphate of soda,	2·5
	100[†]

This is obviously equivalent (leaving out the sulphate of soda) to

1½ atom carbonic acid,	4·125	38·76
1 atom soda,	4·000	37·59
2 atoms water,	2·250	21·14
	10·375	97·49

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[*] Bagge, Kongl. Vet. Acad. Handl. 1773, p. 140.

[†] Beitrage, iii. 80.

When this salt is crystallized artificially, it forms doubly oblique prisms. But I have never obtained crystals sufficiently perfect for measurement.

From a paper by Mariano de Rivero and Boussingault,[*] it is evident that the *Urao* which occurs at the bottom of a lake, a day's journey from Merida in South America, is a sesquicarbonate of soda. For they found its constituents to be

		Atoms.
Carbonic acid,	39	1·37
Soda,	41·22	1
Water,	18·80	1·62
Foreign bodies,	0·98	
	100	

There is a slight deficiency both of acid and water, provided the analysis be correct.

Sp. 3. *Nitrate of Soda.*

An immense deposite of this salt has been recently discovered in the district of Tarapaca, near the northern frontier of Chili, constituting a bed several feet thick, and extending over a space 40 leagues in length. The salt is sometimes in a state of efflorescence, sometimes crystallized, and most frequently mixed with clay and sand. Here and there it contains nests of common salt, and it is seldom free from an admixture of nitrate of potash. Great quantities of it have been brought to Europe, and in Great Britain it is beginning to be employed in the manufactures instead of nitre. I have not ventured to describe it, because I suspect that it has undergone solution and crystallization before it is imported into Great Britain.

Sp. 4. *Hydrous Sulphate of Soda.*

Glauber's salt.

This salt is found occasionally in the neighbourhood of mineral springs. It occurs near Aussee, Ischel, and Halstadt in Austria, at Hallein in Saltzburgh, in Hungary, Switzerland, Italy, Spain, &c.

It is commonly in the state of an effloresced powder; sometimes massive, and sometimes, it is said, crystallized in needles and six-sided prisms; but I have never seen it in that state.

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[*] Ann. de Chim. et de Phys. xxix. 110.

Sp. 5. *Anhydrous Sulphate of Soda.*

Thenardite.

This salt exists at Espartine, about five leagues from Madrid, and two and a-half from Aranjuez. During winter, salt water exudes from the bottom of a basin, and during summer, the liquid becomes concentrated, and deposits crystals of anhydrous sulphate of soda.

They have the form of octahedrons with a rhomboidal basis. They have three cleavages, indicating a right oblique prism with rhomboidal bases, the angles of which are about 125° and 55°. The height of the prism is to a side of its base, as 7 to 3.*

The crystals are translucent; lustre vitreous; specific gravity 2·73.

According to the analysis of M. Casaseca, the constituents are

Anhydrous sulphate of soda,	99.78
Carbonate of soda, .	0·22
	100†

This salt is easily obtained artificially, by keeping a saturated solution of Glauber salt at the temperature of 106°.

Sp. 6. *Borax.*

Pounxa, swaga, tincal, zala, biborate of soda.

This mineral (till within these few years) was brought chiefly from Thibet, where it is procured from a lake which is entirely supplied by springs, and is fifteen days journey from Tisoolumbo, the capital. The water contains both borax and common salt, and being in a very high situation, is frozen during the greater part of the year. The edges and shallows of the lake are covered with a stratum of borax, which is dug up in considerable masses; and the holes thus made are gradually filled up by a fresh deposition.

Its colour is white, but it sometimes has a shade of blue or green.

Lustre vitreous, sometimes earthy.

It is often crystallized in six-sided flat prisms, variously terminated, but yielding to mechanical division, parallel to the faces of a doubly oblique prism.

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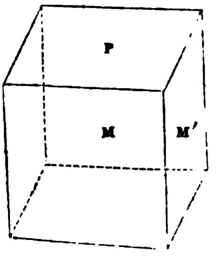
* Cordier, Ann. de Chim. et de Phys. xxxii. 309. † Ibid. p. 311.



M on M′ 86° 30′
P on M or M′ 101° 30

The edges of the prism are often replaced by planes, converting the crystals into a six or eight-sided prism.

Varies from translucent to opaque.

The crystals are often coated with a kind of fatty matter. When heated they frequently blacken and undergo a kind of combustion, indicating the presence of some foreign matter. It froths and swells before the blowpipe, and at last fuses into a transparent globule.

Borax is said to be found also in China, Ceylon, Potosi, and in different places of Europe, viz. Transylvania, Lower Saxony, and Tartary.

Sp. 7. *Common salt.*

Rock salt, salgemme, muriate of soda, chloride of sodium.

This important salt is found in immense beds, situated most commonly in the new red sandstone; though it is occasionally met with in older formations. Poland, Hungary, England, &c., may be mentioned as localities.

Colour generally white, passing into yellow, flesh red, and ash grey. Sometimes blue, streak white.

Frequently in crystals. Primary form the cube. Sometimes the angles and sometimes the edges of the cube are replaced by tangent planes. When these new faces become so much enlarged as to obliterate the original faces of the cube, the regular octahedron and the rhomboidal dodecahedron are produced.

Lustre vitreous, shining; transparent to translucent; rather brittle; hardness 2. Specific gravity, as determined by Mohs, 2·257; taste saline.

Decrepitates before the blowpipe, deliquesces in a moist atmosphere.

It consists essentially of chloride of sodium; but is almost always mixed with a little sulphate of lime, chloride of calcium, and chloride of magnesium.

The minerals containing soda as an essential, though not the only base, are 29 in number. Their names are as follows:

1 Glauberite,
2 Reissite,
3 Soda-alum,
4 Cryolite,
5 Nephelin,
6 Sodalite,

7 Achmite,
8 Blœdite,
9 Pipestone,
10 Albite,
11 Ryacolite,
12 Keiselspath,
13 Elœolite,
14 Commingtonite,
15 Natrolite,
16 Mesolite,
17 Ithnerite,
18 Chalilite,
19 Harringtonite,
20 Levyne,
21 Analcime,
22 Lehuntite,
23 Cluthalite,
24 Bytownite,
25 Cauzeranite,
26 Retinalite,
27 Labradorite,
28 Pitchstone,
29 Obsidian.

These will come to be described chiefly under the genus *alumina*, to which the greater number of them belong.

GENUS IV.—LITHIUM.

Lithium, like potassium and sodium, never occurs in the mineral kingdom in an isolated state; but always united to oxygen, and constituting the alcali, *lithia*. No mineral species is known composed of an acid united to lithia alone. All those which contain it are compound salts, and of course coming to be described under subsequent genera. We shall here merely give the names of those species which contain lithia as a constituent. They are 5 in number.

1	Spodumen,	$4AlS^2+LS^2$
2	Petalite,	$3AlS^4+LS^3$
3	Ambligonite,	$3Al\dot{P}h+L\dot{P}h$
4	Tourmalin,	$14AlS+\underline{mn}S^2+L\dot{B}^2$
5	Lepidolite,	$6AlS+2LS+KS$

GENUS V.—BARIUM.

Barium, like the preceding bases, has been found only in the mineral kingdom united to oxygen and constituting *barytes*. Hitherto barytes has been found almost exclusively combined with carbonic acid or sulphuric acid.

Sp. 1. *Carbonate of Barytes.*

Barolite, witherite.

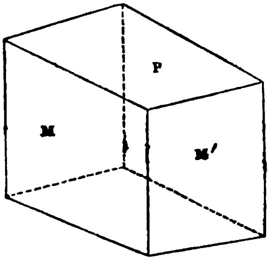
This mineral was first observed at Alston moor in Cumberland, along with galena, in veins passing through the coal formation. It was described and its nature pointed out by

Dr. Withering in 1784.[*] Hence the name *witherite*, by which Werner distinguished it.

Its colour is grey, most commonly with a shade of yellow. It is said also to occur with a shade of blue, green, and red.

The principal fracture is fine radiated or fibrous, the cross fracture is uneven, inclining to splintery.

It occurs crystallized, most commonly in six-sided prisms terminated by six-sided pyramids, resembling at first sight the most common form of rock crystal. Sometimes the summit of the pyramid is replaced by a plane parallel to the base of the prism. The primary form seems to be a right rhombic prism.



M on M′ (according to the measurement of Mr. W. Phillips) 118° 30′.

The six-sided prisms are probably macles, resulting from the intersection of the primary crystals.

Lustre of the principal fracture shining, of the cross fracture glistening; lustre resinous.

The crystals (which are small) are semi-transparent; the massive varieties are only translucent; hardness, 3·75. I found the specific gravity of a fine specimen from Anglesark, 4·2985. Hauy states it at 4·2919.[†] Mohs makes it 4·301.[‡]

Before the blowpipe it fuses readily into a clear glass, which in cooling becomes a white enamel. On charcoal it effervesces strongly, becomes caustic, and then is absorbed by the charcoal. With borax and with biphosphate of soda it melts into a clear glass, which becomes opaque and white on cooling, if the quantity of carbonate of barytes bear a sufficient proportion to that of the fluxes.

Klaproth found the Stirian variety of this mineral pure carbonate of barytes, composed of

1 atom carbonic acid, .	2·75
1 atom barytes, . .	9·50
	12·25[§]

The Anglesark variety contains according to this analysis 1·7 per cent. of carbonate of strontian, a trace of copper, and a

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[*] Phil. Trans. 1784, p. 293.

[†] Mineralogie, ii. 25.

[‡] Mineralogy, ii. 120.

[§] Beitrage, i. 271.

small quantity of alumina and iron.[*] In every specimen which I examined, I found *carbonate of lead*, and in a specimen from the north of England, I found a little carbonate of lime.

It is by no means scarce in the lead mine district in the north of England, where it accompanies galena in the veins. Withering says, that the specimen which he examined came from Alston Moor; but Klaproth assures us, I know not on what authority, that it came in reality from Anglesark in Lancashire, where it is known to exist in considerable quantity, but never quite free from carbonate of lead. It has been found near Neuberg in Stiria, in irregular beds. Hungary, Salzburgh, Siberia, Sicily, are also mentioned as localities.

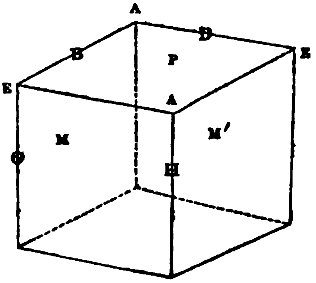
Sp. 2. *Sulphate of Barytes.*

Baroselenite, heavy spar, aehrensten, Bolognian spar, cawk, hepatite, litheospore.

This mineral is rather abundant, and it occurs both in beds and veins; though the finest and most beautiful specimens are met with in veins.

Its colour when pure is snow-white; but it has frequently a shade of red, yellow, blue, or green. In some cases the colour is brown or even brownish black.

The fracture is usually foliated; though in some varieties it is radiated, and in others fibrous.



It occurs very frequently crystallized, and the primary form is a right rhombic prism, in which

M on M′ 101° 42′

Sometimes the edges H, and sometimes the edges G, are replaced by tangent planes. Sometimes the angles A, sometimes the angles E, are replaced by triangular planes. The former parallel to the long diagonal, and the latter to the short diagonal of the base of the prism. The enlargement of these secondary planes at the expense of the primary faces of the crystal, occasion the different forms which have been described and figured by Hauy.[†]

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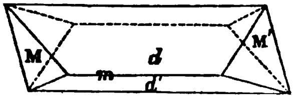
[*] Beitrage, ii. 86.

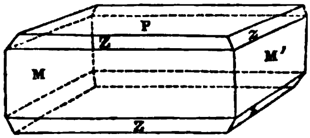
[†] See his Atlas, from plate 33 to plate 42, both inclusive. The varieties figured are 72 in number.

When the faces replacing A acquire such a size that they meet, the base of the prism disappears, and the faces M, M′ become triangular. Thus the crystal is changed into an octahedron. And most frequently it is elongated as in the figure in the margin, where M, M are the faces of the primary form, represented by the same letters as in the former figure, *d*, *d′* are the faces that replace the angles A, much enlarged, and *m*, in the cuneo form ridge of the octahedron. A somewhat similar octahedron is sometimes produced by the enlargement of the faces replacing the angles E, in the primary form.



These two replacements sometimes occur together concealing all the primary faces, and constituting a kind of octahedron.

Sometimes all the edges of the base of the primary prism are replaced by tangent planes, Z, Z, Z, represent these planes of replacement in the figure in the margin.



These are the most remarkable modifications of the primary form. For a description of the rest, the reader is referred to Hauy, and for the measurement of the inclination of the secondary faces to each other, and to the primary faces, to Phillips.*

The lustre is commonly pearly, and varies from glimmering to splendent, according to the purity and state of the specimens.

Sometimes it is opaque, and sometimes translucent on the edges. The crystals are always translucent and sometimes transparent. They refract doubly.

Hardness 3 to 3·5. I found the specific gravity of a pure transparent colourless crystal 4·4720. Mohs states the specific gravity at 4·446.† According to Hauy it varies from 4·2984 to 4·4712.

Before the blowpipe it decrepitates but is not easily fused. This difficult fusibility constitutes a good mark of distinction between this mineral and sulphate of lime, or of strontian. In the blue flame, it is converted into sulphuret of barium, characterized by its pungent and hepatic taste.

* Mineralogy, p. 184. † Mineral. ii. 123.

When pure, it is composed of

1 atom sulphuric acid, .	5
1 atom barytes . .	9·5
	14·5

It occurs in almost every country, chiefly in veins. In the north and middle counties of England, fine crystallized specimens are met with in the veins accompanying galena.

The sub-species into which it has been divided by Werner, are scarcely entitled to the minute attention which they have received from him.

Sp. 3. *Calcareo-sulphate of Barytes.*

This species, hitherto overlooked by mineralogists, occurs rather abundantly in the lead mine of Strontian in Argyleshire, which occupies a vein dividing the granite from the gneiss. It is the common gangue of the galena.

Colour snow-white; texture foliated. I have never met with a specimen of it crystallized. Very frangible; hardness 2·75; translucent on the edges. Specific gravity 4·1907. Before the blowpipe decrepitates, but does not fuse.

I subjected the purest specimen that I could select to analysis. The result was as follows:

		Atoms.
Barytes, . .	48·945	5·15
Strontian, . .	0·790	0·12
Lime, . .	6·605	1·88
Sulphuric acid, .	35·230	7·05
Silica, . .	4·140	2·07
Alumina, . .	3·460	1·53
Protoxide of iron, .	0·450	0·10
Moisture, . .	0·565	
	100·185	

It is obvious that the sulphuric acid just saturates the barytes, strontian, and lime. Hence the other constituents are accidental. The mineral (if we include the strontian with the lime) is obviously a compound of

1 atom sulphate of lime,
2½ atoms sulphate of barytes.

Probably this species occurs in other localities besides Strontian; though hitherto it has been confounded with sulphate of barytes; from which it is easily distinguished by its inferior hardness and specific gravity. The sulphate of barytes stated by Hauy to be as low as 4·2984, probably contains at least a portion of calcareo-sulphate.

Sp. 4. *Baryto-calcite.*

There is another species of calcareous sulphate of barytes which occurs in Yorkshire, between Leeds and Harrowgate, connected with the millstone grit and mountain limestone beds, which occur in such abundance in that country.

Colour white.

Texture foliated.

Translucent, at least on the edges.

Lustre silky.

Hardness 4; exceedingly brittle, and very easily frangible.

Specific gravity 3·868.

Its constituents, by my analysis, are

Sulphate of lime,	71·9	4½ atom,
Sulphate of barytes,	28·1	1 atom.
	100·0	

The foreign matter amounted to about 1½ per cent., and consisted of iron shot sand, seemingly introduced by the infiltration of rain water.

Sp. 5. *Sulphato-carbonate of Barytes.*

This mineral occurs in Brownley hill mine in the county of Cumberland. I found the only specimen which I have seen in a collection of minerals exposed to sale in Glasgow, in November, 1834, by Mr. Cowper, a mineral dealer from Alston Moor.

Colour snow-white.

The specimen consists of a congeries of very large six-sided prisms, terminated by low six-sided pyramids. The surfaces are so rough and irregular that it was impossible to measure the angles with any certainty. One of the angles of the six-sided prism measured about 130°.

Texture seemed foliated, but no regular cleavage was discovered.

Lustre vitreous; translucent.

Hardness about 3; specific gravity 4·141.

On subjecting it to analysis, I obtained

		Atoms.
Sulphate of barytes,	34·30	1
Carbonate of barytes,	64·82	2·2
Carbonate of lime,	0·28	
Moisture,	0·60	
	100·00	

I think it probable from this analysis that the true constituents are

1 atom sulphate of barytes,
2 atoms carbonate of barytes.[*]

GENUS VI.—STRONTIUM.

Strontium, like barium, never occurs in the mineral kingdom except in combination with oxygen, and constituting *strontian.* Strontian, in the state in which it is found in nature, bears a striking resemblance to barytes. There is also a striking analogy in the crystalline forms of the analogous species of each.

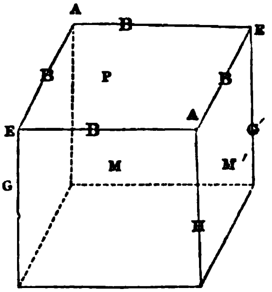
Sp. 1. *Green Carbonate of Strontian.*

Strontianite—peritomous hal-baryte of Mohs.

This species was first discovered in the galena vein at Strontian, in Argyleshire, and was recognised as a peculiar mineral species about the year 1791. It was not till about the year 1816 that it was observed in well defined crystals.

Colour asparagus green; structure radiated, and obviouslyexhibiting the rudiments of crystals (seemingly four-sided prisms) radiating from a centre. In the crystals the fracture is foliated.

The primary form of the crystal is a right rhombic prism.



M on M′ 117° 32′

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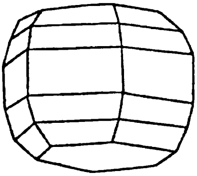
[*] Besides the species here enumerated, there are other three minerals which contain barytes. These are

1 Hormatome, $4AlS^3 + BrS^2 + 6Aq.$
2 Brewsterite, $4AlS^3 + (\frac{1}{3}Br + \frac{2}{3}Str)S^2 + 7Aq.$
3 Psilomelanite, composed of
{ 3 atoms subsesquihydrated binoxide of manganese,
{ 1 atom quadro-manganite of barytes.

These species will come under our consideration hereafter.

It differs from the primary form of carbonate of barytes by about 1 degree.

The crystals are small and rather uncommon. Hauy has given us the figure of a crystal found in England, (but he does not give the locality,) which is the primary form, having the edges G, G′ replaced by tangent planes. These additional faces occur in all the crystals hitherto observed, making the prism six-sided. The edges of the prism B are frequently replaced by single planes, and sometimes by two planes, constituting the figure in the margin. At Broundsdorf, near Freyberg, it occurs in acicular crystals. The large sized crystals have been found at Leogang, in Saltzburg.



Lustre shining, vitreous; translucent; hardness 3·5. The specific gravity of a very fine specimen I found 3·713.

Before the blowpipe it does not fuse, but is converted on the surface into an enamel which assumes a dazzling whiteness, and tinges the flame red. With borax or biphosphate of soda it fuses into a clear glass; with carbonate of soda into a glass which becomes opaque on cooling.

A careful analysis of the purest specimens to be had at Strontian, gave the constituents as follows:

		Atoms.
Carbonate of strontian,	93·493	10·1
Carbonate of lime,	6.284	1·0
Carbonate of manganese, trace,	——	
Iron and alumina,	0·010	
	99·787	

This is obviously equivalent to

10 atoms carbonate of strontian,	92·5
1 atom carbonate of lime,	6·25
	98·75

Unless the green colour be owing to the trace of carbonate of manganese, which it contains, I do not know to what we are to ascribe it.

Sp. 2. *Brown Carbonate of Strontian.*

This mineral occurs in Strontian mine, along with the green carbonate, though it is rather less abundant. Doubtless it is to be found in other localities, though the descriptions given in mineralogical works are not sufficiently precise to enable us to point out any other place where it occurs. The acicular crystals found at Brounsdorf near Freyberg, as is obvious from the specific gravity, belong to this species.

Colour light yellowish brown.

Structure radiated, and obviously a congeries of prisms diverging from a centre. But these prisms are much smaller than those existing in the green carbonate, and they are much more easily detached from each other. Hence the specimens are very friable.

Translucent; lustre vitreous; specific gravity 3·651; hardness 3 to 3·5. It is scratched by green carbonate of strontian.

I found the constituents of a pure specimen

		Atoms.
Carbonate of strontian, .	91·082 .	9·845
———— lime, . .	8·642 .	1·382
———— manganese, .	0·099	
Oxide of iron and alumina, .	0·078	
	99·901	

This is very nearly

7 atoms carbonate of strontian,
1 atom carbonate of lime.

Sp. 3. *Sulphate of Strontian.*

Celestine, zölestine—prismatoidal halbaryte of Mohs.

This species was long confounded with sulphate of barytes, to which it bears a considerable resemblance. Its composition was first determined by the experiments of Klaproth and Vauquelin, who analyzed it, unknown to each other, about the year 1796. Werner gave it the name of *celestine*, from the blue colour which was at that time considered as characteristic of it; though since that period the same colour has been observed in sulphate of barytes. It was soon after discovered, in abundance, in the neighbourhood of Bristol, by Mr. Clayfield; and since that period it has been discovered in Germany and other countries, in very considerable deposites.

The colour is usually white, most frequently with a shade of sky blue; but sometimes with a shade of red or yellowish red.

It occurs most frequently crystallized, and then its fracture is foliated. The cross fracture is conchoidal. The primary form of its crystals, like that of sulphate of barytes, is a right rhombic prism. But the inclination of M on M′ is 104° instead of 101° 34′ as is the case with the prism of sulphate of barytes.

The modifications of this form in sulphate of strontian, are much the same as those in sulphate of barytes. The magnificent crystals from Sicily are elongated octahedrons, similar to that represented in page 104, making allowance for the difference in the measurement of the angles, which amounts to about 3°.

Lustre vitreous, inclining to pearly, and varying from shining to splendent. The impure compact variety, from the neighbourhood of Paris, has no lustre.

Sometimes transparent, sometimes only translucent. Refracts doubly.

Hardness 3 to 3·5. I found the specific gravity of a very fine and pure crystal from Sicily, 3·9626, and that of good translucent crystals from the neighbourhood of Bristol 3.9454.* According to Beudant the specific gravity varies from 3·9297 to 3·9593.*

Before the blowpipe it behaves very nearly as sulphate of barytes does, excepting the red tinge which it communicates to the flame when decomposed, and which characterizes sulphate of strontian.

When pure, it is composed of

1 atom sulphuric acid,	5
1 atom strontian,	6·5
	11·5

I analyzed very fine specimens from the neighbourhood of Bristol, and from Sicily, the result was as follows:

	Bristol.	Sicilian.
Sulphate of strontian, .	98·353 .	98·68
Sulphate of lime, .	1·073 .	1·02
Moisture, . . .	0·200 .	0·30
Foreign matter,† .	0·374	0
	100	100

It generally contains a little oxide of iron, and that of Bouvron, according to the analysis of M. Daurier, contains 27·795 per cent. of carbonate of lime. As Vauquelin, in another specimen from the same locality, found only 10 per

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* Ann. des Mines (second series), v. 275.

† It was silica, with some alumina, and a trace of iron.

cent. of carbonate of lime, it is clear, that this constituent is only accidental.*

Sulphate of Strontian is found most commonly in the new red sandstone, which lies above the coal formation. Sometimes it is found in amygdaloid, connected with basalt, and at Mont Martre, near Paris, it occurs in the tertiary gypsum beds.

Sp. 4. *Baryto-Sulphate of Strontian.*

Radiated celestine.

This species is found in considerable quantity in Drummond island, in Lake Erie, and also at Kingstown, in Upper Canada.

The colour is white, with a very slight shade of blue.

The texture is laminated, and the laminæ, which are obviously imperfect crystals, diverge as if from a central point, so as to form a kind of pencil.

Brittle; very friable; hardness 2·75; specific gravity 3·921.

Before the blowpipe in the platinum forceps becomes of a dazzling white; but does not easily fuse. Melts readily with carbonate of soda into a transparent colourless bead, which becomes white and opaque on cooling. With borax it fuses very readily into a white opaque globule.

By an analysis of it made in my laboratory, its constituents were found to be

Sulphuric acid, . .	40·202
Barytes, . . .	23·059
Strontian, . . .	35·724
Protoxide of iron, . .	0·588
Water, . . .	0·720
	100·293

This is obviously equivalent to

		Atoms.	
Sulphate of barytes, .	35·195	2·42	3
Sulphate of strontian, .	63·204	5·49	7
Sulphate of iron, . .	1·241	0·13	
Water, ...	0·720		
	100·360		

Omitting the small quantity of sulphate of iron as accidental, the mineral is a compound of

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* Ann. de Chim. et de Phys., xlvi. 312

$\left\{\begin{array}{l}\text{3 atoms sulphate of barytes,}\\ \text{7 atoms sulphate of strontian.}\end{array}\right.$

Sulphates of barytes and of strontian occur native combined in other proportions, and constituting therefore other species which have not yet been accurately described. Thus the mineral found at Nörten, in Hanover, and known by the name of radiated Celestine, is a compound, according to the analysis of Dr. Turner, of

Sulphate of barytes, . .	20·41
Sulphate of strontian, . .	78·205
	98·615[*]

This is very nearly

$\left\{\begin{array}{l}\text{1 atom sulphate of barytes,}\\ \text{5 atoms sulphate of strontian.}\end{array}\right.$[†]

Sp. 5. *Calcareo-Sulphate of Strontian.*

I have a specimen of this mineral in my cabinet; but I am unacquainted with its locality; though I suspect that it came from the neighbourhood of Bristol.

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[*] Edinburgh Phil. Jour., ii. 329.

[†] A remarkable variety of this mineral occurs at Nörten, about six miles from Hanover, constituting thin beds in a limestone, probably connected with the oolite formation. It is partly in crystals, and partly in a weathered and friable state. There are three thin beds; in the first the mineral is crystallized, in the two others it is in a weathered and friable state.

The crystals have a silky lustre, and a milk-white colour, here and there passing into blue. The specific gravity, as determined by Gruner, is 3·9506.[*]

These crystals analyzed by Mine Commissioner Gruner of Hanover gave

Ferruginous alumina, . .	0·213
Sulphate of strontian, . .	73·000, or 7 atoms
Sulphate of barytes, . .	26·166, or 2 atoms
	99·379[‡]

The weathered portion from the third bed was found to be composed of

Alumina, ...	1·00
Sulphate of strontian, . .	24·00, or 2 atoms
Sulphate of barytes, . .	74·66, or 5 atoms
	99·66[++]

I have not seen any accurate description of these minerals, but I have little doubt that they will constitute two new species. The first, indeed, is intimately connected with the baryto-sulphate of strontian species from America, if it be not identical with it; but the second seems new.

[*] The specific gravity is stated in the paper at 3.5906; but I take it for granted that the 5 and 9 have accidentally changed places.

[‡] Gilbert's Annalen, lx. 72. [++] Ibid. p. 77.

The colour is white with a shade of red. It is composed of small thin plates, or radii, which are interlaced; lustre silky. The single plates are transparent, and the mass is translucent on the edges; very easily frangible; hardness 2·75; scratched by carbonate of strontian; specific gravity 3·81.

Before the blowpipe behaves nearly as sulphate of strontian.

Its constituents, by the analysis of Dr. Jephson of Leamington, were

		Atoms.
Sulphuric acid,	45·928	9·1856
Lime,	7·160	2·045
Strontian,	46·888	7·25
	99·976	

It is therefore a compound of

2 atoms sulphate of lime,
7 atoms sulphate of strontian.

Sp. 6. *Stromnite.*

This mineral was observed at Stromness, in the Orkneys, by Dr. Trail, in the year 1803. In the year 1817, he analyzed it, and an account of it was read before the Royal Society of Edinburgh, which was published in the ninth volume of the Edinburgh Philosophical Transactions. It occurs in masses, in a kind of slate, connected with an abandoned lead mine.

The colour is greyish-white, passing into pale yellowish-white. The lustre is shining, and pearly in the principal fracture, glistening and resinous in the cross fracture.

The mineral is radiated, or composed of small plates, or radii, somewhat diverging.

Translucent when in thin fragments; specific gravity 3·903; hardness 3·5; rather brittle and easily frangible.

It is infusible per se before the blowpipe.

Its constituents, as determined by the analysis of Dr. Trail are,

Carbonate of strontian,	68·6
Sulphate of barytes,	27·5
Carbonate of lime,	2·6
Oxide of iron,	0·1
	98·8[*]

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[*] Edinr. Trans. vol. ix. p. 81.

If this mineral constitute a chemical compound, it is certainly a very extraordinary one. The preceding numbers approach

4 atoms carbonate of strontian,
1 atom sulphate of barytes,
¼th atom carbonate of lime.

But perhaps the carbonate of lime should be considered only as accidental. What renders it probable, that the constituents of this mineral are chemically combined, is, that the specific gravity is less than the mean. For the mean specific gravity is 3·81 instead of 3·703, which Dr. Trail obtained.

GENUS VII.—CALCIUM.

Calcium, like barium and strontium, is never found near the surface of the earth in the metallic state; but always united to oxygen and converted into lime. Even lime has so strong an affinity for acids, that it exists only in a state of combination with acids. Lime is much more abundant in the mineral kingdom than barytes, or strontian. It occurs most commonly united to carbonic acid constituting limestone, which form whole mountains, or even ranges of mountains. It is met with likewise in considerable quantity combined with sulphuric and fluoric acid, nor is it rare in combination with phosphoric acid. It is found also united to silica, to arsenic acid, tungstic, boracic, and titanic acids; but not so abundantly. The number of species belonging to this genus at present known, amount to 30. Of these 13 are simple salts, 15 double salts, and 2 triple salts, or more probably salts of a still more complex nature.

A. SIMPLE SALTS.

Sp. 1. *Calcareous Spar.*

Agaric mineral, anthraconite, aphrite,* argentine, chalk, inolite, limestone, lumachella, madreporite, marble, marl, oolite, ostreocolla, peastone, pisolite, slate spar, schiefer spar, travertine, tufa.

This species is very abundantly scattered through the mineral kingdom, constituting whole ranges of mountains, or existing in the state of beds alternating with other rocks. But calcareous spar, which alone possesses the complete

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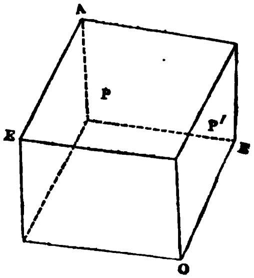
* The term *aphrite* has been also applied to the tourmalin. See Mohs, ii, 349.

characters of the species, is met with only in veins or cavities in other rocks.

The colour of pure calcareous spar is snow-white; but the mineral is frequently tinged yellow, grey, red, or even green, and some varieties are nearly black.



The fracture is foliated, and the cleavage is parallel to the faces of an obtuse rhomboid, in which the faces P, P′ are inclined to each other at an angle of 105° 5′. This constitutes the primary form of the mineral, which occurs very frequently in the mineral kingdom. But calcareous spar is met with crystallized in a greater variety of forms than any other mineral hitherto known. Count Bournon in his *Traité de Mineralogie* has engraven figures of no fewer than 680 modifications; and Hauy, in the second edition of his Mineralogy, has given figures and descriptions of 155 different modifications. These crystalline shapes may be referred to rhomboids, prisms, and pyramids. When the angle of the summit A is replaced by three or six planes resting on the primary planes or edges of the crystal, and when these replacements increase so much as to obliterate the primary faces of the crystal, they occasion three-sided or six-sided pyramids. These being double, and applied base to base, the three-sided pyramids constituted long and acute rhomboids; while the six-sided pyramids constitute pyramidal dodecahedrons. When the lateral solid angles are replaced by planes parallel to the perpendicular axis of the rhomboid regular six-sided prisms are formed, which is the most common shape of the crystals of calcareous spar found in Derbyshire; while the pyramidal dodecahedron characterizes the calcareous spar of strontian.

When each lateral solid angle of the rhomboid is replaced by two planes meeting at an edge which is parallel to the perpendicular axis, twelve-sided prisms are formed. When only the alternate lateral angle is replaced by a plane parallel to the perpendicular axis, a three-sided prism is formed. This figure is uncommon; but occurs in a quarry not far from Kirkaldy, in the County of Fife.

Various other modifications are produced by the superior edges of the rhomboid being replaced by tangent plane, or by two planes; or by the lateral edges being replaced by tangent planes, or by two planes. The first produces a rhomboid more obtuse than the primary; the second produces pyramidal dodecahedrons, whose faces are usually isosceles triangles; the third produces a regular six-sided prism; and the fourth pyramidal dodecahedrons, whose faces are generally scalene triangles.

The lustre of calcareous spar, when the mineral is pure, is splendent and vitreous. It is transparent, and refracts doubly very powerfully, doubling an image viewed through parallel faces of the crystal.

Hardness 3; specific gravity when pure 2·721. Haidinger has given us the specific gravity of a variety of specimens more or less pure tried by him. The lowest was 2·508, and the highest 2·778;* but neither of these two extremes exhibits the mineral in a state of purity. According to Beudant, the specific gravity of Iceland crystal (the purest kind of calcareous spar) varies from 2·5239 to 2·7234.†

Before the blowpipe, on charcoal, it becomes caustic lime, and then shines with peculiar lustre. With borax, or with biphosphate of soda, it fuses with effervescence into a glass. With soda it does not fuse, nor enter into combination.

When pure, it is composed of

1 atom carbonic acid, .	2·75
1 atom lime, . . .	3·5
	6·25

But it is very rarely free from some slight admixture of foreign matter.

It occurs in veins in every kind of rock, from the oldest to the newest.

Limestone, chalk, marble, &c., consist of the same materials as calcareous spar, but not crystallized, and therefore not constituting proper mineral species. The property which all these minerals have of dissolving with effervescence in muriatic acid, while the neutral solution is thrown down white by oxalate of ammonia characterizes all the varieties of carbonate of lime.

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* Annals of Philosophy (second series), ix. 392.

† Ann. des Mines (second series), v. 275.

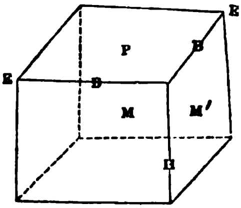
Sp. 2. *Arragonite.*

Igloite—flos ferri—needle spar.

This mineral was for some time confounded with the preceding; but it was rightly constituted a peculiar species by Werner, because its hardness, specific gravity, and crystalline form are peculiar. He gave it the name of Arragonite, because the first specimens came from Arragon, in Spain.

The most common colour of arragonite is white; but frequently it has a shade of blue, or yellow, and sometimes of grey, or even green.

The structure is foliated with a threefold cleavage. In the stalactitical variety, called *flos ferri,*[*] the structure is usually fibrous, and the fibres run in a longitudinal direction.



The primary form of the crystal is a right rhomboidal prism, in which M on M′ is 116° 10′, according to the measurement of Mr. Brooke, and 116° 5′, according to the measurement of Mr. Phillips.

Three of these crystals are frequently grouped together in such a manner as to constitute a six-sided prism. The two acute angles of the prism are sometimes replaced by two faces, which conceal the base P, and convert the crystal into a very elongated octahedron. Sometimes the edges B are replaced by tangent planes, which occasionally become very large. The edge H is at the same time replaced by a tangent plane. In consequence of this the crystal terminates in a long six-sided pyramid, the extremity of which is not a point, but a ridge. A good account of the crystalline forms of the arragonite is given by Bournon.[†]

The lustre is glassy. The mineral is sometimes only translucent, sometimes transparent. It refracts doubly, but not nearly so much so as calcareous spar.

Hardness 3·75; specific gravity, as determined by Haidinger, 2·931;[‡] by Bournon, 2·920;[§] by Biot, 2·9267.[||] Stromeyer found the specific gravity of different specimens, from

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[*] *Flos ferri* was considered by the older mineralogists as an ore of iron, Hauy first showed that it was a variety of arragonite.

[†] Traité de Mineralogie, ii. 119.

[‡] Annals of Philosophy (second series), ix. 392.

[§] Traité de Mineralogie, ii. 120.

[||] Mem. d'Arcueil. ii. 202.

2·9304 to 2·885.[*] According to Beudant, it varies from 2·7647 to 2·9467.[†]

The action of the blowpipe on arragonite, is precisely similar to that on calcareous spar.

Arragonite, like calcareous spar, is essentially a carbonate of lime. Stromeyer discovered that it contained also carbonate of strontian, which varies in quantity in different specimens from 4·1 per cent. to 0·5 per cent.; those specimens which have the highest specific gravity containing the greatest quantity, and *vice versa*. Arragonite contains also some water, which varies from 0·6 per cent. to 0·154 per cent. Those specimens which contain the most carbonate of strontian, in general containing also the most water. Whether the carbonate of strontian is in chemical combination with the carbonate of lime, is not clear. The specimens containing the most of the strontian, consist of

35 atoms carbonate of lime,
1 atom carbonate of strontian,
$1\frac{1}{3}$ atom water.

While the specimens containing the least, are composed of

288 atoms carbonate of lime,
1 atom carbonate of strontian,
3 atoms water.

Stromeyer ascribes the peculiar crystalline form of arragonite to the carbonate of strontian which it contains. The primary forms of the two minerals do not differ more from each other than 1° 22′; but as this difference is constant, it indicates two distinct species. The presence of water in arragonite was first observed by Mr. Holme. When arragonite is heated it falls to powder and loses its water. This readily distinguishes it from calcareous spar.

It was first found embedded in gypsum. It occurs in cavities and veins in basalt and other trap rocks. Fine specimens of it are met with at Leadhills in Lanarkshire, in veins traversing transition rocks.

Sp. 3. *Subsesquicarbonate of Lime.*

Blue Vesuvian limestone.

This species is found in loose masses among ejected minerals in the neighbourhood of Vesuvius. It was described by Karsten and analyzed by Klaproth[‡] in 1807.

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[*] Untersuchungen, p. 74, &c. [†] Ann. des Mines (2d series), v. 275.

[‡] Beitrage, v. 91.

Its colour is dark bluish grey partly veined with white. Externally it appears as if it had been rolled. Surface uneven; fracture fine grained earthy, passing into splintery; opaque; streak white; semihard in a low degree; not particularly heavy.* Its constituents as determined by Klaproth, are

Lime, ...	58
Carbonic acid, . . .	28·5
Water, slightly ammoniacal,	11
Magnesia, . . .	0·5
Oxide of iron, . . .	0·25
Charcoal, . . .	0·25
Silica, ...	1·25
	99·75

These numbers (supposing them exact) are equivalent to

1·595 atom lime,
1 atom carbonic acid,
0·94 atom water,
0·015 atom magnesia,
0·05 atom silica.

If we leave out the magnesia and silica, which are in so small quantity as not much to affect the chemical constitution of the mineral, the constituents seem to be

1½ atom lime,
1 atom carbonic acid,
1 atom water.

It is therefore a hydrous subsesquicarbonate of lime.

Sp. 4. *Hydrous Sulphate of Lime.*

Alabaster, gypsum,† selenite.

This mineral, so useful under the name of *plaster*, is very abundant, occurring in beds chiefly in the new red sandstone, though it is found also in other situations, particularly in the neighbourhood of Paris where it lies over the chalk. Very

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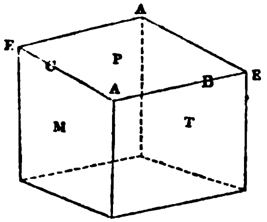
* The description given is that of Karsten. I have not myself seen this mineral.

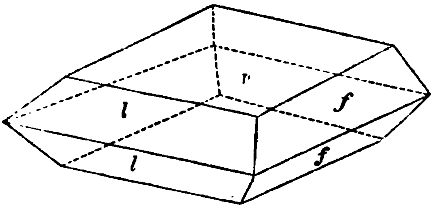
† The term γυψος (*gypsum*) was used by the Greeks, at least as early as the time of Theophrastus. Gypsum was applied by the ancients to the same uses that we apply it; but they were ignorant of its composition. One of the earliest of the analytical attempts of Lavoisier was to analyze it (1768). He determined the nature of the constituents but not their proportions. Margraaff had already made the same discovery in 1750.

fine specimens are met with in Shotover hill near Oxford, and at Carrickfergus in the County of Antrim.

The colour of this mineral when pure, is snow-white; but it occurs often red, yellow, blue, and grey.

When crystallized it is foliated; but it is found also fibrous, granular, and compact. The foliated varieties are called *selenite* from their fine white colour. They split into thin leaves parallel to the base of a right oblique prism, the faces of which, as determined by Hauy, are inclined to each other at angles of 113° 8′, and 66° 52′. And this determination has been conrfimed by subsequent measurements with the reflecting goniometer. Sometimes the solid angles A or E, are replaced by tangent planes, and sometimes the lateral edges, B, C are replaced by tangent planes. These replacements occasion the different varieties in the crystalline forms observed. The replacement of the edges constitutes the most common form observed. It is represented in the margin, where P represents the base of the primary prism, and *l*, *l*, and *f*, *f*, the new faces produced by replacing the lateral edges of the prism.





Hemitrope crystals of this mineral are very common.*

Lustre of the lateral faces of the prism and of those by replacement, vitreous; that of the base of the prism is pearly, and this face is usually streaked.

It varies from translucent to transparent. The transparent varieties refract doubly, when an object is viewed through two oblique faces.

Hardness 2; easily scratched by the nail. This renders ornaments of alabaster very easily soiled and injured.

Specific gravity of a transparent, white crystal from Oxford, as determined by Hisinger, 2·310.† According to Beudant,

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* By *hemitrope* is meant a figure produced by cutting the primary crystal in two, causing one of the fragments to make half a revolution, and then uniting the sides actually in contact.

† Annals of Philosophy (2d series), ix. 391.

the specific gravity of this mineral varies from 2·3121 to 2·3257.*

When the *faces* of a fragment are heated before the blowpipe it does not fuse; but when the *edges* are exposed to the flame, the layers gradually separate and fuse into an enamel. In a few hours the bead falls spontaneously to powder. When heated with fluor spar, it easily undergoes fusion.

The constituents of this mineral are

1 atom sulphuric acid, .	5
1 atom lime, . . .	3·5
2 atoms water, . . .	2·25
	10·75

When heated the water is easily driven off. When the anhydrous powder is mixed with water, it forms a liquid paste which easily attaches itself to the inside of a mould, and in a few minutes becomes solid. In this way it is used to make casts of statues, &c. To fit it for this purpose, it must be mixed with about a third of its weight of lime. What is called *Plaster of Paris* constitutes such a native mixture. It is so called because it occurs in that state in the gypsum quarries round Paris.

The new red sandstone formation, as has been already stated, constitutes the great deposite of this mineral. But it occurs also in other situations. Thus, it is found occasionally in the coal beds, and indeed occurs in small quantities in most of the secondary formations. In Germany it abounds; but in England it is, comparatively speaking, scanty in the new red sandstone.

Sp. 5. *Anhydrous Sulphate of Lime.*

Anhydrite, karstenite, muriacite, cube spar, pierre de trippes, gekrösstein.

This mineral seems to have been first noticed by the Abbé Poda, who gave it the name of *muriacite,* probably from the common salt with which it is often associated. Fichtel gave an account of it in 1794; but it was Hauy who first determined its characters and described it with accuracy. The crystalline shape was first determined by Bournon.†

The colour of the pure mineral is white; but it has very frequently a flesh red, grey, or light blue colour.

The fracture is imperfect conchoidal; the crystals are always foliated, but some of the compact varieties are granular.

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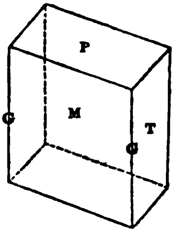
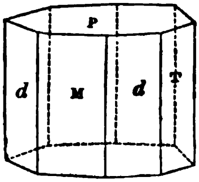
* Ann. des Mines (2d series), v. 275.

† Jour. des Mines, xiii. 345.



The primary form of the crystal is a right rectangular prism. Pretty frequently the lateral edges of the prism G are replaced by planes, which converts the primary form into the octahedral prism represented in the margin. The faces *d*, make with the face T an angle of 129° 56′, and with the face M an angle of 140° 4′.



The lustre is vitreous, inclining to pearly, upon the most distinct cleavage planes.

Translucent, sometimes nearly transparent. It refracts doubly very powerfully, when an object is viewed through two faces oblique to each other.

The specific gravity, as determined by Haidinger, is 2·899.* Bournon found that of a crystal 2·940. It was not quite free from common salt. The purest specimen tried had a specific gravity of 2·957: that of another crystal was 2·929.† Hardness from 2·75 to 3, or even 3·25.

Before the blowpipe it behaves like the preceding species, except that it gives out no water.

Its constituents, when pure, are

1 atom sulphuric acid,	5
1 atom lime, . .	3·5
	8·5

But it very frequently contains a little common salt, the maximum of which rarely exceeds 1 per cent.

Crystals of this mineral are occasionally met with which have absorbed water, and so are converted into common hydrous sulphate; yet they retain their original shape. A variety of this kind, of a fine blue colour, from a trap dyke at the base of the Cave Hill, near Belfast, had a specific gravity of 2·905, and consisted of

Carbonate of lime,	63·12
Sulphate of lime, .	32·84
Water, . . .	3·60
	99·56

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* Annals of Philosophy (second series), ix. 391.

† Jour. des Mines, xiii. 350.

This is equivalent to

2½ atoms carbonate of lime,
1 atom sulphate of lime,
⅘ atom of water.

If we consider the water as united to the sulphate, it will follow that it has absorbed nearly half the water which exists in hydrous sulphate of lime. But from the great increase in the specific gravity, it is probable that the carbonate and sulphate of lime in this mineral are in chemical combination. If we leave out of view the water altogether, the specific gravity of a mixture of 63·12 carbonate of lime, and 32·84 sulphate of lime, would be only 2·708; and if we take the water into account, and suppose it only mechanically mixed, that specific gravity would be reduced to 2·646. Even if we suppose the water to be absorbed by the mineral without any increase of its bulk, the specific gravity would only be 2·745. All these numbers are so much below 2·905, that we cannot avoid admitting a chemical combination between the constituents, and a contraction in consequence.

Anhydrous sulphate of lime occurs along with the preceding species; but it is much less abundant, and never constitutes extensive beds.

Sp. 6. *Siliceous Sulphate of Lime.*

Vulpenite, bordiglione.

This mineral, which occurs at Vulpino, in Italy, has been generally considered as a mechanical mixture of anhydrous sulphate of lime and silica; but neither its hardness nor its specific gravity is reconcileable with that supposition.

Colour greyish white, and veined with bluish grey. The mineral is foliated, and it is said to exhibit a threefold slightly oblique cleavage, indicating for the primary crystal a right four-sided prism, slightly oblique.

Internal lustre splendent; translucent on the edges; specific gravity 2·8787, as determined by Hauy;* hardness 2·75.

Fuses readily before the blowpipe into an opaque white enamel.

Its constituents, according to the analysis of Vauquelin, are

Sulphate of lime, .	89·76
Silica, . . .	8
	97·76†

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* Mineralogie (first edition), iv. 353.

† Jour. des Mines, vi. 808. The sulphate of lime is corrected.

This corresponds with

$2\frac{5}{8}$ atoms sulphate of lime,
1 atom silica.

If the loss (as is probable) be sulphate of lime, the constituents will be

$2\frac{3}{4}$ atoms sulphate of lime,
1 atom silica.

Both of these ratios are rather improbable.

This mineral is cut and polished in Italy, and applied to various ornamental purposes.

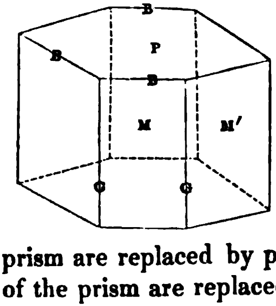
Sp. 7. *Subsesquiphosphate of Lime.*[*]

Apatite, asparagus stone, moroxite, phosphorite.

This mineral, which occurs pretty commonly in translucent crystals, having the form of a six-sided prism, and pretty frequently a blue colour, was considered by Romé de Lisle as a *gem*. When the prism was terminated by a six-sided pyramid he called it *chrysolite*, when by a hexahedral face he considered it as a variety of *emerald*. In the year 1788, Klaproth discovered that it was a compound of phosphoric acid and lime; and Werner gave it the name of *apatite*, on account of the variety of mistaken opinions which had been embraced respecting it by mineralogists.[†] The asparagus green variety he afterwards distinguished by the name of *spargelstein*.

The colour of apatite is sometimes white, but much more frequently violet blue; often green; sometimes yellow, grey, red, and even brown. The colours are never bright.

The mineral is always foliated, and the cleavage, which is not very perfect, is parallel to the faces and base of the regular six-sided prism. This is the most common form of the crystal. Sometimes the terminal edges B, B, &c., are replaced by tangent planes, which causes the prism to terminate in a six-sided pyramid. A similar six-sided pyramid is produced when the solid angles of the prism are replaced by planes. Sometimes the lateral edges of the prism are replaced by tangent planes, or by two planes. The first changes the prism into one with twelve sides, and the second into one with eighteen sides. Of this last crystal



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[*] Called by the French jewellers *chrysolite*.

[†] See Bergmannische Jour. 1788, i. 76, &c.

I have never seen a specimen, but the replacements on the angles and edges often occur together.

Cross fracture conchoidal; apatite is usually translucent, but seldom transparent. Refracts singly; hardness 5.

The specific gravity of asparagus green crystals, from Spain, was found by Haidinger to be 3·225, and that of green transparent crystals from Saltzburg 3·180.[*] According to Hauy the specific gravity varies from 3·0989 to 3·2.[†] G. Rose found the specific gravity of different specimens to vary from 3·166 to 3·235.[‡]

Before the blowpipe it remains unaltered, unless the flame be directed against the edges of the fragment, when it fuses with difficulty into an enamel. With borax or biphosphate of soda it melts easily into a glass. It fuses also when mixed with carbonate of iron.

The phosphoric acid and lime in this mineral are combined in the proportion of 1 atom acid to $1\frac{1}{2}$ atom lime, as is evident from the analysis of Klaproth, who obtained

Phosphoric acid, .	4·572
Lime, . . .	5·428
	10·000[§]

Now an atom of phosphoric acid weighs 4·5, and $1\frac{1}{2}$ atom of lime 5·25. There is a small excess of lime; but G. Rose has shown that the mineral always contains fluoric acid and chlorine, both of which are in combination with lime or calcium. The following table exhibits the result of his analysis of seven different specimens of apatite, from different localities.

Locality.	Chloride of Calcium.	Fluoride of Calcium.	Subsesqui-phosphate of lime.	Specific gravity.
Snorum, Norway,	4·28	4·59	91·13	3·174
Cubo de Gata, Spain,	0·885	7·049	92·066	3·235
Arendal, Norway,	0·801	7·01	92·189	3·194
Greiner, Tyrol,	0·150	7·69	92·160	3·175
Faldigt, Tyrol,	0·1	7·62	92·28	3·166
St. Gothard, Alps,	Trace	7·69	92·31	3·197
Ehrenfriedsdorf, Germany,	Trace	7·69	92·31	13·21

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[*] Annals of Philosophy (second series), ix. 391.

[†] Mineralogie, i. 488.

[‡] Poggendorf's Annalen, ix. 185.

[§] Beitrage, iv. 194.

If we take the chloride of calcium and fluoride of calcium together, the mineral will be composed of

1 atom chloride and fluoride of calcium,
6 atoms subsesquiphosphate of lime.

Subsesquiphosphate of lime is not unfrequently mixed with the carbonate of iron, which is so abundant in the coal beds; though in a state of purity it is very rarely found in that situation. But at Fins, in France, it has been observed in shale in small spherical nodules, sometimes flattened, and enveloped in carbonate of iron. A specimen of this mineral, analyzed by M. Jules Guillemin, and having a specific gravity of 2·65, was composed of

Subsesquiphosphate of lime, .	86·3
Carbonate of iron, . . .	11·7
Alumina, ...	0·6
Coal and water, . . .	1·4
	100·0

Another specimen yielded M. Berthier

Subsesquiphosphate of lime, .	67·0
Carbonate of iron, . . .	15·7
Alumina, ...	9·0
Water and bitumen, . .	6·0
	97·7[*]

From the great variation in the proportions in these two specimens, it is obvious that the apatite and carbonate of iron are only mechanically mixed.

Apatite occurs usually in primary formations; sometimes it forms a constituent of granite, but very rarely. It is often met with in veins, particularly along with tin and iron ore. It exists in the talky looking substance which accompanies the tinstone in some of the Cornish mines, and which I have distinguished by the name of *Gilbertite*. It is found also in the serpentine of Portsoy. The phosphorite, which constitutes a rock, exists in beds in Estremadura, in Spain, and Schlockenwald, in Bohemia.

Sp. 8. *Fluor Spar.*

Fluate of lime, fluoride of calcium, ratoffkit, chlorophane.

This mineral is abundant, and very interesting on account of the beauty of its colours, and the perfection and variety of

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[*] Memoires de Berthier, i. 138.

its crystalline forms. It is alluded to by Theophrastus, and pretty minutely described by Agricola, in his *Bermannus*, under the name of *fluor*.

Fluor spar is sometimes transparent and colourless; but much more frequently it is tinged of some colour or other. Yellow and violet blue are two of the most common colours; sometimes it is green of different shades, and more rarely rose red or crimson red.

When crystallized the texture is always foliated, but that of the compact varieties is granular; fracture conchoidal.

The primary form of the crystal is the regular octahedron; but in general the solid angles are replaced by tangent planes, which change the figure into the cube. Both of these sets of faces occur, sometimes together, constituting the cubo-octahedron; sometimes the edges of the octahedron are replaced by tangent planes. When these increase so as to conceal the primary faces, the *garnet* or *rhomboidal* dodecahedron is produced. Sometimes the solid angles are replaced by three planes, which produces the 24 sided figure, known by the name of *leucite crystal*, (see *leucite*); and sometimes the solid angles are replaced by six planes, which constitutes a crystal nearly spherical, and bounded by 48 faces. These different replacements are frequently combined together in the same crystal, which renders the figure pretty complex. One crystal figured by Mr. Phillips had no fewer than 322 faces.*

The lustre is vitreous; varies from transparent to translucent; hardness 4. The specific gravity, as determined by Haidinger, varies from 3·140 to 3·178.† Hauy states it to vary from 3·0943 to 3·1911.

Before the blowpipe the mineral decrepitates and at last fuses into an enamel. If the flame be continued, the fluoric acid is partly expelled, and the assay assumes a cauliflower appearance.

Two views may be taken of the composition of fluor spar. It may be considered as a compound of

1 atom fluoric acid, . .	1·25
1 atom lime, ...	3·5
	4·75
Or of 1 atom fluorine, . . .	2·25
1 atom calcium, . . .	2·5
	4·75

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* Mineralogy, p. 170. † Annals of Philosophy (2d series), ix. 391.

The last of these views is the one at present most generally adopted by chemists.

Fluor spar is very rarely met with in a state of purity. It is generally mixed with silica, the presence of which cannot be detected except by digesting the pounded mineral with sulphuric acid. If silica be present, fluosilicic acid gas is driven off, easily recognised by its odour, and its depositing silica when passed through water.

Fluor spar occurs but seldom in rocks, and is still more rarely met with in beds. In a trap rock at Gourock, on the Frith of Clyde, small yellow cubes of it are occasionally observed. It is met with in a similar rock at Papa Stour, one of the Shetland islands. In Ireland it occurs in cavities in the granite of the Dalkey coast. It is much more abundant in veins, and very commonly accompanies the ores of lead, particularly galena. Hence its great abundance in the north of England, where it constitutes the gangue of the lead veins which intersect the coal formations of Northumberland, Cumberland, Durham, and Yorkshire. In Derbyshire it is very abundant, and by no means uncommon in Cornwall, where the veins traverse much older rocks. In the mining districts of Saxony, &c., it is very abundant.

Most of the varieties of fluor spar phosphoresce when heated; but there is a great variety both in the colour of the light transmitted, and in its intensity.

Sp. 9. *Sesquisilicate of Lime.*

Zeagonite, abrazite, gismodin.

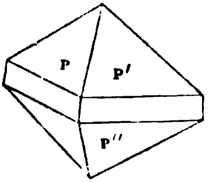
This mineral occurs in the drusy cavities of a volcanic rock at Capo di Bove, near Rome. It was first noticed by Gismondi. Breislak has given an imperfect description of it, with which I must satisfy myself here, as I have never had an opportunity of examining the mineral.

Colour pale smalt blue; sometimes white or grey, and sometimes rose red.

The fracture is conchoidal. It is always crystallized, and the crystals are octahedrons, with a square base. The figure in the margin represents a crystal in possession of Mr. Brooke, who has determined the angles as follows:

P on P' 122° 58′.

P' on P'' 85° 40′.



Lustre adamantine; translucent, and

when in small crystals, transparent; hardness 7 to 7·5; specific gravity not given.

Before the blowpipe it phosphoresces and becomes friable, but does not fuse.

According to the analysis of Carpi, its constituents are,

Silica, . . .	41·4
Lime, . . .	48·6
Alumina, . .	2·5
Magnesia, . .	1·5
Oxide of iron, . .	2·5
	96·5

If we admit that no alkali is present, and that the alumina, magnesia, and oxide of iron, are not essential constituents, then the mineral will be a compound of

Silica, . . .	1·491 atom,
Lime, . . .	1 atom.

This is very nearly

1½ atom silica,
1 atom lime.

It is not unlikely from this that it may be a sesquisilicate of lime; but a more accurate analysis would be requisite, in order to establish its chemical constitution in a satisfactory manner.

Sp. 10. *Bisilicate of Lime.*

Table spar, schaalstein, grammite, wollastonite of Hauy.

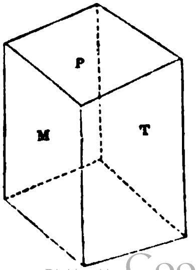
This mineral was first found by Stütz, at Dograzka, in the Bannat of Temeswar, and called by him *table spar*, about the year 1793. Its nature was first determined by the analysis of Klaproth, which appeared in the third volume of his *Beitrage*, in 1802.

The colour of this mineral is white, with a shade of grey, yellow, red, or brown. The streak is white.

Structure foliated, with a single distinct cleavage. It yields by mechanical division a doubly oblique prism, in which, according to the measurement of Brooke,

P on M 126°
P on T 93° 40′
M on T 95° 15′

The lustre is vitreous, inclining to pearly; semitransparent; sometimes only translucent on the edges.



Hardness 3 to 4.

Haidinger found the specific gravity of a brownish white specimen from the Bannat 2·805. I found the specific gravity of different specimens from Rhode Island to vary from 2·785 to 2·895. Karsten states the specific gravity at 2·863.

Before the blowpipe it melts with difficulty into a semi-transparent colourless glass; with borax it fuses easily into a transparent glass.

We have a great many analyses of this mineral, all of which concur to show that it is a compound of 2 atoms silica, and 1 atom lime, but never free from small quantities of foreign matter. The following table exhibits the most accurate of these analyses:

	Per me	*	†	‡	§	Per me.	‖	¶
Silica,	49·56	50	51	51·445	51·6	51·716	52·58	53·1
Lime,	45·52	45·9	46	47·412	46·41	43·352	44·45	45·1
Protox. of iron,	3·00	—	1·3	0·401	trace,	1·908	1·13	—
Protox. of mangan.,	—	—	—	0·257	—	—	—	—
Magnesia,	—	—	—	—	—	—	0·68	1·8
Water,	1·44	5	1	0·076	—	3·20	0·99	—
Actinolite,	—	—	—	—	1·11	—	—	—
	99·52	100·9	99·3	99·591	99·12	100·176	99·83	100

The mean of these analyses gives us

1·964 atom silica,
1 atom lime.

This comes exceedingly near 2 atoms silica and 1 atom lime, showing that the mineral is a bisilicate. Doubtless the slight error is owing to the presence of small portions of foreign matter.

It occurs most commonly in limestone, both primary and secondary. It is a constituent of the cinnamonstone rock from Ceylon, and is found in a state of great purity in Rhode Island, near New York. The specimens of it said to be found in the Castle rock at Edinburgh, proved, when analyzed in my laboratory, to be prehnite.

Sp. 11. *Wollastonite.*

Hauy gave the name of *Wollastonite* to the preceding spe-

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* Klaproth, Beitrage, iii. 289. † Seybert, Ann. des Mines, ix. 399.

‡ Stromeyer, Untersuchungen, i. 356.

§ Nordenskiöld's Bidrag, p. 94.

‖ Bonsdorf, Annals of Philosophy (second series), ii. 300.

¶ Beudant, Ann. des Mines (second series), v. 305.

cies; but as that mineral had been long known and already distinguished by the name of *table spar*, there was no great probability of mineralogists in general adopting this designation. The benefits conferred upon mineralogy by the late Dr. Wollaston were of no ordinary kind, and rendered it exceedingly desirable that some well characterized mineral species should be distinguished by his name. This was the reason which led me to give the appellation *Wollastonite* to the present species, which occurs in considerable quantity in veins in a greenstone rock, situated near Kilsyth, and not far from the banks of the Forth and Clyde Canal. It has also been discovered by Lord Greenock in the neighbourhood of Edinburgh. It is related to *table spar*, being in fact a compound of 4 atoms of that mineral with 1 atom of tersilicate of soda.

The colour of Wollastonite is white, with a slight shade of green.

The texture is fibrous, and the fibres are in tufts, diverging from a centre. This structure shows that the mineral is imperfectly crystallized.

Lustre inclining to silky; translucent on the edges; fracture splintery; fragments sharp edged; hardness 2·5.

Specific gravity varies in different specimens from 2·850 to 2·876.

Before the blowpipe it fuses with some difficulty, and without frothing into a white enamel. With borax it fuses into a bead, which is yellow while hot, but becomes colourless when cold. With biphosphate of soda in considerable excess it melts into a colourless bead, leaving a silica skeleton. With carbonate of soda it froths, and forms an opaque bead, having a shade of reddish blue.

Its constituents were found to be

		Atoms.
Silica,	52·744	26·37
Lime,	31·684	9·05
Soda,	9·600	2·4
Magnesia,	1·520	0·6
Protoxide of iron,	1·200	0·24
Alumina,	0·672	0·3
Water,	2·000	1·77
	99·420	

If we reckon the magnesia along with the lime, and neglect the protoxide of iron and alumina, as only accidental ingredients, it is evident that Wollastonite is a compound of

4 atoms bisilicate of lime,
1 atom tersilicate of soda.

The water being less than an atom is probably only mechanically lodged in the interstices of the fibres. The formula exhibiting its composition is $4CalS^2+NS^3$.

Sp. 12. *Tersilicate of Lime.*

This mineral was first noticed by Hisinger, in 1823. It is found at Gjellebäk, four Swedish miles south from Christiania, in Norway, in a transition limestone which extends some way south along the coast. It had from its appearance been mistaken for a tremolite, till Hisinger subjected it to analysis, and recognised its true nature.* There is in my cabinet a specimen of a mineral whose constituents are similar to those of the Gjellebäk mineral, but I do not know its locality. It is from this specimen that I have drawn up the following description and analysis; for Hisinger's specimen was obviously less pure than mine.

The colour of this mineral is snow-white. Hisinger says that by exposure to the air it becomes grey; but my specimen, which I have had about 20 years, is still snow-white.

The texture is fine radiated, which gives it a good deal of the aspect of *tremolite.*

It phosphoresces strongly when rubbed or struck; but only slightly when heated.

Does not effervesce in acids, even when reduced to powder. The specimen analyzed by Hisinger effervesced in acids, because it contained about the fourth part of its weight of carbonate of lime, which is absent in my specimen.

Easily frangible; specific gravity 2·2055; hardness 3·5.

Before the blowpipe it behaves nearly as table spar does. On the edges it fuses with difficulty into a semitransparent colourless glass. With borax it fuses easily, and forms an amethyst coloured glass.

Its constituents, determined by analyzing the specimen in my cabinet, are as follows:

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* Kong. Vetens. Acad. Handl. 1823, p. 177.

		Atoms.
Silica, . .	55·200 .	3
Lime, . .	34·284 .	1·06
Alumina, .	4·160 .	0·2
Protoxide of iron,	2·896 .	0·07
Moisture, .	3·400 .	0·3
	99·940	

If we omit the alumina, oxide of iron, and moisture, which amount only to a fraction of an atom, the mineral is obviously a compound of

3 atoms silica,
1 atom lime,

or its symbol is $CalS^3$.

Sp. 13. *Dysclasite.*

This mineral is found in the Faroe islands. Specimens of it were brought to Edinburgh by Count Vargus Bedemar of Copenhagen, who gave a few fragments of it to Sir D. Brewster, Mr. Rose, and probably other individuals. It was first described and analyzed, and its peculiar nature determined by Mr. Arthur Connel.

Colour white, with an opalescent tint.

Texture imperfectly fibrous, and it is obviously formed of a congeries of minute crystals; accordingly, when a thin slice of it was polished, it was found by Sir D. Brewster to be capable of polarizing light in all directions.

Translucent, and when in thin slices, transparent; refracts doubly; reflects a yellow, and of course transmits blue light.

Specific gravity 2·362.

Hardness about 4¼, but it is exceedingly tough; so much so that it is very difficult to break it, even by repeated blows of a hammer. Hence the name *dysclasite* bestowed upon it by Mr. Connel.

When heated in a glass tube it gives out pure water. Before the blowpipe per se it becomes opaque and white, and fuses only on the edges. With carbonate of soda melts with effervescence into a semitransparent glass. With biphosphate of soda it fuses into a colourless glass, leaving a silica skeleton. The bead opalizes on cooling, especially if the heat be continued a considerable time. With borax it fuses into a transparent colourless glass. When heated with soda on platinum foil it gives slight indications of the presence of manganese. Gelatinizes in muriatic acid.

Its constituents, as determined by the analysis of Mr. Connel, are

		Atoms.	
Silica, . .	57·69 .	28·84	
Lime, . .	26·83 .	7·66	
Water, . .	14·71 .	13·07	
Soda, . .	0·44 .	0·11	0·25
Potash, . .	0·23 .	0·04	
Peroxide of iron,	0·32 .	0·06	
Protoxide of manganese,	0·22 .	0·04	
	100·44		

Atoms of silica, . .	28·84 .	3·64
bases, . .	7·91 .	1
water, . .	13·07 .	1·65

Equivalent to $5CalS^4+CalS^2+9Aq$.

Leaving out the other bases, and supposing the silica combined with them in the same ratio as with the lime.

Sp. 14. *Sesquihydrous Arseniate of Lime.*

A single specimen of a mineral belonging to this species exists in the cabinet of Mr. Ferguson of Raith, and has been imperfectly described by Mr. Haidinger, and analyzed by Dr. Turner.* The locality of the specimen is unfortunately unknown.

The colour is white, and the streak white.

The specimen is crystallized in the form of an octahedron, with an oblique base.

Lustre glassy; translucent when in small crystals; sectile; hardness 2 to 2·5; specific gravity 2·848.

Its constituents, according to the analysis of Dr. Turner, are,

		Atoms.
Arseniate of lime, .	85·681 .	1
Water, . . .	14·319 .	1·597
	100·000	

or very nearly

1 atom arseniate of lime,
1½ atom water.

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* Poggendorf's Annalen, v. 189.

The small excess of water is undoubtedly mechanically lodged between the plates of the crystal.

Sp. 15. *Bisesquihydrous Arseniate of Lime.*

Pharmacolite, picropharmacolite.

This mineral was first observed by Selb in the mine of Sophia, near Wittichen, in Suabia. Selb ascertained its constituents to be arsenic acid, lime, and a little cobalt, to which it owed its red colour;* and these results were afterwards confirmed by an analysis by Klaproth.†

The colour of this mineral, when pure, is snow-white, but it is frequently tinged red by an admixture of arseniate of cobalt. Sometimes the colour is yellowish, owing probably to an admixture of iron ochre.

The structure is radiated, owing to the mineral being composed of a congeries of capillary crystals, so arranged as to form sphericles. Haidinger has described some crystals which he observed in the collection of Mr. Ferguson of Raith; he considers the primary form as an octahedron composed of eight triangular faces, alternately larger, but the crystals observed were right oblique prisms, having two of their terminal edges and two of the lateral edges replaced by tangent planes.‡

Lustre vitreous; but in the thin columnar particles of composition also pearly.

Translucent; sometimes opaque; sectile; hardness 2·5.

Selb states the specific gravity to be 2·536. Klaproth found it 2·640, and Haidinger states the specific gravity of the crystals to be 2·730.

The pure crystals in Mr. Ferguson's collection were analyzed by Dr. Turner, and found composed of

		Atoms.
Arseniate of lime, .	79·01 .	1
Water, . . .	20·99 .	2·53
	100·00	

This is obviously

1 atom arseniate of lime,

2½ atoms water.

The *picropharmacolite* of Stromeyer, from Riegelsdorf, in

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* Scherer's Jour. xxiii. 537.

† Beitrage, iii. 277.

‡ Poggendorf's Annalen, v. 181.

Hesse, is merely a variety of this species. He gives no farther description of it than stating that it occurs in balls having an earthy aspect. The constituents, as determined by Stromeyer, are,

		Atoms
Arsenic acid,	46·971	6·47
Lime,	24·646	7·04
Magnesia,	3·218	1·29
Oxide of cobalt,	0·998	0·21
Water,	23·977	21·31
	99·810*	

There is obviously an excess of

0·78 atom lime,
1·29 atom magnesia,
0·21 atom arseniate of cobalt,

and the water, instead of 2½ atoms, amounts to 3½, very nearly; but a portion of it was probably mechanically lodged in the mineral.

Pharmacolite occurs in veins at Andreasberg, in the Hartz, and at Reichelsdorf, in Hesse, along with native arsenic, cobalt pyrites, &c.

Sp. 16. *Tungstate of Lime.*

Tungsten, scheelate of lime, scheelin calcaine.

This mineral, though rather scarce, had attracted the attention of mineralogists, and Cronstedt in his mineralogy published in 1758, describes it thus: *Ferrum calciforme, terra quadam incognita intime mixtum.* Scheele examined it in 1781, and pointed out its true nature.†

The colour is usually white, often inclining to yellow, grey, or brown. Some specimens are orange yellow

The mineral occurs usually in small detached crystals coating some other mineral, as quartz. The primary form of the crystal is an octahedron, with a square base.

P on P′ 100° 40′
P on P″ 128° 40′

B are frequently replaced

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ngen, p. 135.

† Nya Handl. 1781, p. 89.

by tangent planes. When these new faces increase so much as to obliterate the primary faces, an octahedron is formed less acute than the primary. This last is the most usual form under which the mineral occurs.

The structure is imperfectly foliated; the cross fracture conchoidal; lustre glassy, inclining to adamantine; varies from translucent to semitransparent; hardness 6·5.

The specific gravity, as determined by Haidinger, is 6·076. Bucholz and Brandes found it to vary in different specimens from 5·959 to 6·076.*

Before the blowpipe it crackles, and becomes opaque, but does not melt. With borax it easily fuses into a white or transparent glass, according to the proportions employed.

We have three analyses of this mineral, one by Berzelius, and two by Bucholz and Brandes. The result of these is as follows:

	Berzelius.†	Bucholz and Brandes.‡	
Tungstic acid,	80·417	78·00	76·50
Lime,	19·400	19·06	16·50
Oxide of iron,	—	—	1·47
Silica,	—	2·80	2·94
Alumina,	—	—	1·09
	99·817	99·86	98·50

The mean of these analyses gives us very nearly

1 atom tungstic acid,	15·5
1 atom lime,	3·5
	19

which is doubtless the true constitution of the mineral.

Tungstate of lime is most commonly met with along with tin ore, both in veins and beds. In this way it occurs in Schlackenwald and Zinnwald, in Bohemia; Zinnwald and Ehrenfriedersdorf, in Saxony, and Pengelly Croft mine, in Cornwall. In Sweden and some other localities it is found along with octahedral iron ore. At Neudorf, in Anhalt-Bernburg, it occurs in veins traversing grey wacke. Splendid specimens have been found at Carroch, in Cumberland.

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* Schweigger's Jour. xx. 285.

† Afhandlingar, iv. 305.

‡ Schweigger, xx. 285.

B. DOUBLE SALTS.

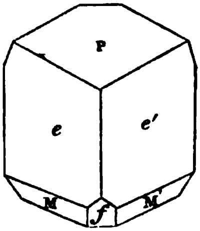
Sp. 17. *Glauberite.*

Brogniartine.

This mineral was discovered in 1807, by M. Alex. Brogniart, in specimens of common salt, brought by M. Dumeril from Ocagna, in New Castile.* It has been since observed at Aussee, in Upper Austria. It occurs also, but impure, in the common salt of Vic, in France.

Colour yellowish, or greyish white; streak white.

Massive, and also crystallized in very flat rhomboidal prisms, consisting of the planes P, *e*, *e′* of the annexed figure. But it readily yields to mechanical division, parallel to the planes P, M, M′ giving for its primary form a doubly oblique rhomboidal prism.



M on M′ 83° 20′
P on M or M′ 104° 15′
P on *e* or *e′* 137° 9′
P on *f* 112° 20′
M or M′ on *f* 131° 35′
e on *e′* 116° 20′

according to the measurement of Mr. W. Phillips.†

The faces *e*, *e′* are the result of tangent planes replacing the terminal edges of the primary prism. *f* is produced by the replacement of a lateral edge by a tangent plane.

Lustre vitreous; from semitransparent to translucent; brittle; hardness 2·5 to 3; specific gravity, as determined by Haidinger, 2·807. Broigniart states it at 2·73.

Taste saline, astringent, and weak.

When heated it decrepitates, and then melts into a white enamel; when put into water it becomes in a short time white and opaque; when taken out and dried, the white portion falls to powder, and when rubbed off discovers the central nucleus as transparent as ever.

According to the analysis of M. Brogniart, glauberite is a compound of

Sulphate of lime, . .	49
Sulphate of soda, . .	51
	100

Both being anhydrous.

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* Jour. des Mines, xxiii. 5.

† Mineralogy, p. 198.

This corresponds very nearly with

1 atom sulphate of lime,	8·5
1 atom sulphate of soda,	9
	17·5

Sp. 18. *Gay-Lussite.*

This mineral was discovered in the Natron lake, in Columbia, by M. Boussingault, who published an analysis and description of it.[*] The crystalline form was investigated by M. Cordier,[†] and afterwards from a more perfect specimen by Mr. W. Phillips.[‡]

It occurs in detached crystals in clay. The less perfect of them might readily be mistaken for selenite; while the more perfect and smooth have rather the aspect of calcareous spar.

These last are yellowish white and translucent, and refract doubly in a high degree, extremely brittle, easily reduced to a grey powder, and without phosphorescence, either from friction or heat.

Cross fracture conchoidal, and the surfaces produced, have a vitreous lustre.

The primary form of the crystal is, according to Mr. Phillips, a doubly oblique prism, the faces of which are inclined at an angle of 68° 50′. The inclination of the base to either of the contiguous sides 96° 30′. In general, the obtuse lateral edges of the prism are replaced by tangent planes.

Hardness 2·5; specific gravity from 1·928 to 1·990.

When heated in a matrass, the crystals decrepitate and become opaque. Before the blowpipe it melts rapidly into an opaque globule, which once formed is infusible, and has an alkaline taste. In nitric acid dissolves with brisk effervescence, and by spontaneous evaporation yields crystals of nitrate of soda, floating in a solution of nitrate of lime.

Its constituents, as determined by Boussingault, are,

		Atoms.	
Carbonate of soda,	33·96	5·03	1
Carbonate of lime,	31·39	5·02	1
Water,	32·20	28·62	5·72
Alumina,	1·00		
Carbonic acid,	1·45		
	100·00		

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[*] Ann. de Chim. et de Phys. xxxi. 270.

[†] Ibid, p. 276.

[‡] Phil. Mag. (new series), i. 263.

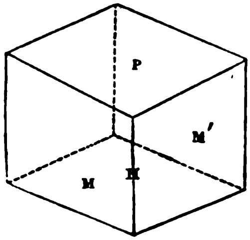
Obviously 1 atom carbonate of soda,
1 atom carbonate of lime,
6 atoms water.

Sp. 19. *Calcareo-Carbonate of Barytes.*

Baryto-calcite of Brooke and Children.

This mineral occurs in considerable quantity at Alston Moor, in Cumberland, both crystallized and massive. It was first described by Mr. Brooke, and analyzed by Mr. Children.[*] It has been noticed also by Mr. Haidinger.[†]

Its colour is white, with a shade of grey, yellow, or green; cross fracture uneven, and imperfect conchoidal.



The primary form of the crystal is an oblique rhombic prism.

P on M or M′	102° 54′
M on M′	106° 54′

The edge H and its opposite, are almost always replaced by tangent planes. Several other replacements occur on the other angles and edges, and the crystal is often lengthened in the direction of the modified planes.

Lustre vitreous, inclining to resinous; varies from translucent to transparent; hardness 4; specific gravity as determined by Mr. Children 3·66; by Mr. Richardson 3·6363.

Before the blowpipe it does not fuse per se; but melts easily with borax, or biphosphate of soda, into a transparent glass. It gives indications of the presence of a little iron and manganese.

According to the analysis of Mr. Children, its constituents are

Carbonate of barytes, .	13·178 to 14·5
Carbonate of lime, . .	6·72 to 7·39

Mr. Richardson subjected it to a careful analysis in my laboratory, and obtained,

		Atoms.
Carbonate of barytes, .	62·20 .	5·077
Carbonate of lime, . .	31·65 .	5·064
Sulphate of barytes, . .	0·30	
Peroxide of iron, . .	0·85	
Water, or volatile matter, .	3·15	
	98·15	

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[*] Annals of Philosophy (second series), viii. 114.

[†] Mohs' Mineralogy, iii. 76.

Obviously a compound of

1 atom carbonate of barytes, .	13·25
1 atom carbonate of lime, . .	6·25
	19·5

Sp. 20. *Bicalcareo-Carbonate of Barytes.*

I got the specimen of this mineral in my possession, and from which the description and analysis were made out, from Mr. Cowper, of the firm of S. Cowper and Sons, of Alston and Keswick, Cumberland. He exposed a collection of minerals from the north of England for sale in Glasgow, in the month of November, 1834. Upon looking at his minerals, I was attracted by the specimen as exhibiting something with which I was unacquainted, and purchased it for examination.

Colour snow-white.

Composed of dodecahedrons, consisting of two six-sided pyramids applied base to base. The faces were too rough to admit of being measured by the reflecting goniometer; but by the common goniometer the inclination of the face of one pyramid to the corresponding face of the other was as nearly as I could estimate 132°. The angles of the plane between the two pyramids could not be measured accurately, because few of the crystals were sufficiently disentangled to admit of the application of the goniometer. One that I measured was 110°, and another about 120°. I could observe no cleavage except in one instance, when the cross fracture exhibited what might be the face of a primary rhomboid.

These crystals were in groups, and proceeded from a white crystallized substance, which had the aspect of sulphate of barytes.

Lustre vitreous; fracture in general granular and uneven. In one case only I observed what had the appearance of a foliated fracture.

Translucent.

Hardness 2·25; specific gravity 3·718.

When dissolved in nitric acid it left 0·75 per cent. of sulphate of barytes. This I considered as accidental impurity derived from the base on which the crystals are deposited. The moisture also, which amounted to rather more than 2 per cent., was doubtless merely hygrometrical. Abstracting these two substances, which I consider as accidental impurities, I found the constituents to be,

		Atoms.
Carbonate of barytes,	49·31 or	4·02
Carbonate of lime,	50·69 or	8·01
	100·00	

This is obviously

1 atom carbonate of barytes,	12·25
2 atoms carbonate of lime,	12·5
	24·75

It therefore contains exactly twice the quantity of carbonate of lime that exists in the baryto-calcite of Mr. Brooke.

Sp. 21. *Baryto-Fluate of Lime.*

This mineral occurs in Derbyshire, constituting a bed an inch thick in a slaty limestone. In appearance it is very similar to grey compact limestone. Its specific gravity is 3·75. It was analyzed by Smithson, who found it composed of

Sulphate of barytes,	51·5
Fluoride of calcium,	48·5
	100·0

This corresponds with

1 atom sulphate of barytes,
3 atoms fluoride of calcium.*

Sp. 22. *Xanthite.*

This mineral occurs in small grains, and crystals in a limestone bed at Amity, Orange County, New York. From a specimen of it, which I received from Mr. Nutall about the year 1826, I was enabled to analyze it, and I gave it the name of *xanthite*, from the yellow colour by which it is distinguished.† Since that time, I have been favoured with a much more perfect specimen by the kindness of Dr. Torrey of New York.

Xanthite has a greyish yellow colour, and consists of a congeries of very small rounded grains, easily separable from each other, and not larger than small grains of sand. More lately Lieutenant Mather met with it in the same locality in

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* Schweigger's Jahrbuch, i. 362. I have not seen this species noticed any where else; nor do I know where Smithson's analysis is consigned.

† See Annals of the Lyceum of Natural History of New York, for April, 1828.

foliated masses, which are very friable, and readily fall into grains, some of which are prisms about $\frac{1}{20}$th of an inch in length.*

It readily yields by cleavage a doubly oblique prism, whose faces are inclined to each other, according to Mr. Mather's measurement, as follows:

P on M 97° 30′
P on T 94°
M on T 107° 30′

The grains are translucent; some of them, indeed, are transparent; and Mr. Mather observed that the transparent portions refract doubly.

Hardness does not exceed 2; specific gravity 3·201; but that of the more perfect specimens which I afterwards got from Dr. Torrey, was 3·221.

According to Mather, it fuses per se before the blowpipe into a greenish translucent bead, which is slightly attracted by the magnet. I did not succeed in fusing it per se or when mixed with carbonate of soda. With borax it melts into a glass which is yellow while hot, but becomes colourless on cooling.

The result of two different analyses of this mineral was as follows:

Silica, . . .	37·708	35·092
Lime, . . .	36·308	33·080
Alumina, . .	12·280	17·428
Peroxide of iron, .	12·000	6·368
Protoxide of manganese,	3·680	2·801
Magnesia, . .	——	2·001
Water, . . .	0·600	1·680
	97·576	98·430

The second of these analyses was performed upon a purer specimen than the first. As the peroxide of iron and protoxide of manganese are much more abundant in the first specimen than the second, it seems reasonable to consider them as only accidentally present. For the same reason the magnesia cannot be essential. The atomic values of the three remaining constituents, are as follows:

	By 1st analysis.	By 2d analysis.
Silica, . .	16·35	17·54
Lime, . .	10·37	9·45
Alumina, . .	5·46	7·74

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* Poggendorf's Annalen, xxiii. 367.

If we take the two bases together and compare them with the silica, we have

	1st analysis.	2d analysis.
Silica, . .	16·35	17·54
Bases, . .	16·64	17·54

We see from this that the mineral is composed of simple silicates. The 2d analysis (which was on the purest specimen) gives us

6 atoms silicate of lime,
5 atoms silicate of alumina.

Hence the symbol of the constitution of xanthite is

$$6CalS+5AlS$$

From the first analysis I had concluded the composition to be $2CalS+AlS$.

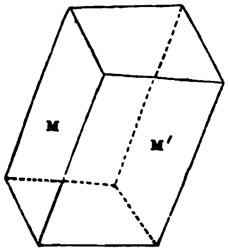
Sp. 23. *Borosilicate of Lime.*

Datholite, esmarkite, humboldtite.

This mineral was discovered by Esmark at Arendal, about the year 1805. It was afterwards found also in the Tyrol, and more lately at Andreasberg in the Hartz, and I have also specimens of it from Paterson in New Jersey. Its constitution was determined by Klaproth in 1806.*

The colour of datholite is white, sometimes inclining to green, yellow, or grey.

Texture imperfectly foliated; cross fracture imperfect conchoidal.



The primary form of the crystal is a right rhombic prism, in which

M on M′ 103° 25′

according to the measurement of Levy.

The obtuse edges of the prism H, are usually replaced by tangent planes. The terminal edges are also commonly replaced by planes more inclined to the faces M, than to the base of the prism. Finally, the solid angles of the prism are replaced by one, two, or more planes.†

The lustre is vitreous, but the faces of cleavage have a lustre inclining to pearly; translucent; streak white; hardness 4·25 to 5.

Specific gravity, as determined by Klaproth, of a specimen

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* Beitrage, iv. 354.

† For a description of the modified crystal, the reader is referred to Mr. vy, Annals of Philosophy (2d series), v. 130.

from Arendal, 2·980.* Haidinger found that of a specimen from Arendal, 2·989.† But the specific gravity of the Datholite from Andreasberg in the Hartz, is much higher, being found by Stromeyer to be 3·3463.

When this mineral is held in the flame of a candle it becomes opaque, and may be crumbled to powder between the fingers. Before the blowpipe it gradually fuses into a glassy globule. With borax and carbonate of soda it also easily fuses into a glass, which is colourless, if the mineral be pure.

We have two analyses of this mineral, one by Klaproth and another by Stromeyer. The following table exhibits the result of these analyses:

	Klaproth.	Stromeyer.
Silica, . . .	36·5	37·36
Boracic acid, . .	24·0	21·26
Lime, . . .	36·12	35·67
Water, . . .	4·0	5·71
	100·62‡	100·00§

Both of these analyses lie under the defect that the boracic acid was not actually obtained, but calculated from the loss of weight sustained during the analyses. If we take Stromeyer's as the most accurate, we have the constituents of datholite, as follows:

3 atoms tersilicate of lime,
2 atoms biborate of lime,
2½ atoms water.

The formula exhibiting its constitution therefore is,

$$3CalS^3+Cal\dot{B}^2+2\tfrac{1}{2}Aq.$$

Mr. Levy gives a description of some small brilliant transparent crystals from the Seisser Alps, which were considered as datholite, and which Dr. Wollaston found to contain the same constituents. Mr. Levy is of opinion, that these crystals‖

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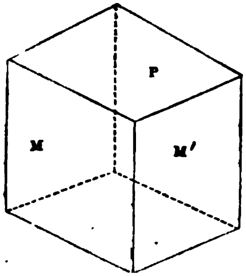
[*] Beitrage, iv. 356.

[†] Mohs' Mineralogy, ii. 223. There is reason to suspect these specific gravities; for Stromeyer informs us, that he took the specific gravity of a very pure specimen from Arendal, and found it 3·3541. See Poggendorf's Annalen, xii. 156.

[‡] Beitrage, iv. 356. The quantity of lime found has been rectified.

[§] Poggendorf's Annalen, xii. 157.

[‖] A figure of these crystals is given in the Annals of Philosophy (2d series), v. 131.



cannot be derived from a *right* rhombic prism but from an *oblique* rhombic prism, in which

M on M′ 115° 45′
P on M 91° 25′

This induces him to consider them as a new species, to which he has given the name of Humboldtite, an appellation already appropriated to the oxalate of iron by M. de Rivero. Levy's determination must remain doubtful till a sufficient quantity of the crystals be obtained, to admit of an accurate analysis.

Sp. 23. *Botryolite.*[*]

Biboro-silicate of lime.

This mineral which occurs in the Kjenlie mine at Arendal, in Norway, was first noticed by Haussmann during his travels in Norway. At his request, Assessor Gahn examined it by the blowpipe, and found it to contain silica, boracic acid, lime, and some alumina. It was afterwards analyzed by Klaproth.

The colour is pale rose red, pearl grey, yellowish white, or isabella yellow. These colours generally appear in concentric stripes.

Texture delicate, stellular fibrous, showing that it is composed of minute crystals.

It occurs only in botryoidal masses. Hence the name, *botryolite*, given it by Haussmann.

Lustre dull or glimmering, pearly; translucent; hardness 4, scratches glass with difficulty; specific gravity, as determined by Klaproth, 2·885.

Before the blowpipe it behaves exactly as datholite.

Its constituents as determined by Klaproth, are

		Atoms.	
Silica, . .	36	18	7·83
Boracic acid, .	13·5	4·37	1·9
Lime, . .	40·32	11·5	5
Peroxide of iron,	1	0·2	0·08
Water, . .	6·5	5·77	2·5
	97·32[†]		

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[*] From βοτρυς, a bunch of grapes.

[†] Beitrage, v. 123.

This approaches very nearly to

4 atoms bisilicate of lime,
1 atom biborate of lime,
2½ atoms water.

Hence the formula is $4\mathrm{CalS}^2+\dot{\mathrm{C}}\mathrm{al}\dot{\mathrm{B}}^2+2\frac{1}{2}\mathrm{Aq}$. It differs in its constitution essentially from datholite, with which mineralogists have hitherto associated it.

Sp. 24. *Colophonite.*[*]

Topazolite, yellow garnet, allochroite, succinite.

This mineral occurs in the same kind of rocks as those which contain common garnet, but is rare.

The colour is various shades of yellow, often with a shade of brown or grey. It is said also to occur with a green colour, but I have never seen a specimen.

When crystallized it has the shape of the rhomboidal dodecahedron with its various modifications peculiar to the garnet.

Fracture imperfect conchoidal.

Lustre resinous; from shining to splendent.

Translucent, at least on the edges.

Hardness 6·75; specific gravity from 3·871 to 3·965.

Its constituents determined by the analysis of Trollé Wächtmeister,[†] are as follows:

Silica, . . .	35·10	35·64
Protoxide of iron, . .	29·10	30
Protoxide of manganese,	7·08	8·02
Magnesia, . . .	——	2·35
Lime, . . .	26·91	29·21
	99·17[‡]	100·22[§]

The mean of these two analyses gives us the atomic proportions as follows:

	Atoms.
Silica, . . .	17·68
Protoxide of iron, .	8·79
Protoxide of manganese,	1·22
Magnesia, . .	0·94
Lime, . . .	8·01

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[*] Named from its resemblance to resin.

[†] Kong. Vet. Acad. Handl. 1823, p. 133.

[‡] From Långbanshittan. Sp. gravity 3·965.

[§] From the neighbourhood of Altenau, in dodecahedral crystals. Sp. gravity 3·871.

Leaving out the oxide of manganese, the atoms of the bases are 17·74, and those of silica 17·68. Hence the mineral is composed of simple silicates. And joining the magnesia to the lime, the constitution will be

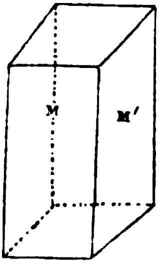
1 atom silicate of lime,
1 atom silicate of iron.

Sp. 25. *Ilvaite.*[*]

Yenite, lievrite, fer-calcareo-siliceux.

This mineral was brought from the Isle of Elba by M. Lelievre, in 1802. He studied its characters, and published an account of it in the Journal des Mines for 1807.[†] Lelievre gave it the name of Yenite, to commemorate the battle of Jena, which had been recently fought. Gehlen, in a letter to Delametherie, remonstrated against this name as an insult to the Prussian nation[‡]. Werner gave it the name of *Lievrite*, in honour of the discoverer. The name *Ilvaite* seems to have been substituted by the French mineralogists instead of Yenite, in consequence of the remonstrance of Gehlen.

The colour of Ilvaite is iron black, with a shade of brown or green. The fracture is imperfectly conchoidal.



It occurs usually in long prismatic crystals; and the primary form obtained from natural cleavage, is a right rhombic prism.

M on M′ according to Lelievre, 112° 37′ 9″
Brooke, 112°
Phillips, 111° 30′

The most usual form is a long oblique four-sided prism terminated by a low four-sided pyramid. The inclination of a side of the pyramid to the corresponding face of the prism, is 128° 50′. The pyramid is usually without its apex, in consequence of a portion of the base of the primary prism still remaining. The inclination of a face of the pyramid to this base, is 141° 10′. Sometimes the lateral edges of the prism are replaced by one or two faces. The lateral faces of the prism are usually longitudinally striated.

Lustre imperfectly metallic; opaque; hardness 4·75 to 5; specific gravity, as determined by Haidinger, 3·994.[§] Stro-

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[*] Named from the island of Elba, where it was first found.

[†] Vol. xxi. p. 65.

[‡] Gehlen's Jour. x. 38.

[§] Mohs' Mineralogy, ii. 415.

meyer found it 3·9796.* Lelievre found that of different specimens 3·825, 3·974, 3·985, 4·061.†

Before the blowpipe on charcoal it fuses into a black globule, which becomes vitreous in the external flame. In the interior flame the surface becomes dull, and it is attracted by the magnet, provided the globule has not been heated to redness. With borax it fuses into a dark, almost black glass; with carbonate of soda, into a black glass. With biphosphate of soda it leaves a skeleton of silica, and gives a glass strongly coloured by iron.

We have three analyses of this mineral, one by Collet Descotils, another by Vauquelin, and a third by Stromeyer. The specimens analyzed by each were from Elba. The following table exhibits the results obtained.

	Descotils.‡	Vauquelin‡. 1	Vauquelin‡. 2	Stromeyer.§
Silica, ...	28	29	30	29·278
Lime, ...	12	12	12·5	13·779
Protoxide of iron, . .	55	57	57·5	52·542
Protoxide of manganese, .	3			1·587
Alumina, ...	0·6	—	—	0·614
Water, ...	—	—	—	1·268
	9·86	98	100·0	99·068

Stromeyer's analysis, which is probably the most correct, corresponds with the following atomic quantities.

3·72 atoms silica,
1 atom lime,
2·97 atoms protoxide of iron,
0·089 atom protoxide of manganese,
0·056 atom alumina.

If the alumina and protoxide of manganese be considered as combined in the mineral with two atoms of protoxide of iron, and these compounds to be accidental, then ilvaite will be a compound of

1 atom silicate of lime,
3 atoms silicate of iron,

and the formula denoting its composition will be $CalS+3\underline{f}S$.

This mineral has been found rather abundantly in limestone among the primary rocks of Elba. It has been observed also

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* Untersuchungen, p. 373.

† Jour. des Mines, xxi. 66.

‡ Jour. des Mines, xxi. 70.

§ Untersuchungen, p. 374.

at Kupferberg in Silesia, at Fassum in Norway, in Siberia, in North America, and I have a specimen of it from Greenland.

Sp. 26. *Hedenbergite.*

This mineral was first observed in Marmor's mine, Tunaberg, in Södermanland, Sweden; where it is associated with calcareous spar. It was described and analyzed by M. A. Ludvig Hedenberg in the year 1807.*

Its colour is greenish black; sometimes inclining to dark green, sometimes to brown.

Structure foliated. Mr. W. Phillips informs us, that it yields by mechanical division a rhombic prism, the faces of which are inclined to each other at angles of 124° 30′ and 55° 30′. But Hedenberg affirms that its shape is precisely the same as that of calcareous spar.

Lustre shining; surface of the cleavage faces streaked; streak olive green.

Hardness 3·5; specific gravity 3·154.

Before the blowpipe it fuses with a very slight effervescence into a black, shining glass. With borax it fuses easily into a glass coloured by iron. With biphosphate of soda it fuses into a bead at first yellow; but becoming at last dark red. These colours are destroyed by the deoxidizing flame. With carbonate of soda it fuses into a greyish green bead, which blackens when the heat is increased.

Its constituents as determined by the analysis of H. Rose, are

		Atoms.	
Silica, ...	49·01	. 24·5	. 4·23
Lime, ...	20·87	. 5·96	. 1·03
Magnesia with manganese,	2·98	. 1·2	. 0·20
Protoxide of iron, .	26·08	. 5·79	. 1
	98·94†		

It is obvious that it consists of bisilicates of lime and iron, and of silicate of magnesia. And if we neglect the small quantity of silicate of magnesia, amounting only to one-fifth of an atom, the constitution of it is

1 atom bisilicate of lime,
1 atom bisilicate of iron.

The formula is $CalS^2+fS^2$.

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* Afhandlingar, ii. 164. † Kong. Vet. Acad. Handl. 1820, p. 328.

Sp. 27. *Ligurite.*

This mineral has hitherto been described and analyzed by Viviani alone. Never having seen it, I can only introduce the very imperfect description given of it by him. It was found on the banks of the Stura in the Appenines, in a talcose rock.

The colour is apple green; streak greyish white; fracture uneven.

Primary form an oblique rhombic prism, with angles of 140° and 40°.

Lustre between vitreous and resinous; transparent to translucent; hardness above 5; used as a gem; specific gravity 3·49.

Its constituents as determined by Viviani, are

			Atoms.
Silica,	57·45	28·725	7
Lime,	25·30	7·22	1·75
Alumina,	7·36	3·22	0·78
Magnesia,	2·56	1·02	0·23
Oxide of iron,	3·00	0·66	0·16
Oxide of manganese,	0·50	0·11	0·02
	96·17[*]		

If we unite the magnesia and lime, and the alumina with the oxides of iron and manganese, the mineral will consist of

2 atoms tersilicate of lime,
1 atom silicate of alumina.

The formula will be $2CalS^3+AlS$.

The tersilicate of magnesia and the silicates of iron and manganese may be foreign bodies.

Sp. 28. *Sphene.*[†]

Brunon, semelin, spinellane,[‡] spinthere, rayonnante en gouttiere, braunmenakerz, and gelbmenakerz.

This mineral seems to have been first noticed by Saussure, who described it under the name of *rayonnante en gouttiere*, in his *Essai de la Lithologie du St. Gothard.*

The colours are brown, yellow, green, and grey. These colours are not lively, if we except some yellow, and some pistacio green varieties.

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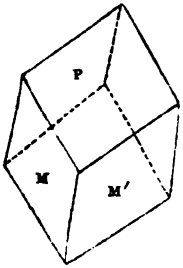
[*] Mohs' Mineralogy, iii. 121.

[†] From σφην, a wedge.

[‡] *Spinellane* is applied also to quite a different mineral. See Mohs' Mineralogy, iii. 156.

The texture is foliated, with a very apparent cleavage in one direction, less distinct in another; cross fracture conchoidal.



It is always crystallized, and the primary form of the crystal, as determined by M. G. Rose, is an oblique rhombic prism.

M on M′ 76° 2′
P on M or M′ 93° 1′

It occurs most commonly in very oblique prisms, the greater angles of which are about 136°.

Lustre vitreous, or even adamantine; in some varieties inclining to resinous.

Varies from transparent to translucent on the edges; hardness 5 to 5·5; the specific gravity, as determined by Haidinger, 3·468. Cordier found that of a specimen from St. Gothard 3·2378; and a specimen from Passau, analyzed by Klaproth, was 3·510.

Before the blowpipe it fuses with difficulty on the edges into a dark coloured glass. With carbonate of soda it fuses into an opaque glass, which becomes greyish white on cooling. With borax it fuses pretty readily into a clear yellow transparent glass. With biphosphate of soda it melts with difficulty, and the unfused portion is milk-white.*

We have two analyses of this mineral, one by Klaproth, and another by Cordier; but neither is likely to be quite accurate, as they were made before the characters of titanic acid were fully developed.

Silica,	35	28
Titanic acid,	33	33·3
Lime,	33	32·2
	100†	93·5‡

Klaproth analyzed another variety of sphene from Salzburg, and found its constituents as follow:

Silica,	36
Titanic acid,	46
Lime,	16
Water,	1
	99§

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* Berzelius on the Blowpipe, p. 256.

† Klaproth, Beitrage, i. 251. ‡ Cordier, Jour. des Mines, xiii. 70.

§ Beitrage, v. 243.

Notwithstanding the great difference in the constitution of the two varieties resulting from the analyses, their characters agree very nearly with each other.

Our uncertainty respecting the atomic weight of titanic acid makes it difficult to estimate the constitution of sphene from these analyses. They agree best with the supposition that it consists of

1 atom tersilicate of lime,
1 atom titaniate of lime.

The formula on that supposition will be $CalS^3 + Cal\dot{T}t$.

Sphene is found interspersed among primary rocks, particularly granite, gneiss, and chlorite. It occurs in some of the oldest veins, and it is said also in trap rocks. It is almost a constant ingredient in syenite.

C. TRIPLE AND QUADRUPLE SALTS.

Sp. 29. *Raphilite.*[*]

I have given this name to a mineral from the township of Perth, in Upper Canada. For the specimen subjected to analysis, and from which the description of the mineral was drawn up, I am indebted to Dr. Holme of Montreal, to whose zeal the mineralogy of Canada lies under very considerable obligations.

Colour white, with a shade of bluish green.

The stone is composed of needle-form crystals, diverging slightly as if from a centre. These needles, when viewed under the microscope, appear to be four-sided oblique prisms.

Lustre between glassy and silky; hardness 3·75; the needles or fibres easily separable from each other; they are slightly flexible, but easily broken; specific gravity 2·85.

Before the blowpipe becomes opaque and white, and the extremity of the fibre is rounded off, but does not fuse into a globule. With carbonate of soda it melts slowly, and with effervescence into a translucent white glass. Fuses with borax into a transparent colourless glass, leaving silica. In biphosphate of soda it does not dissolve, or only very imperfectly,

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[*] From ῥαφις, a needle, from the structure of the stone.

leaving a white substance (silica) considerably more bulky than the original assay.

This mineral yielded by analysis the following constituents:

		Atoms.	
Silica, . .	56·478	28·24	7
Lime, . .	14·750	4·2	1·03
Alumina, . .	6·160	2·73	0·67
Protoxide of iron,	5·389	1·3	0·32
Protoxide of manganese,	0·447		
Magnesia, . .	5·451	2·18	0·54
Potash, . .	10·533	1·75	0·43
Moisture, . .	0·500		
	99·708		

These numbers correspond pretty well with this formula,

$$\mathrm{CalS^3+(\tfrac{2}{3}Al+\tfrac{1}{3}f)S^2+(\tfrac{1}{2}k+\tfrac{1}{2}mn)S^2}.$$

which therefore represents the constitution of raphilite.

Sp. 30. *Polyadelphite.*[*]

The mineral to which I have given this name, from the complex nature of its constitution, was sent me by Mr. Nutall, and its locality I believe to be Franklin, New Jersey.

Colour yellow of different shades, wine yellow, and greenish yellow. The colours are not bright.

The mineral is composed of translucent roundish grains, and of imperfectly foliated masses agglutinated together.

Lustre resinous; mass opaque; small grains translucent.

The hardness at first was only 3·25, but after remaining in my cabinet for several years, it became 4·75. Specific gravity 3·767; brittle.

Before the blowpipe blackens, and assumes the appearance of magnetic iron ore, but does not fuse. With carbonate of soda it fuses into a green glass, which becomes black and opaque in the oxidizing flame. With borax fuses into a dark brown opaque glass; with biphosphate of soda it fuses slowly into a transparent coloured glass, leaving a silica skeleton. Its constituents are,

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[*] From πολυς, and αδηλφος, a brother. So named because it consists of five different silicates united.

		Atoms.
Silica,	36·824	18·422
Lime,	24·724	7·06
Protoxide of iron,	22.948	5·09
Protoxide of mangan.,	4·428	0·98
Magnesia,	7·944	3·17
Alumina,	3·356	1·48
Moisture,	0·550	
	100·774	

These numbers give us the following formula for the constitution of this mineral:

$$7\mathrm{Cal}S+5\underline{f}S+3\mathrm{Mg}S+1\tfrac{1}{2}\mathrm{Al}S+\underline{mn}S.$$

It is therefore a quintuple salt, or we may consider it as

$$5\mathrm{Cal}S+4(\tfrac{5}{6}f+\tfrac{1}{6}mn)S+2\mathrm{Mg}S+\mathrm{Al}S.$$

Sp. 31. *Pektolite.**

M. von Kobell has given this name to a mineral which is found on natrolite, on Monte Baldo, in South Tyrol.

Colour greyish.

Occurs in spheroidal masses, which have a columnar composition, and consist of delicate flat needles, diverging from a centre.

Surface generally dull; lustre pearly at the fracture.

Hardness 4·5; specific gravity 2·69. Its constituents, according to Kobell, are,

		Atoms.	
Silica,	51·30	25·65	11
Lime,	33·77	9·64	4·15
Soda,	8·26	2·06	1
Potash,	1·57	0·26	
Alumina and oxide of iron,	0·90	—	
Water,	8·89	7·9	3·4
	104·69		

This is obviously (including the potash with the soda),

4 atoms bisilicate of lime,
1 atom tersilicate of soda,
3½ atoms water.

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* Kastner's Archiv. xiii. 385.

GENUS VIII.—MAGNESIUM.

Magnesium, like the bases of the other alkaline earths, has too great an affinity for oxygen, ever to exist on the surface of the earth in the metallic state. It is always in the form of *magnesia*, and, like the other alkaline earths, magnesia is always combined either with water or with an acid. Though magnesia is not nearly so abundant a constituent of the globe of the earth as lime, and though it is not met with combined with so many different acids, yet, from the great number of proportions in which it is found united to silica, and the various ways in which the magnesian silicates enter into combination with other silicates, it happens that the number of species belonging to this genus rather exceeds those belonging to the preceding genus.

A. SIMPLE SALTS.

Sp. 1. *Hydrate of Magnesia.*

Brucite of the American mineralogists.

This beautiful mineral was discovered by Dr. Bruce, in the serpentine of Hoboken, in New Jersey. Much finer specimens of it have been found at Swinaness, in Unst, one of the Shetland islands, by Dr. Hibbert. In this place, as at Hoboken, it is in veins traversing serpentine.

Colour white, inclining to green.

Texture foliated, and the mineral is easily split into thin flexible laminæ.

Lustre pearly, splendent.

It has been observed crystallized in low six-sided prisms; but in general no regular shape can be discovered. At Hoboken, in New Jersey, it occurs on serpentine in needle-form crystals diverging from a centre.

Translucent, at least on the edges; sectile; hardness 1; specific gravity, as determined by Haidinger, 2·350.

Before the blowpipe it gives out water, but does not fuse. By the oxygen and hydrogen blowpipe, however, small portions of it may be fused into an enamel.

We have several analyses both of the New Jersey and the Swinaness varieties. The following table exhibits the results.

	*	†	‡	§
Magnesia, ...	64	68·345	66·67	67·98
Water, ...	29	30·902	30·30	30·96
Protoxide of manganese,	—	0·637	1·57	1·57
Protoxide of iron, .	2·5	0·116	1·18	
Lime, ...	—	——	0·19	—
Silica, ...	2	——	—	—
	97·5	100·000	99·91	100·52

The oxides of manganese, and iron, and lime, are only accidental ingredients. It is obviously a compound of

1 atom magnesia, . .	2·5
1 atom water, . .	1·125
	3·625

Sp. 2. *Carbonate of Magnesia.*

Baudisserite, razoumuffskin, magnesite.

This mineral was first observed in Germany, in small quantities; and afterwards at Hoboken, in New Jersey, where it traverses serpentine in veins. It was found at Baudissero, at Piedmont, and in various parts of Germany. In the peninsula of Hindostan it would seem to abound; for about twelve years ago Mr. Babington brought home a cargo of it from India, and he informed me that in that country it constitutes a range of low hills. I have also specimens from one of the islands in the Indian Archipelago.

The colour is yellowish white; the fracture flat conchoidal, and sometimes earthy.

Hitherto observed only massive, and composed of very fine particles without the smallest tendency to crystallization.

Dull; opaque, or feebly translucent on the edges; hardness 4·5; exceedingly difficult to break. Owing to this circumstance, it sometimes strikes fire with steel; though, from its softness, one would not expect this to happen. There is a

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* Vauquelin; Ann. de Mus. d'Hist. Nat. xx. 167.

† Stromeyer; Untersuchungen, p. 407.

‡ Stromeyer; Annals of Philosophy (second series), x. 232.

§ By my analysis. The specimen was from Swinaness, as was also that which constituted the second analysis of Stromeyer. The two first analyses in the table were from specimens from New Jersey.

variety found at Baumgarten, which, according to Haussmann, is harder than the common carbonate of magnesia. The magnesian marble of Nutall is the same with this variety.

Breithaupt found the specific gravity 2·808. Klaproth found it 2·915.[*] According to Stromeyer, the specific gravity of the hard variety from Baumgarten is 2·95.[†]

When exposed to the blowpipe on charcoal, it shrinks a little, and then acts upon vegetable blues, like magnesia. With borax, or biphosphate of soda, it fuses into a glass. When heated in contact with nitrate of cobalt, it assumes a flesh red colour.

It dissolves very slowly in dilute sulphuric or nitric acid. The solution does not take place well unless the mineral be in powder, and heat be applied.

We have five different analyses of this mineral, the results of which may be seen in the following table:—

	‡	§	‖	¶	**
Carbonic acid,	49	50·7512	51	51·35	51·83
Magnesia,	48	47·6334	46	48·03	47·88
Protox. of manganese,	—	0·2117	—	0·62	trace
Insoluble matter,	—	—	1·5	—	trace
Lime,	—	—	—	—	0·28
Water,	3	1·4037	0·5	—	—
	100	100	99	100	99·99

It is obvious that the mineral is a compound of

1 atom carbonic acid,	2·75	or 52·381
1 atom magnesia,	2·5	or 47·619
	5·25	

There is a very slight deficiency of carbonic acid. Probably the external crust of this mineral is liable to lose a little

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[*] Beitrage, v. 99.

[†] Untersuchungen, p. 121.

[‡] Klaproth, Beitrage, v. 100.

[§] Stromeyer, Untersuchungen, p. 183. It was the hard variety from Baumgarten.

[‖] Henry; Annals of Philosophy (second series), i. 252.

[¶] By my analysis, the specimen was from Sulem, in India. In the manganese, there was a trace of lime.

[**] Stromeyer; Annals of Philosophy (second series), x. 233. The [illegible] was from Sulem, in India.

of its acid. At least, I find that this happens with the artificial carbonate of magnesia.

This species was discovered by Dr. Mitchell, about the year 1800, at Hrubschitz, in Mähren.

Sp. 3. *Hydro-Carbonate of Magnesia.*

This mineral occurs at Hoboken, in New Jersey, in serpentine, along with the various magnesian minerals, which have rendered that locality so famous.

It is a white powder exactly similar in its appearance to *magnesia alba.*

It was analyzed by Trollé-Wāchtmeister, who obtained the following constituents:—

		Atoms.	
Magnesia, . .	42·41 .	17 .	13
Carbonic acid, . .	36·82 .	13⅓ .	10·19
Water, . . .	18·53 .	16½ .	12·6
Silica, . . .	0·57		
Peroxide of iron, .	0·27		
Foreign matter, .	1·39		
	99·99*		

These numbers approach nearest to

{ 5 atoms bicarbonate of magnesia,
{ 8 atoms sesquihydrate of magnesia.

How far this represents the real constitution of the mineral is doubtful.

Sp. 4. *Sulphate of Magnesia.*

Epsom salt—hair salt—hollotrichum.

This salt occurs pretty frequently as an efflorescence on other minerals. Thus it occurs at Freiberg as an efflorescence on gneiss. We meet with it also in Scotland, and in different parts of Germany.

Colour white; fracture conchoidal.

It crystallizes in right rhombic prisms, very nearly rectangular; the greater angle being 90° 38′.

Lustre vitreous; transparent to translucent; hardness 2·25; specific gravity 1·751; soluble in water; taste bitter.

Before the blowpipe on charcoal it is converted into sulphuret of magnesium.

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* Kong. Vet. Acad. Handl., 1827, p. 17.

Its constituents are,

1 atom sulphuric acid, . .	5
1 atom magnesia, . . .	2·5
7 atoms water, . . .	7·875
	15·375

Sp. 5. *Reissite.*[*]

Soda sulphate of magnesia.

This name was given by Karsten to a salt first analyzed and made known by Reuss.[†] It occurs in the neighbourhood of Sedlitz.

It constitutes a meally efflorescence, in loose, earthy, dull particles, and likewise crystallized in needles, and in flat six-sided prisms; colour snow-white; taste saline and bitter; soluble in water.

Its constituents, according to the analysis of Reuss, are,

Sulphate of soda, . .	66·04
Sulphate of magnesia, .	31·35
Muriate of magnesia, .	2·19
Sulphate of lime, . .	0·42
	100·00

This corresponds with

16 atoms sulphate of soda,
9 atoms sulphate of magnesia.

But the analysis is an old one, and therefore probably not very accurate.

It is not unlikely that this salt may be found ultimately to be a compound of

2 atoms sulphate of soda,
1 atom sulphate of magnesia.

Sp. 6. *Bloedite.*

This name has been given by Dr. John to a saline substance which occurs at Ischel, in Upper Austria, and which seems to be a mixture of sulphate of magnesia, sulphate of soda, and common salt.

It is in irregular columns, has an uneven and splintery fracture, a vitreous lustre, and a brick-red colour. It is

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[*] I place this salt and the next here, though they are not simple salts, [illegible] of their intimate connexion with sulphate of magnesia.

[illegible] pronounced in Germany, *Reiss*. Hence, the appellation [illegible] translucent, but becomes opaque and white by decomposition. It is soft.

Its constituents, as determined by John, are,

Sulphate of magnesia, . .	36·66
Sulphate of soda, . . .	33·34
Common salt, ...	22·00
Sulphate of manganese, . .	0·33
Water, ...	0·34
	92·67

Together with a quantity of sulphated peroxide of iron with excess of base.

These numbers approach

3 atoms common salt,
4 atoms sulphate of soda,
5 atoms sulphate of magnesia.

But it is probable, that Bloedite is nothing more than a mixture.

Sp. 7. *Biborate of Magnesia.*

Boracite.

This mineral was first observed in a gypsum hill, near Luneburg, in the Dutchy of Brunswick. It was brought to Luneburg, where it was familiarly known by the name of *cubic quartz;* but little attention was paid to it till Westrumb examined it in 1788, and discovered in it *boracic acid*, magnesia, and lime.* Vauquelin afterwards showed, that the lime was only accidental, and that it was essentially a compound of boracic acid and magnesia.†

Colour white, inclining to grey, yellow, or green; streak white; fracture conchoidal, uneven.

It is always crystallized in small cubes, having their edges

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* Crell's Annalen, 1788, ii. 483.

His analysis gave,

Boracic acid, . .	65
Magnesia, . . .	20·5
Lime, . . .	7
Oxide of iron, . .	1·25
Alumina, . . .	2·25
Silica, . . .	1·00
Water, . . .	2·00
	99

Westrumb gave it the name of *muriatico-calcareus*, or *sedative spar*.

† Hauy's Mineralogie, ii. 57.

and alternate solid angles replaced by tangent planes. It occurs also in rhomboidal dodecahedrons.

Lustre vitreous; semitransparent to translucent. According to Dr. Brewster, it has one axis of double refraction. Hardness 4·25; specific gravity, as determined by Haidinger, 2·974. Westrumb states it at only 2·566, but the crystals which he examined were impure.

When heated, the eight solid angles became electric; four of them positive and four of them negative. On cooling, the state of electricity in each pole is reversed.

Before the blowpipe on charcoal, it fuses and intumesces. It is difficult to obtain the globule transparent. On cooling, it is bristled over with needle crystals. With borax it fuses into a transparent glass tinged with iron. With biphosphate of soda it fuses into a transparent glass, capable of becoming opaque by flaming. With carbonate of soda it fuses. If only the quantity necessary to procure a transparent glass be used, the assay on cooling forms crystals with broad facets as perfect as those of phosphate of lead.[*]

If boracite, previously decomposed by soda, be dissolved in muriatic acid, and a paper dipt in the solution be dried, and then moistened with alcohol, and burnt while moist, the flame towards the end of the combustion is tinged green.

We have two accurate analyses of this mineral, one by Stromeyer, and another by Arfwedson. The result of these is as follows:—

	[†]	[‡]
Boracic acid, . .	67	69·7
Magnesia, . . .	33	30·3
	100	

It is a biborate of magnesia, or a compound of

2 atoms boracic acid, .	6	70·588
1 atom magnesia, . .	2·5	29·412
		100·000

Hitherto boracite has been found only in two places, Luneburg and Segenberg, in Holstein. In both places it is imbedded in gypsum.

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[*] Berzelius on the Blowpipe, p. 236.

[†] Stromeyer, Gilbert's Annalen, xlviii. 215.

[‡] Arfwedson; Kong. Vet. Acad. Handl., 1822, p. 92.

Sp. 8. *Hydroboracite.*

Hydrous calcareo-biborate of magnesia.

This mineral was found by M. Hess in a collection of Caucasian minerals. It had been taken for gypsum.

Colour white, but with spots of red from silicated peroxide of iron, and very like both fibrous and foliated gypsum; hardness the same as that of gypsum.

The thin plates are translucent.

The specific gravity is 1·9.

The whole mass is full of holes, which are filled with clay, containing different salts.

Its constituents, as determined by two different analyses of M. Hess, are as follows:—*

	1st.	2d.	Mean.	Atoms.	
Lime, . . .	13·298	13·74	13·519	3·86	0·91
Magnesia, . . .	10·430	10·71	10·570	4·20	1
Boracic acid, . .	49·922	49·22	49·571	16·52	3·93
Water, . . .	26·330	26·33	26·330	23·4	5·57
	99·980	100·00			

The constituents are obviously,

1 atom lime,
1 atom magnesia,
4 atoms boracic acid,
5½ atoms water.

Hence the constituents are,

1 atom biborate of lime,
1 atom biborate of magnesia,
5½ atoms water.

The formula is $\mathrm{Cal}\dot{B}^2+\mathrm{Mg}\dot{B}^2+5\frac{1}{2}\mathrm{Aq}$.

Sp. 9. *Chrysolite.*

Anhydrous silicate of magnesia, peridot, olivine, chusite.

The colour of this mineral is green of various shades; pistachio, olive, asparagus, grass-green, sometimes passing into brown, streak white.

It occurs both in crystals and amorphous. The primary form of the crystal is a right rectangular prism; the longi-

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* Poggendorf's Annalen, xxxi. 49.

tudinal edges of which are often replaced by one, or sometimes by two planes. The terminal edges of the prism are also frequently replaced by faces, which nearly obliterate the base of the prism, though not completely in any crystal that I have seen. The crystallized specimens (which come from the Levant) are known in commerce by the name of *chrysolite;* while the granular specimens so common in basalt and greenstone are called *olivine*, from their olive-green colour.

Cross fracture conchoidal; lustre vitreous.

Varies from transparent to translucent. The transparent varieties are occasionally used for ornamental purposes; but they are not much valued.

Hardness 6·5 to 7.

Haidinger found the specific gravity of a crystal of chrysolite 3·41.[*] Stromeyer[†] found the specific gravity of pure grains of olivine to vary from 3·3386 to 3·3445; while he found that of a crystal of chrysolite to be 3·3514. The specific gravity of the olivine in Pallas's meteoric iron was determined by the same chemist to be from 3·3404 to 3·3497.

Chrysolite does not fuse before the blowpipe, nor lose its transparency; but becomes brown on the edges. With borax and biphosphate of soda, it fuses into a glass coloured by iron, but giving no indication of iron by saltpetre. With soda, it is very slowly converted into a brown scoria.

The following table exhibits the constituents of this mineral as determined by chemical analysis:—

	‡	§	‖	‖	‖	¶	¶	¶
Silica, . . .	39	38	39·73	40·09	40·45	38·48	38·25	61.88
Magnesia, . . .	43·5	50·5	50·13	50·49	50·67	48·42	49·68	25·83
Protoxide of iron, .	19·0	9·5	9·19	8·17	8·07	11·19	11·75	9·12
Oxide of nickel, .	—	—	0·32	0·37	0·33	—	—	—
Oxide of manganese,	—	—	0·09	0·20	0·18	0·34	0·11	9·31
Oxide of chromium,	—	—	—	—	—	—	—	0·33
Alumina, . . .	—	—	0·22	0·19	0·19	0·18	—	—
Driven off by heat, .	—	—	—	—	—	—	—	0·45
	101·5	98	99·68	99·51	99·89	98·61	99·79	106·92

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[*] Mohs' Mineralogy, ii. 346.

[†] Poggendorf's Annalen, iv. 195.

[‡] Klaproth, Beitrage, i. 110.

[§] Vauquelin; Ann. de Chim. xxi. 97.

[‖] Stromeyer; Poggendorf's Annalen, iv. 194. The first specimen was a crystallized *chrysolite;* the two last *olivine.*

[¶] Stromeyer. Ibid. The specimens were of grains of olivine, contained in Pallas's meteoric iron. The last specimen, though resembling olivine was obviously a different substance. Its specific gravity was 3·2759.

Walmstedt, in the Memoirs of the Stockholm Academy for 1824, has published the result of a very careful analysis of six specimens of olivine. The following table exhibits the results which he obtained:—

	*	*	*	*	*	*	†
Silica, . . .	41·54	41·42	41·44	40·83	40·08	40·16	40·8
Magnesia, . .	50·04	49·61	49·19	47·74	44·24	44·87	41·6
Protoxide of iron,	8·66	9·14	9·72	11·53	15·16	15·38	16·4
Protox. of mangan.,	0·25	0·15	0·13	0·29	0·48	0·10	—
Lime, ...	—	—	0·21	trace	—	—	—
Alumina, . . .	0·06	0·15	0·16	trace	0·18	0·10	—
	100·55	100·47	100·85	100·39	100·24	100·61	98·8

When we consider these analyses, we cannot avoid observing, that the silica is nearly constant the greatest amount, being 41·54. The magnesia in the purest specimens approaches 50 per cent. The protoxide of iron is much more variable, the least quantity being 8, and the greatest 16·4 per cent. In crystallized chrysolite the constitution is

1 atom silica,
1 atom magnesia,
$\frac{1}{10}$th atom protoxide of iron.

The quantity of iron being small and variable is probably only accidental. If that were admitted, chrysolite would be a simple anhydrous silicate of iron.

From Mitcherlich's experiments it appears, that silicate of iron, when fused and slowly cooled, assumes a crystalline form, which agrees in its measurement with chrysolite. Probably, therefore, there are two species of minerals, which have nearly the same crystalline form; namely, *silicate of magnesia* and *silicate of iron*. Olivine is sometimes almost pure silicate of magnesia; but frequently, also, it is contaminated with silicate of iron. An account of this last mineral will be given in the 15th genus, when we treat of iron and its native compounds.

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* Kongl. Vet Acad. Handl., 1824, p. 259. The first specimen was from Iserwiese, in Silesia; the second from Bohemia; the third from the Vivarais; the fourth from Siberian meteoric iron; the fifth and sixth from Monte Somma.

† Berthier, Memoires par i. 70. The specimen was from Langeoc, in the Department of the Haute Loire.

Sp. 10. *Nemalite.*

Siliceous hydrate of magnesia.

This mineral occurs in veins in the serpentine rocks at Hoboken, in New Jersey. It was first described and its constituents determined by Mr. Nutall.[*]

Colour white, with a slight shade of yellow.

Composed of elastic fibres, easily separable, and bearing a striking resemblance to asbestus.

Hardness about 2; specific gravity, by my trials, 2·353. Mr. Nutall found it 2·44.

By exposure to a red heat it is rendered brown; it still retains its fibrous structure, but the fibres have become brittle, and easily reducible to powder. By this treatment it loses 29·66 per cent., consisting of pure water.

It dissolves in nitric acid without effervescence, leaving silica. I found its constituents,

		Atoms.	
Magnesia, .	51·721 .	20·69 .	17
Silica, .	12·568 .	6·28 .	5·16
Peroxide of iron,	5·874 .	1·17 .	0·96
Water, .	29·666 .	26·33 .	21·63
	99·829		

These numbers are nearly equivalent to

5 atoms silicate of magnesia,
11 atoms bihydrate of magnesia,
1 atom ferrate of magnesia.

Were the ferrate of magnesia to be considered as accidental, nemalite would be $MgS + 2MgAq^2$.

Sp. 11. *Nephrite.*[†]

Hydrous sesquisilicate of magnesia.

The term *nephrite* has been applied by mineralogists to minerals possessing very different characters, and therefore belonging to distinct species. The mineral to which I mean to confine the name here, is found on the sea-shore of Icolmkill, in water-worn nodules, having been originally disseminated through a limestone, which has long ago been wrought out. But I have specimens from North America, which, though much whiter, possess the same characters, and yield

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[*] Silliman's Jour., iv. 19.

[†] From νεφρος, the kidney; because it was considered as a cure for diseases of the kidney.

the same constituents when analyzed. Several of the rocks distinguished by the name of serpentine, possess the same chemical constitution, though more or less contaminated with foreign matter. Indeed it will appear immediately that nephrite and serpentine constitute only one species.

Colour leek green, of very different degrees of intensity in different parts of the mineral, which, in consequence, appears mottled.

Massive and compact without any visible cleavage; fracture splintery; feel soapy; lustre resinous; brittle; hardness 3·5; specific gravity 2·595.

Infusible per se before the blowpipe: with biphosphate of soda fuses into an opaque white bead.

A translucent light-coloured specimen from Iona, yielded

		Atoms.	
Silica,	44·85	22·42	1·55
Magnesia,	36·05	14·42	1
Protoxide of iron,	3·60	0·80	0·05
Alumina,	1·30	0·57	0·03
Water,	13·55	12·04	0·82
	99·35		

In the nephrite from Hoboken, which is white, the oxide of iron is wanting. I am therefore disposed to consider it in the Iona specimens as accidental. If this be so, nephrite is a compound of

1 atom sesquisilicate of magnesia,
1 atom water.

It is therefore a hydrous sesquisilicate of magnesia.

The following table exhibits the constituents of a specimen of common yellow-coloured serpentine from Hungary. Its specific gravity was 2·8.

		Atoms.	
Silica,	28·75	14·375	2
Alumina,	6·45	2·86	
Peroxide of iron,	3·05	0·61	
Magnesia,	33·10	13·24	2
Lime,	5·18	1·48	
Water,	24·25	21·55	3
	100·88		

If we include the lime we perceive that the mineral is a silicate of magnesia; but the water is more than in nephrite.

Nephrite is $MgS^{1\frac{1}{2}}+1Aq.$; but the common serpentine is $1MgS+1\frac{1}{2}Aq.$ The alumina and peroxide of iron are doubtless accidental.

Another specimen of common serpentine, also yellow, and from Zeoblitz, and having a specific gravity of 2·412, was composed of

		Atoms.	
Silica,	38·95	19·475	14.5
Magnesia,	39·80	15·92	11·88
Peroxide of iron with trace of alumina,	6·70	1·34	1
Water,	14·00	12·4	9·25
	99·45		

Here $2\frac{1}{2}$ atoms of silica appear to be united with 1 atom of peroxide of iron and alumina. This being abstracted the mineral is very nearly $MS+1Aq.$

From these and two or three other analyses which I made, common serpentine seems in general to be nothing else than a hydrous silicate of magnesia.

Sp. 12. *Precious Serpentine.*

Hydrous sesquisilicate of magnesia, picrolite.

The name *serpentine* or *ophites*, has been long applied by mineralogists to a species of rock distinguished by a remarkable variety of colours, which gave it a fancied resemblance to the skin of a serpent. The *precious serpentine*, so named from its superior beauty, seems to have been constituted a peculiar species first by Werner. Haussmann, during his journey through Sweden in 1813, first described a mineral to which he gave the name of *picrolite*, and which he says occurs in different parts of Sweden. It is obvious, both from his description and from the analysis of picrolite, that it is identical with the precious serpentine of Werner.

Colour various shades of green, particularly leek green and mountain green, also dirty straw yellow.

The texture is compact, and the fracture conchoidal.

I have never seen any specimen which had the least tendency to a regular form; but Dr. Fowler assures us that in the township of Warwick, Orange County, New York, crystals of it occur from twelve to sixteen inches in circumference. They are four-sided prisms, slightly oblique. They are often greenish, but sometimes yellow, with an admixture of hydrated magnesia.[*]

Lustre resinous, inclining to pearly; translucent on the edges; hardness 3·5; specific gravity 2·591.

Before the flame of the blowpipe, in the platinum forceps, it assumes a brownish red colour, but does not fuse. With borax it fuses with difficulty into a green glass, which becomes almost white on cooling. With biphosphate of soda it melts with difficulty into a glass tinged with iron. With carbonate of soda it fuses into a yellowish brown enamel.

The following table exhibits the result of four different analyses of this mineral; the first three were of the picrolite of Haussmann, the last of precious serpentine.

	†	‡	§	‖
Silica,	40·04	41·660	45·804	43·07
Magnesia,	38·80	37·159	39·664	40·37
Lime,	—	—	—	0·50
Alumina,	—	—	0·920	0·25
Protoxide of iron,	8·28	4·046	2·000	1·17
Protoxide of manganese,	—	2·247	—	—
Water,	9·08	14·723	12·52	12·45
Carbonic acid,	4·70	—	—	—
	100·9	99·838	100·908	97·81

The following table exhibits the analyses of a considerable number of serpentines from different localities. The nine first by Lychnell,[¶] the tenth by Mosander.[**]

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[*] Annals of Philosophy (second series), x. 314. Are not these rather crystals of killinite than of serpentine?

[†] Almroth, Afhandlinger, vi. 267.

[‡] Stromeyer; Untersuchungen, p. 365. The specimen was from Philipstad, in Wermeland.

[§] By my analysis. The specimen was a picrolite sent me by M. Swedensjierna.

[‖] Hisinger Afhandl. iv. 341. The specimen was a precious serpentine from Skyttgruvan, Fahlun.

[¶] Kong. Vet. Acad. Handl. 1826, p. 175.

[**] Ibid. 1825, p. 227.

	*	†	‡	§	‖	¶	**	††	‡‡	§§
Silica, . . .	41·95	40·98	41·58	42·16	43·20	41·67	42·01	41·66	35·28	42·34
Magnesia, . .	40·64	33·44	42·41	42·26	40·09	41·25	38·14	40·64	35·35	44·20
Lime, . . .	—	trace	—	—	—	—	3·22	0·31	—	—
Alumina, . .	0·37	0·73	trace	—	—	—	—	0·70	13·73	—
Protoxide of iron, .	2·22	8·72	2·17	1·98	5·24	1·64	1·30	2·11	1·79	0·18
Protoxide of manganese,	—	—	—	—	—	—	trace	—	—	—
Protoxide of cerium,	—	—	—	—	—	—	2·24	1·25	—	—
Carb. acid and bitumen,	3·42	1·73	2·38	1·03	—	1·37	0·19	0·13	6·28	0·87
Water, . . .	11·68	12·86	11·29	12·33	11·42	13·80	12·15	12·93	7·33	12·38
	100·28	98·46	99·83	99·76	99·95	99·73	99·25	99·73	99·76	99·97

If we leave out Almroth's analysis in the first table, because the specimen seems to have been impure, the mean of the other three gives us

1·4 atoms silica,
1 atom magnesia,
0·74 atom water.

But as it appears from Lychnell's analyses, and those of Almroth and Mosander, that serpentine is scarcely ever free from carbonic acid, we may perhaps without any sensible error, consider the ratio of the atoms of silica and magnesia to be 1½ : 1. The water present amounts only to ¾ths of an atom. But as all the specimens examined had been long exposed to the atmosphere, they might perhaps have sustained a loss of water. Hence I am disposed to consider the constitution of precious serpentine to be

1½ atom silica,
1 atom magnesia,
1 atom water,

And its formula will be $MgS^{1\frac{1}{2}}+Aq$.

The mean of the ten analyses given in the second table,

---

* Precious serpentine from Skyttgruvan at Fahlun.

† Radiated Picrolite from Taberg.

‡ A yellow translucent serpentine from Sjögruvan in Svärdsjo.

§ Common serpentine from Sala.

‖ Green radiated serpentine from Massachusetts.

¶ Marmolite from Hoboken.

** A very light yellow serpentine from Hvittis in Finland; translucent when in thin plates.

†† A dark yellow and slightly translucent serpentine from Ozen in Norberg.

‡‡ A so called serpentine from the lime quarry of Oker. Light grey yellow, and translucent.

§§ From the limestone quarry of Gullsjo in Wermeland. Almost colourless; but here and there having a tint of apple green. Sp. gr. 2·52.

leaving out the 9th, which obviously belongs to another mineral, gives us

1·35 atom silica,
1 atom manganese,
0·7 atom water.

But the mean quantity of carbonic acid obtained in these 9 analyses, is 1·23 equal to 0·02 atom, supposing the magnesia present to amount to one atom. This will raise the silica to 1·37 atom, and the water to 0·715. So that the results of these analyses do not differ much from those of the preceding.

From these analyses compared with the preceding analysis of nephrite, it is clear that precious serpentine and nephrite constitute in fact only one species. The *metaxite* of Breithaupt is also a variety of serpentine. The following is the description of *metaxite*.

Colour greenish white; lustre inclining to silky.

Texture fibrous; seemingly composed of a congeries of oblique prisms about half an inch long, and attached to each other without any cement. The faces of these prisms measured by the common goniometer, meet at angles of 99° and 81°. In the specimen in my possession, there are four sets of such prisms following each other in succession, as if the specimen were divisible into four successive plates (each half an inch thick). I believe this appearance to be an ocular deception; for on breaking off some of the prisms, those between them were seen passing, without interruption, from one end of the specimen to the other.

Rather sectile.

Hardness 3·5; specific gravity 2·4212.

Before the blowpipe it fuses without communicating any colour to the flame. When heated in a glass tube, it gives out pure water. With carbonate of soda it fuses into a white bead. With biphosphate of soda it fuses slowly, leaving a silica skeleton. When strongly ignited with nitrate of cobalt it assumes a lilac colour, showing the presence of magnesia.

It was subjected to analysis by my son, who obtained

		Atoms.	
Silica,	45·04	22·52	1½
Magnesia,	34·00	12·4	1
Peroxide of iron,	5·28	1·05	
Water,	15·40	13·68	1
	99·72		

It is therefore obviously a compound of

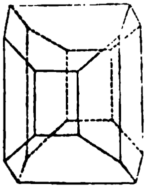
1½ atoms silica,
1 atom magnesia (including the iron),
1 atom water,

Or it is a hydrous sesquisilicate of magnesia.

Sp. 13. *Picrosmine.*

Dihydrous bisilicate of magnesia.

This mineral was constituted into a species by Haidinger, who named it from the peculiar smell which it exhales when moistened.* The only locality hitherto known, is the iron mine called Engelsborg, near Presnitz in Bohemia.



Colour greenish white, passing into greenish grey and mountain green; sometimes oil, leek, and blackish green. Streak white, dull.

Fracture uneven; scarcely perceptible.

Crystallizes in octahedrons with scalene triangular faces. The figure in the margin represents the most usual crystal.

Lustre pearly; hardness 2·5 to 3; varies from translucent on the edges to opaque.

Specific gravity from 2·596 to 2·660.

Before the blowpipe infusible per se, but gives out water; becomes first black, then white and opaque, and acquires a hardness equal to 5. Fuses with biphosphate of soda, leaving a silica skeleton. With nitrate of cobalt it assumes a pale red colour.

Its constituents, as determined by Magnus, are as follows:

		Atoms.
Silica, . .	54·886	. 27·443
Magnesia, .	33·348	. 13·34
Alumina, .	0·792	. 0·35
Peroxide of iron,	1·399	. 0·28
Protoxide of manganese,	0·420	. 0·09
Water, . .	7·301	. 6·5
	98·146†	

It is obvious that the constitution of this mineral is

2 atoms silica, .	4
1 atom magnesia, .	2·5
½ atom water, .	0·5625
	7·0625

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* From [illegible] *bitter*, and οσμὴ, *odour*.

† Poggendorf's Annalen, vi. 53.

About seven years ago, I received an American mineral from Mr. Nutall, which is very intimately connected with picrosmine.

Colour white, with a slight shade of green.

The specimen is composed of a congeries of prismatic crystals very irregularly disposed, and so involved in each other that the shape cannot be accurately determined. They seem to be four-sided oblique prisms.

Lustre vitreous; translucent on the edges; crystals cleave longitudinally; hardness 3·5; specific gravity 2·976.

Its constituents were

		Atoms.
Silica,	56·64	28·32
Magnesia,	36·52	14·6
Alumina,	6·07	2·7
Protoxide of iron,	2·46	0·54
	101·69	

If we admit the alumina and protoxide of iron to be accidental ingredients, the mineral will be an anhydrous bisilicate of magnesia. The only difference between it and picrosmine is the absence of the half atom of water which the latter contains.

Sp. 14. *Schiller spar.*

Hydrous bisilicate of magnesia, karstin, otrelite—diallage metalloide, foliated?

This mineral has only been met with hitherto at Baste, in the forest of Harzburg in the Hartz. It was first noticed by Von Trebra, in 1783, in his mineralogical description of the Hartz. Since that period a great deal has been written on it, and it has been admitted into most mineralogical systems; but both its description, and the historical details concerning it, are so full of inaccuracies that it would be hazardous to notice them. By far the best account of it which has appeared is by Dr. F. Köhler of Cassel.

Schiller spar occurs in a rock which is generally considered as a serpentine. It has a dark green colour, an uneven and splintery fracture; is translucent when in thin plates; its hardness is 3·75; it is sectile, and has a specific gravity of 2·668. Besides schiller spar it contains crystals of augite, and rounded particles of compact felspar.

The schiller spar occurs in it in broad foliated masses, which cleave in two directions, one of which is highly perfect and easily obtained, while the other appears only in slight traces.

These cleavages give a rhombic prism for the shape of the primary crystal, with angles of about 93° 30′, and 86° 30′, but the base of the prism has not yet been obtained.

Lustre metallic pearly, and considerable upon the perfect faces, indistinctly vitreous upon the other faces.

Colour olive green and blackish green, inclining to pinchbeck brown upon the perfect faces of cleavage; streak greyish white, inclining a little to yellow.

Very sectile; hardness 3·75; specific gravity, as determined by Köhler, 2·652; translucent on the edges.

Before the blowpipe, in the platinum forceps, it loses its green colour, and becomes tomback brown, the lustre inclining still more to the metallic. Thin pieces thus treated become attracted by the magnet. It does not melt, but the thin edges are rounded off. It gives off water when heated in a glass tube, which exhibits traces of ammonia. When thus deprived of water, its colour becomes tomback brown. With borax it enters into fusion with difficulty; it shows the presence of iron, and the bead on cooling becomes slightly emerald green, in consequence of the presence of chromium. With biphosphate of soda it exhibits the same phenomena, and leaves a silica skeleton. With carbonate of soda it does not fuse, but exhibits on platinum foil the presence of manganese.[*]

The constituents of schiller spar, as determined by the analysis of Köhler, are as follows:

		Atoms.
Silica,	43·900	21·95
Magnesia,	25·856	10·34
Protoxide of iron and chromium,	13·021	2·89
Protoxide of manganese,	0·535	0·12
Lime,	2·642	0·75
Alumina,	1·280	0·55
Water,	12·426	11·04
	99·660[†]	

If we admit the lime to be united to the same proportion of silica as the magnesia, and the iron, manganese, and alumina to be accidental, the mineral will be a compound of

2 atoms silica,
1 atom magnesia,
1 atom water,

and its formula will be $MgS^2 + Aq$.

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[*] Köhler, Poggendorf's Annalen, ii. 192.

[†] Ibid.

Köhler likewise analyzed the stone in which the schiller spar occurs. The result was as follows:

Silica, ...	42·364
Magnesia, ...	28·903
Protox. of iron, with some chromium,	13·268
Lime, ...	0·627
Alumina, ...	2·176
Protoxide of manganese, . .	0·853
Water, ...	12·071
	100·262

It is at once evident from this analysis that the stone and the schiller spar are identical in their composition, consequently the matrix of schiller spar is not serpentine, but a substance sui generis.

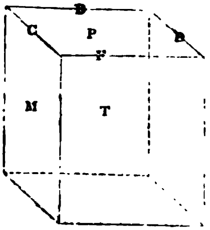
There were three analyses of schiller spar published many years ago, the results of which may be seen in Mohs' Mineralogy, ii. 207. It will be at once evident upon inspecting these analyses, that the minerals analyzed by Heyer and Vauquelin were not schiller spar, but something else; but that Drappier had experimented upon real schiller spar.*

Sp. 15. *Tersilicate of Magnesia.*

Pyrallolite.

This mineral has hitherto been observed only at Storgord, in the parish of Pargas, in Finland, where it occurs in a limestone bed along with felspar, augite, scapolite, moroxite, and sphene. It was first observed by Count Steinheil, and it was first described and analyzed by Nordenskiöld.†

Colour white, inclining to greenish; structure foliated; fracture earthy.



The primary form of the crystals is a doubly oblique prism, in which

M on T 94° 36′
P on T 80°.

The edges B, F are almost always replaced by a face inclined upon T, at an angle of 140° 49′. These two new faces frequently obliterate the face P, and cause the prism to terminate in a bihedral summit. Sometimes the edges C,

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* Jour. de Phys. lxii. 48.

† Bidrag till närmare kennedom of Finlands, &c. p. 21.

D are replaced by a face, making an angle with M of about 138° 30′. The face T is considerably larger than the face M.

Lustre dull; sometimes slightly resinous; opaque, when of a considerable size, but translucent when in thin plates; hardness 3·5 to 4; specific gravity 2·555 to 2·594.

Before the blowpipe it becomes first black, then white again; afterwards it intumesces and melts on the edges into a white enamel. With borax it yields a transparent glass. The addition of nitre shows the presence of manganese. With biphosphate of soda it effervesces a little, and then fuses with very great difficulty. With soda it fuses easily into a transparent glass, having a yellowish green colour.

According to the analysis of Nordenskiöld, its constituents are

		Atoms.
Silica, . .	56·62	28·31
Magnesia, . .	23·38	9·35
Alumina, . .	3·38	1·5
Lime, . .	5·58	1·59
Protoxide of manganese,	0·99	0·22
Peroxide of iron,	0·09	0·018
Water, . .	3·58	3·18
Bitumen and loss, .	6·38	
	100	

The alumina and lime are probably in combination, and the oxides of manganese and iron accidental ingredients. On this supposition, pyrallolite is a compound of

3 atoms silica,
1 atom magnesia,
$\frac{1}{3}$ atom water,

And its formula will be $MgS^3+\frac{1}{3}Aq$.

Sp. 16. *Hydrous tersilicate of Magnesia.*

Meerschaum—myrzer—kil—kilkeffe.

The term meerschaum is applied by the Germans to different earthy substances, which are employed for making the bowls of the Turkey tobacco pipes. The mineral to which we wish to confine the term is dug up at Eski Scheher, in Natolia. The sale of it supports a monastery of Dervises established near the place where it is dug. It is found in a large fissure, six feet wide, in grey calcareous earth. The workmen assert that it grows again in the fissure, and puffs itself up like froth. When fresh dug it is of the consistence of wax; when thrown on the fire it sweats, emits a fetid vapour, becomes hard, and perfectly white.

Colour snow-white; fracture fine earthy, passing into flat conchoidal; surface smooth, and the grains so fine that they are imperceptible; dull; opaque; hardness 2; after exposure to a red heat 6; specific gravity (after being for some years in my cabinet) 2·127.

The constituents, on analysis, were found to be

		Atoms.	
Silica, . . .	42	21	5·16
Magnesia, . . .	30·5	12·2	3
Water, . . .	23	20·44	5·02
Lime, . . .	2·3	0·65	0·16
Alumina, with trace of manganese,	2·0		
	99·8		

It is obviously composed of

5 atoms silica,
3 atoms magnesia,
5 atoms water.

Another specimen which I got under the name of meerschaum, was obviously a deposite from water. Its colour was yellowish white. It was composed of particles which had a visible size; they were soft, and did not seem quite free from extraneous matter. The specific gravity was 1·3. It yielded to analysis,

		Atoms.
Silica, . .	49·000	24·5
Magnesia, . .	13·480	5·4
Water, . .	20·440	18
Carbonic acid, .	4·560	1·65
Alumina, . .	10·800	4·8
Lime, . .	1·108	0·31
Protoxide of iron,	0·712	0·15
Protoxide of manganese,	0·160	0·03
	100·260	

The constitution of this mineral is quite different from that of the preceding. It is probably a mere mixture. If we abstract the carbonates of lime and magnesia, which it obviously contains, it may be considered as a mixture of

1 atom tersilicate of magnesia,
1 atom tersilicate of alumina,
4 atoms water.

Klaproth analyzed two varieties of meerschaum.* One of his specimens approached the last of mine in its constituents; but the other contained much more silica and much more water. It is obvious that unless we restrict the meaning of the term, as I have done, meerschaum cannot be considered as a chemical compound, but merely a mixture.

Sp. 17. *Magnesite.*

This name is applied by the French mineralogists to *meerschaum;* but there is another mineral which occurs in considerable quantities in thin beds in the marly limestone formations round Paris, to which this name has been given. It has been met with in greatest purity at Coulommiers, about 30 miles east of Paris. It was first described by M. Alex. Brogniart, and analyzed by M. Berthier.†

Colour greyish white; with sometimes a very slight tint of red. When heated it loses its grey red tint, and becomes white.

It is soft, and has a smooth and unctuous feel; but its powder is pretty hard.

It imbibes water easily, and swells out much; becomes feebly translucent, and forms a soft paste without plasticity, similar to jelly.

When exposed to the heat of a porcelain furnace it becomes hard, and exfoliates a little, but does not experience any farther alteration. It exhibits no symptom of fusion, but becomes hard enough to strike fire with steel.

Its constituents, as determined by Berthier, are as follow:

		Atoms.	
Silica,	54	27	2·81
Magnesia,	24	9·6	1
Water,	20·1	17·77	1·85
Alumina,	1·4	0·62	0·06
	99·4		

This approaches pretty nearly to

3 atoms silica,
1 atom magnesia,
2 atoms water.

It is therefore a bihydrous tersilicate of magnesia, and its formula is MgS^3+2Aq.

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* Beitrage, ii. 172.

† Ann. des Mines, vii. 290.

It is obvious that the second specimen of meerschaum, of which the analysis is given in page 177 of this work, is in reality an impure specimen of magnesite. Hitherto meerschaum and magnesite have been confounded, though their composition is essentially different.

M. Berthier has given us the constituents of several other varieties of magnesite, from the environs of Paris, and other localities.* We shall exhibit the results in the following table:

	From Asia Minor.	From Cabanas, near Madrid.	From Sallinelle, Gard.	From St. Ouen, at the foot of Mont Martre.
Silica,	50	53·8	51	51
Magnesia,	25	23·8	19·8	13·4
Water,	25	20·0	22	18·2
Alumina,	—	1·2	4·4	17·0
Oxide of iron,	—	—		
Sand,	—	—	2·8	—
	100	98·8	100·0	99·6

Sp. 18. *Quincite.*†

This name has been applied by M. Berthier to a red-coloured substance which occurs interspersed through a limestone deposite which exists at Mehun, in France; and extends from that town to the village of Quincey, and even beyond it. The limestone the most coloured contains very little *quincite.* It may be obtained in a state of purity by treating the limestone with acetic or dilute muriatic acid.

It is in light flocks, and has a fine carmine red colour. A very moderate heat deprives it of its colour. It becomes first violet, then grey, and at last yellowish white, and at the same time pure water is disengaged. The weaker acids, or the strong acids diluted with water, do not act upon it. The strong concentrated acids act on it imperfectly. Silica is obtained in the gelatinous state, and magnesia and iron are dissolved. Its constituents, as determined by Berthier, are

			Atoms.
Silica,	54	27	15·25
Magnesia,	19	7·6	4·29
Protoxide of iron,	8	1·77	1
Water,	17	15·11	8·5
	98		

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* Ann. des Mines, vii. 314.

† Memoires par Berthier, i. 71.

This approaches pretty nearly

4 atoms tersilicate of magnesia,
1 atom tersilicate of iron,
$8\frac{1}{2}$ atoms water.

Its formula is $4MgS^3+\underline{f}S^3+8\frac{1}{2}Aq$.

Though this mineral is a double salt, we have been induced to place it here in consequence of the analogy which it has to magnesite and meerschaum.

B. DOUBLE SALTS.

Sp. 19. *Ferro-carbonate of Magnesia.*

Brachytypous lime haloid of Mohs.

This species was first distinguished from *bitter spar* and other similar minerals, by Mohs. It occurs in various places in Salzburg, the Tyrol, and Switzerland; and has also been discovered in Unst, one of the Shetland isles.

Colour white or grey, generally inclining to yellow; also yellow and brown; streak greyish white. Fracture conchoidal; structure foliated.

Usually in crystals. The primary form is a rhomboid, approaching very nearly to that of calcareous spar. But P on P′ is 107° 22′ instead of 105° 5′, as in calcareous spar.

Lustre vitreous, sometimes inclining to pearly on the cleavage faces; hardness 4 to 4·5; specific gravity from 3·001 to 3·112.

From the analysis of this mineral given by Mohs, it would seem that it is a compound of

9 atoms carbonate of magnesia,
1 atom carbonate of lime.

But we have four analyses by Stromeyer of four varieties of this mineral, which give the following results:*

	1.	2.	3.	4.	Berthier.†
Magnesia,	41·06	40·19	42·40	43·44	44.5
Protoxide of iron,	8·57	10·53	6·47	4·98	4·9
Protoxide of manganese,	0·43	0·49	0·62	1·52	—
Coal,				0·11	—
Carbonic acid,	48·94	48·48	49·67	49·93	50·6
	99·00	99·69		99·98	100·0

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* Schweigger's Jahrbuch, for 1827, iii. 219.

† Ann. des Mines (second series), iii. 34.

It is obvious that the carbonate of iron cannot be chemically combined with the carbonate of magnesia; because its quantity is variable.

The constitution of these varieties is nearly as follows:

1. 8 atoms carbonate of magnesia,
   1 atom carbonate of iron.
2. 7 atoms carbonate of magnesia,
   1 atom carbonate of iron.
3. 10 atoms carbonate of magnesia,
   1 atom carbonate of iron.
4. 12 atoms carbonate of magnesia,
   1 atom carbonate of iron.

Is it it not likely that it will be found ultimately to be merely a variety of carbonate of magnesia?

Sp. 20. *Calcareo-carbonate of Magnesia.*

Dolomite—conite—gurhofian—anthraconite—miemite—muricalcite—pearl spar—picrite—tharandite—brown spar (in part)—magnesian limestone.

There can be no doubt that several distinct species are at present confounded together under the names of pearl spar and brown spar; and the external characters of these different species approach so nearly that they can only be accurately distinguished by chemical analysis. The following description applies to the mineral compound of 1 atom carbonate of lime, and 1 atom carbonate of magnesia; usually distinguished by the names of *dolomite* and *magnesian limestone.*

Colour white, generally inclining to red or green. It occurs also green, red, brown, grey, and black, owing to foreign admixtures; streak greyish white.

Fracture conchoidal; structure foliated. Primary form of the crystal a rhombohedron, approaching very nearly to the shape of calcareous spar. But P on P′ is 106° 15′, as was first determined by Dr. Wollaston.

Lustre vitreous, inclining to pearly in some varieties; from semitransparent to translucent; hardness 3·5 to 4; specific gravity from 2·815 to 2·884.

Before the blowpipe it behaves like carbonate of lime.

I analyzed several specimens, both crystallized and granular, and found the constitution to be

1 atom carbonate of lime, .	6·25
1 atom carbonate of magnesia,	5·25
	11·5

This is the case with the magnesian limestone from the neighbourhood of Sunderland. Berthier analyzed eight different varieties of calcareo-carbonate of magnesia, from different localities, and found their constituents as follow:*

	1. St. Briene.	2. Namar.	3. Bruniquel.	4. Namar.	5. Bourbonne.	6. Bourbonne.	7. Estovon.	8. Schirmech.
Lime, . . .	44·0	37·6	34·2	29·1	29·2	30·0	10·7	29·5
Magnesia, . .	8·4	13·6	16·2	21·0	21·2	22·4	7·7	20·0
Protoxide of iron, .	—	1·8	—	1·2	—	—	0·8	1·3
Protoxide of mangan.,	—	—	—	—	—	—	0·3	—
Carbonic acid & water,	40·6	45·6	44	46·7	44·6	47·0	18·6	46·4
Foreign matter, .	7·0	0·4	5·2	2·0	5·0	0·6	61·9	2·2
	100·0	99·0	99·6	100·0	100·0	100·0	100·0	99·4

It is obvious that the 4th, 5th, 6th, 7th, and 8th of these minerals were compounds of

1 atom carbonate of lime,
1 atom carbonate of magnesia.

The first was a compound of

4 atoms carbonate of lime,
1 atom carbonate of magnesia.

The second of

2 atoms carbonate of lime,
1 atom carbonate of magnesia.

And the third of

3 atoms carbonate of lime,
2 atoms carbonate of magnesia.

Nothing very precise can be stated about the geological position of this mineral. It occurs in transition beds, in coal beds, in new red sandstone, in lias, and probably in even newer rocks.

Sp. 21. *Wagnerite.*

Fluophosphate of magnesia.

This mineral has been hitherto found only in short and irregular quartz veins in clay slate in the valley called Höllgraben, near Herpen, in Salzburg. It was noticed in Moll's Ephemerides for 1805.† Professor Fuchs saw a specimen of it in the cabinet of Mr. Wagner, at Munich, and published a description and analysis of it in 1821. He called the mineral Wagnerite, because Mr. Wagner supplied him with the specimen which he subjected to analysis.

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* Ann. des Mines (second series), iii. 27.

† i. 209, as quoted by Fuchs; Schweigger's Jahrbuch, iii. 269.

Colour wine yellow; sometimes orange yellow, or inclining to grey.

Fracture flat conchoidal; sometimes splintery and uneven.

Crystals right oblique prisms, with angles of 94° and 86°. The faces are streaked longitudinally.

Lustre vitreous; translucent; hardness 5 to 5·5; specific gravity 3·13, as determined by Fuchs.

When heated to redness, it loses no weight, and undergoes no alteration.

Before the blowpipe it fuses with great difficulty into a dark greenish grey bead. With borax it fuses easily into a transparent glass, yellowish green while hot, but colourless when cold. With biphosphate of soda it behaves almost in the same way. With carbonate of soda it effervesces, but does not dissolve, though it is decomposed. When the assay is dissolved in water a yellowish white powder remains undissolved, which dissolves readily in sulphuric acid, and which consists chiefly of magnesia.

According to the analysis of Fuchs, wagnerite is composed of

		Atoms.
Phosphoric acid,	41·73	9·26
Fluoric acid,	6·50	5·2
Magnesia,	46·66	18·66
Protoxide of iron,	5·00	1·11
Protoxide of manganese,	0·50	0·11
	100·39	

If the fluoric acid, oxide of iron, and oxide of manganese, were accidental ingredients, wagnerite would be a diphosphate of magnesia, or a compound of

1 atom phosphoric acid,
2 atoms magnesia.

If the fluoric acid be an essential constituent, it is not so easy to form a distinct notion of the nature of the combination.

Sp. 22. *Chondrodite.*[*]

Fluosilicate of magnesia—maclurite—brucite.

This mineral was first described and analyzed by Count D'Ohsson, in the Memoirs of the Stockholm Academy for 1817, (p. 206). It had indeed been discovered several years before, by Dr. Bruce, imbedded in calcareous spar at Newton,

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[*] From χονδρος, a grain: so named from its granular structure.

Sussex county, in New Jersey; but was mistaken for sphene. Berzelius recognised the identity of the American and Finland mineral, which had been analyzed by D'Ohsson, and confirmed his opinion by an analysis. In 1822 it was again analyzed by Mr. Seybert, who detected fluoric acid in it, and gave it the name of maclurite.*

The colour of chondrodite is wine yellow. The fracture is small conchoidal. But it cleaves, according to Hauy, parallel to the faces of a right oblique prism, the greater angle of which is 112° 12′. He even describes and gives a figure of a six-sided prism of this mineral from the United States. Though I have a number of specimens of it from New Jersey, none of them exhibits any traces of crystallization.

Lustre vitreous; translucent; hardness 4·5; specific gravity of the Finland variety, as determined by D'Ohsson 3·18; by Haidinger 3·199; Seybert states that of the New Jersey variety to vary from 3·157 to 3·228. I found that of the purest specimens I could select 3·118.

Infusible per se by the blowpipe; but becomes darker coloured. With carbonate of soda on charcoal it fuses with difficulty into a light grey slag. With borax it effervesces a little, and fuses easily into a yellowish green glass. With biphosphate of soda it leaves a silica skeleton.

The following table exhibits the constituents of this mineral as determined by analysis:—

	†	‡	§
Silica,	38·00	32·666	36·00
Fluoric acid,	—	4·086	3·75
Magnesia,	54·00	54·000	54·64
Peroxide of iron,	5·10	2·333	3·97
Alumina,	1·50	—	—
Potash,	0·86	2·108	—
Water,	—	1·000	1·62
	99·46	96·193	99·98

This gives (assuming my analysis)

18 atoms silica,
3 atoms fluoric acid,
21·85 atoms magnesia,
0·79 atom peroxide of iron.

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* Silliman's Jour., v. 336.

† D'Ohsson, Kong. Vet. Acad. Handl., 1817, p. 206.

‡ [illegible]; Silliman's Jour., v. 336.

§ By my analysis.

If the peroxide of iron be admitted to have been in combination with magnesia, it is evident that chondrodite is a compound of

6 atoms silicate of magnesia,
1 atom fluate of magnesia.

I could discover no potash in chondrodite, though I searched for it.

The only localities of chondrodite at present known are Ersby, in the parish of Pargas, in Finland, imbedded in limestone, and Newton, Sussex, New Jersey, where it is likewise imbedded in calcareous spar.

Sp. 23. *Potash Bisilicate of Magnesia.*

This substance was observed in the quarries of St. Yrieix, and first described and analyzed by M. Le Play.*

It occurs both crystallized and in an earthy state.

Colour yellowish white. The crystals resemble those of tremolite; but the prisms are more oblique than those which constitute the primary form of amphibole. The cleavage parallel to the base is indistinct.

Friable and easily reduced to fine soft powder; specific gravity 2·87.

It has considerable resemblance to steatite in its characters.

The constituents, as determined by M. Le Play, are as follow:—

	Crystals.	Earthy variety.
Silica,	58·16	58·50
Magnesia,	26·48	33·12
Potash,	6·32	5·74
Peroxide of iron,	7·60	1·04
Alumina,	0·40	trace
Lime,	0·64	1·20
Water,	0·40	—
	100·00	99·60

If we take the second analysis, which seems the most accurate, it is obvious that the mineral consists of bisilicates, and nearly in the proportion of

13 atoms bisilicate of magnesia,
1 atom bisilicate of potash.

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* Ann. des Mines (second series), v. 187.

The peroxide of iron and lime differing in quantity so much in the two analyses, must be accidental ingredients.

Sp. 24. *Venetian Talc.*

This mineral is found imbedded in serpentine in the mountains of Salzburg and the Tyrol, and was formerly carried to Venice as an article of commerce, being employed in medicine. Hence the name Venetian talc. It was chiefly employed as a cosmetic. It was reduced to a fine powder by heating it to redness, and afterwards pounded in a hot mortar. I have specimens also from Marlborough, Vermont, United States.

Colour apple green. It is composed of thin flexible plates, having a silvery appearance and a pearly lustre, and easily separable from each other. These plates are not elastic.

I have never seen a specimen of true Venetian talc in crystals.

Lustre pearly and splendent; from semitransparent to translucent; very sectile; hardness 1; specific gravity 2·697.

Infusible before the blowpipe per se.

Its constituents, determined by analysis, are as follow:—

			Atoms.
Silica, . .	62·588	. 31·29	. 5
Magnesia, .	30·528	. 12·21	. 1·95
Protoxide of iron,	3·848	. 0·85	. 0.13
Water, . .	3·400	. 3·02	. 0·48
	100·364		

It is obvious, that Venetian talc is a compound of

1 atom bisilicate of magnesia,
1 atom tersilicate of magnesia,
½ atom water.

What is called *talc slate* agrees in its chemical constitution with Venetian talc, but is not quite so pure. A specimen of this mineral from Novorda, in Piedmont, in my cabinet, possesses the following characters:—

Colour white, with a slight shade of yellow; massive and slatey; composed of impalpable particles; fracture flat conchoidal; opaque, or only translucent on the edges; sectile; lustre silky; hardness 2 to 2·5; specific gravity 2·877. Its constituents, as determined by analysis, are as follow:—

		Atoms.	
Silica,	57·560	28·78	5·19
Magnesia,	27·216	10·88	2
Lime,	7·944	2·27	0·41
Alumina,	1·720	0·76	0·14
Protoxide of iron,	4·716	1·04	0·19
Water,	1·600	1·42	0·26
	100·756		

We see that it is anhydrous, (or contains no chemically combined water,) and that its constitution is the same as that of Venetian talc, though it is mixed with a little impurity, consisting of silica, lime, alumina, and protoxide of iron.

Swedish potstone which has a specific gravity of 2·88, is a mixture of Venetian talc with a black substance in small crystalline grains.

Its constituents were

		Atoms.
Silica,	49·01	5
Magnesia,	30·20	$2\frac{1}{2}$
Protoxide of iron,	11·40	$\frac{1}{2}$
Alumina,	6·08	$\frac{1}{2}$
Water,	4·20	$\frac{3}{4}$

Obviously a mixture of talc and a mineral composed of

1 atom magnesia,
1 atom alumina,
1 atom protoxide of iron,

Sp. 25. *White Augite.*[*]

Diopside, mussite, alalite, sahlite, malacolite.

The specimens of this mineral in my cabinet are from the United States. But it occurs also in Finland, in Sweden, and doubtless in many other places.

Colour white or grey, generally with a slight shade of green.

Texture foliated. It is always crystallized in pretty long four-sided prisms slightly oblique. In no specimen in my possession can the termination of the prisms be observed. But the cleavage shows that it is oblique. Fracture conchoidal.

Cleaves parallel to the faces of a doubly oblique prism.

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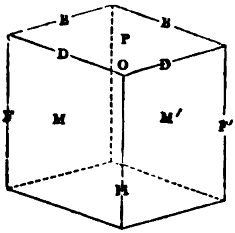
[*] Augite, named from *αυγη*, *lustre;* because its lustre is much greater than that of hornblende.



P on M or M′ 101°
M on M′ 87° 5′

In the common crystals M is at least double the size of M′. The edge H is always replaced by a tangent plane. Sometimes the edge F′ is also replaced by a tangent plane; but the edge F is usually entire. In the variety called diopside, found in the Piedmontese Alps, the edge H is replaced by three planes, the edge F′ by a tangent plane, and the terminal edges of the prism are also replaced by planes, which cause the prism to terminate in a truncated four-sided pyramid. Finally, the solid angle O is replaced by a small tangent plane.

Lustre vitreous, usually translucent, sometimes transparent; refracts doubly very powerfully; hardness 4·75; specific gravity 3·297; that of diopside, as determined by Tonnellier, 3·2374;[*] that of sahlite, as determined by D'Andrada, 3·2307.

Before the blowpipe it fuses per se into a colourless glass. With borax it fuses readily into a diaphanous glass. With biphosphate of soda it decomposes slowly and leaves a silica skeleton. With carbonate of soda it fuses into a transparent glass.

We are indebted to M. H. Rose[†] for an elaborate analysis of this species, and of several other minerals hitherto confounded together under the common name of pyroxene. The following table exhibits the result of the most accurate analyses hitherto made.

	‡	§	‖	¶	**	††	‡‡
Silica, ...	54·64	55·32	54·83	55·40	53	54·18	57
Lime, ...	24·94	23·01	24·76	15·70	20	22·72	16·5
Magnesia, . .	18·	16·99	18·55	22·57	19	17·81	18·25
Protox. of mangan,	2·00	1·59	—	0·43	4	1·45	6·00
Peroxide of iron,	1·08	2·16	0·99	2·50	—	2·18	
Alumina, . . .	trace	—	0·28	2·83	3	—	—
Water, . . .	—	—	0·32	—	—	1·20	—
	100·66	99·07	99·73	99·43	99	99·56	97·75

[*] Jour. des Mines, xx. 67. [†] Kong. Vet. Acad. Hand. 1820, p. 325.

‡ From Orrijervi, Finland. Analyzed by Rose. Ibid.

§ Colour yellowish. From Langbanshyttan, Wermeland. Rose. Ibid.

‖ From Tammare in Finland. Bonsdorf's analysis. Ibid.

¶ From Pargas, analyzed by Nordenskiöld, Bidrag, p. 70.

** Sahlite; Vauquelin, Hauy, iv. 382.

†† Sahlite; Hisinger Afhandlingar, iii. 300.

‡‡ Diopside; Laugier, Ann. de Mus. d'Hist. Nat. ii. 157.

It is obvious that the three first of these analyses are identical, and show that the mineral is a compound of

1 atom bisilicate of lime,
1 atom bisilicate of magnesia,

So that the formula for white augite is $CalS^2+MgS^2$.

But the analysis in the 4th column is equivalent with

		Atoms.
Silica,	27·7	6·205
Lime,	4·48	1
Magnesia,	9·02	2·013
Protoxide of manganese,	0·09	0·020
Protoxide of iron,	0·55	0·127
Alumina,	1·25	0·279

This is obviously

1 atom bisilicate of lime,
2 atoms bisilicate of magnesia,

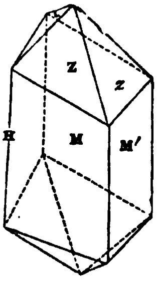
With a small admixture of disilicates of alumina and iron. The composition is therefore essentially different from that of white augite. We shall therefore give a description of this mineral as it has been drawn up by Nordenskiöld.

The colour is light bluish green. It is always in crystals.

The most common form is a four-sided prism, whose faces M, M′ are inclined at angles of 87° 33′ and 92° 27′. The crystal has an oblique cleavage in the direction of the greater diameter of the prism, which makes an angle of 106° 0′ 30″ with the axis of the prism. The prism terminates in a four-sided pyramid in which

M on Z 134° 46′

Most commonly the obtuse edges of the prism H are replaced by tangent planes which render the prism six-sided.



The specific gravity is 3·267.

Fracture splintery and small conchoidal. Hard enough to scratch glass, but it is scratched by quartz.

The action of the blowpipe is nearly the same as upon white augite.

It must be admitted that both the crystalline form, and the other characters of this mineral, agree very closely with those of common white augite. The form of the crystal, however, though deducible from the primary crystal of augite, is one which I have never seen white augite assume.

The fifth and sixth minerals whose analyses were given in the preceding table, are sahlites; so named because they occur in the lead mine of Sahla in Sweden. Sahlite has a greenish grey colour, and is seldom in regular crystals, but readily admits of cleavage in the direction of the faces of the primary form of white augite. In chemical composition it agrees with white augite, excepting that there is a slight deficiency of lime.

In the analysis of the diopside which constitutes the last column of the table, there is a deficiency of 2½ per cent. To this perhaps we are to ascribe the apparent excess of silica. There is present 1 atom of tersilicate of iron, and the rest of the constituents constitutes very nearly

$$3CS^2+5MS^2.$$

Thus the constitution of diopside does not exactly agree with that of white augite.

The colour of diopside is light green. It is transparent, and has a specific gravity of 3·310. In its crystalline form it agrees with white augite. It occurs in veins traversing serpentine at Mussa, in Piedmont.

Sp. 26. *Pyroxene.*[*]

Augite, baikalite, coccolite, euchysiderite? fassaite, pentaclusite, pyrgom, vulcanite, asbestus in part.

Under the name *pyroxene* is at present placed a great number of substances which occur in crystals and have the crystalline form of white augite, though they do not agree with that mineral in their composition.

The colour is usually green, or green inclining to brown; sometimes black. The streak is white.

The fracture is conchoidal, and the crystals, which are usually in four or six-sided oblique prisms, cleave parallel to the faces of a rhomboidal prism, having the same shape as the primary form of white augite.

Lustre vitreous, inclining to resinous.

Sometimes translucent, but frequently also opaque.

Hardness 4·75; specific gravity from 3·233 to 3·349.

Before the blowpipe it behaves like white augite, excepting that the colour of the bead is affected by the great proportion of iron which it contains.

The following table exhibits the composition of several of these varieties, as determined by the analysis of H. Rose.[†]

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[*] From πυρ, *fire*, and ξενος, *a stranger;* because it occurs in lava; to which Hauy considered it as not belonging.

[†] Kong. Vet. Acad. Hand. 1820, p. 329.

	*	*	†
Silica,	54·08	54·55	53·36
Lime,	23·47	20·21	22·19
Magnesia,	11·49	15·25	4·99
Protoxide of iron,	10·02	8·14	17·38
Protoxide of mangan.,	0·61	0·73	0·09
Alumina,	——	0·14	——
	99·67	99·02	98·01

The first of these has the same constitution as white augite; with this remarkable difference, that one-third of the bisilicate of magnesia is replaced by bisilicate of iron. The atomic numbers are,

Bisilicate of lime,	6·7 atoms
Bisilicate of magnesia,	4·6
Bisilicate of iron,	2·2

This is obviously equivalent to

1 atom bisilicate of lime,
1 atom bisilicate of magnesia and iron.

The formula will be

$$\text{CalS}^2+(\tfrac{2}{3}\text{Mg}+\tfrac{1}{3}\underline{\text{f}})\text{S}^2.$$

We might also consider this mineral as a compound of

2 atoms white augite,
1 atom hedenbergite.

And this in all probability is its true constitution.

The second of the pyroxenes analyzed is also composed of bisilicates, and in this respect agrees with white augite. The atomic quantities of these are

Bisilicate of lime,	5·77 atoms
Bisilicate of magnesia,	6·1
Bisilicate of iron,	1·8

The greatest part of the mineral was white augite. It was composed of

White augite,	5·77 atoms
Bisilicate of magnesia,	0·43
Bisilicate of iron,	1·8

Bisilicate of magnesia is the mineral already described under the name of *picrosmine*. Bisilicate of iron has not hitherto been met with native, but it constitutes a common slag; and Mitcherlich informs us, that he has observed it crystallized

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* Both specimens from Björnmyresveden, in Dalecarlia. Colour green.

† From Taberg, in Wermeland. Colour black.

and having exactly the form of pyroxene. Hence it is not surprising that it should occur mixed in an impure augite without altering the form of the crystal.

The third of the pyroxenes whose constituents are given by Rose, differs from the other two in this respect, that it is not constituted of bisilicates; or at least there is a surplus of silica, as will appear by stating the atomic weight of the different constituents:

Bisilicate of lime, . .	6·34 atoms
Bisilicate of magnesia, .	2
Bisilicate of iron, .	3·86
Surplus of silica, .	2·28

It might be considered as containing

2 atoms white augite,
3·86 atoms hedenbergite,
0·48 atoms bisilicate of lime,
2·28 atoms silica.

The bisilicate of lime is the well known mineral called *table spar*.

Thus the black augite from Taberg might be a mixture or compound of

1 atom table spar,
4 atoms white augite,
8 atoms hedenbergite,
4½ atoms silica.

Rose has placed hedenbergite among the pyroxenes; probably because, like white augite, it consists of bisilicates; but as its crystalline form and its constituents differ essentially from those of white augite, it ought undoubtedly to constitute a peculiar species.

Sp. 27. *Jeffersonite.*[*]

This mineral was discovered in the beds of iron ore at Franklin, in New Jersey, by Mr. Keating and Mr. Vanuxem, and an account of it was published by the former of these gentlemen in the year 1822.[†]

It occurs in lamellar masses, which were described as not larger than a pigeon's egg; but a specimen in my cabinet, for which I am indebted to the kindness of Dr. Torrey of New

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[*] From Mr. Jefferson, of Virginia, formerly President of the United States of America.

[†] Edinburgh Phil. Jour. vii. 317.

York, is at least six inches long, and three inches over in the broadest part.

The colour is dark olive green, passing into brown.

Structure foliated, and according to Keating it admits of being cleaved in various directions, so that its primary form is not easily ascertained; but as far as I can make out the form from the specimen in my possession, it seems to approach that of pyroxene very closely.

Lustre between resinous and semimetallic; streak grey; powder light green.

Hardness 4·5; specific gravity from 3·51 to 3·55; slightly translucent on the edges.

Before the blowpipe fuses readily into a dark coloured globule.

Its constituents, as determined by Mr. Keating, who analyzed it twice with almost the same results, are as follow:

		Atoms.
Silica, . . .	56 .	28
Lime, . . .	15·1 .	4·31
Protoxide of manganese,	13·5 .	3
Peroxide of iron, .	10·0 .	2
Oxide of zinc, .	1·0 .	0·19
Alumina, . .	2·0 .	0·88
Moisture, . .	1·0	
	98·6	

If we leave out the oxide of zinc and the alumina, as accidental, it is obvious that Jeffersonite is composed of tersilicates, and the constituents are nearly

4 atoms tersilicate of lime,
3 atoms tersilicate of manganese,
2 atoms tersilicate of peroxide of iron.

Sp. 28. *Amphibole.*[*]

Actinolite, actinote, amianthinite, amianthoid, asbestinite, foliated augite, bissolite, corinthine, green diallage,[†] grammatite, hornblende, blue hyperstene, keraphyllite, keratophyllite, lotalite, pargasite, smaragdite, tremolite, asbestus in part, amianthus.

This mineral was constituted into a distinct species in the

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[*] From αμφιβολος, ambiguous, so named by Hauy, because it was at first confounded with the *tourmaline.*

[†] *Green diallage,* according to Haidinger, is a mixture of very thin plates of hornblende and augite.

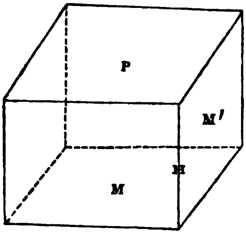
very infancy of mineralogy, under the name of *hornblende*—a name originally imposed by the Swedish mineralogists, though it is very difficult to determine what the varieties were to which that appellation was applied.

Hauy proved to the satisfaction of mineralogists in general that the numerous minerals arranged by Werner under the names *tremolite*, *actinolite*, *hornblende*, &c., constitute in fact but one species, as they all possess the same crystalline form. He contrived the general term *amphibole*, which includes them all. But these different varieties are so distinct from each other in their properties, that they cannot be made out by their external characters, if we except the crystalline shape; nor does chemical analysis enable us to subdivide them with accuracy. I am disposed to consider *white tremolite* as the mineral which exhibits amphibole in a state of purity, and shall therefore describe it in the first place.

Tremolite was first observed in the valley of Tremola, in Switzerland: hence the name. Hauy distinguished it at first by the appellation *grammatite*.

Its colour is white, though it frequently has a greenish, bluish, yellowish, or reddish tinge.

It occurs usually in masses composed of delicate crystalline fibres, and likewise in very flat and deeply striated four, six, or eight-sided prisms, rarely terminated by dihedral summits.



It cleaves with brilliant surfaces parallel to the sides of an oblique rhombic prism, in which

P on M or M′ 130° 15′
M on M′ 124° 30′

Its lustre is vitreous, inclining to pearly on the faces of cleavage.

It is always translucent, at least on the edges; sometimes semitransparent.

Hardness 4·75; exceedingly frangible.

Specific gravity, according to Hauy, varies from 2·9257 to 3·200.

Before the blowpipe it fuses readily, with slight bubbling, into a semitransparent glass. With borax it fuses easily into a colourless transparent glass. With biphosphate of soda it is not decomposed; the assay remains milk-white throughout, and is rounded on the edges; after a long blast the glass becomes opaline on cooling. With a very small quantity of carbonate of soda it fuses into a transparent glass. A larger quantity of the flux causes it to intumesce, and converts it into a white infusible scoria.

We are indebted to Bonsdorf for a very complete analytical investigation of tremolite, and all the varieties of amphibole.*

The following table exhibits the constituents of tremolite, according to the analysis of this excellent chemist:

	†	‡
Silica, . .	60·31 .	60·10
Magnesia, .	24·23 .	24·31
Lime, . .	13·66 .	12·73
Alumina, . .	0·26 .	0·42
Protoxide of iron,	0·15 .	1·00
Protoxide of manganese,	—— .	0·47
Fluoric acid, .	0·94 .	0·83
Water, . .	0·10 .	0·15
	99·65	100·01

It is obvious at once that these two minerals are identical, as the differences are within the limits of errors in the analysis.

Taking the mean of the two, we have the following atomic quantities:

	Atoms.
Silica, . .	30·2
Magnesia, . .	9·7
Lime, . .	3·77
Alumina, . .	0·15
Protoxide of iron, .	0·12
Protoxide of manganese,	0·10
Fluoric acid, .	0·7
Water, . .	0·11

It is probable that the fluoric acid existed in the mineral in combination with lime or calcium. This supposition would reduce the atoms of lime to 3·07, and the atoms of all the bases, excluding 0·7 atom of fluor spar, amount to 13·14; the atoms of silica being 30·2. Now 30·2 : 13·14 : : 9 : 4 very nearly; while the atoms of magnesia are to those of lime very nearly as 3 to 1. If therefore we exclude the minute quantity of silicated alumina, iron and manganese, as insignificant, it is evident that tremolite is a compound of

1 atom tersilicate of lime,
3 atoms bisilicate of magnesia.

Its formula is $CalS^3+3MgS^2$.

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[*] Kong. Vet. Acad. Handl. 1821, p. 197.

[†] Colourless tremolite from Gullsjö. [‡] Yellow tremolite from Fahlun.

That the alumina, oxides of iron and manganese, with their corresponding quantity of silica, may be excluded, is probable from this circumstance that they were much more abundant in the second specimen, which was yellow, than in the first specimen, which was white.

The variety of amphibole distinguished by the names of *actinolite*, *actinote*, and *strahlstein*, from its radiated structure, is very similar to tremolite, except in its colour.

The colour is green of various shades, as leek green, olive green, and emerald green.

It is usually in long thin oblique six-sided prisms, composed of radiating fibres. To mechanical division it yields crystals, having the same primary form as those of tremolite.

When the lustre is vitreous the mineral has much of the aspect of green glass, and is then called *glassy actinolite;* when the lustre is resinous, the mineral is called *common actinolite.*

Usually translucent, at least on the edges; hardness the same as that of tremolite; specific gravity varies from 3·175 to 3·482.

In its other properties it agrees with tremolite. The phenomena before the blowpipe are the same, only the beads are coloured by the iron to which the actinolite is indebted for its green colour. The following table exhibits the constituents of a glassy actinolite from Taberg, analyzed by Bonsdorf:

		Atoms.
Silica, . .	59·75 .	29·87
Magnesia, .	21·10 .	8·44
Lime, . .	14·25 .	4·07
Protoxide of iron,	3·95 .	0·87
Protoxide of manganese,	0·31 .	0·06
Fluoric acid, .	0·76 .	0·60
	100·12	

If we suppose (as before) that the fluoric acid is united to lime, the atoms of lime in the mineral will be reduced to 3·47. The atoms of silica are 29·87, and those of the bases 12·84. Now 29·87 : 12·84 : : 9 : 3·86. This is very nearly as 9 to 4, as in the tremolite; but the proportion of lime is greater than in tremolite, and the protoxides of iron and manganese, taken together, amount to very nearly an atom.

It seems to be $\text{CalS}^3+3\text{MgS}^2$, (the same as tremolite,) intimately mixed or combined with

$\frac{1}{3}$d atom tersilicate of lime,
$\frac{1}{3}$d atom bisilicate of iron.

What is called *pargasite* is a green coloured mineral which occurs in grains in calcareous spar at Obo, in Finland.

It is translucent, at least on the edges.

Its specific gravity and hardness is the same as that of tremolite. Some of the grains are six-sided prisms, with dihedral summits, and it yields to mechanical division an oblique prism, having precisely the dimensions of the primary form of tremolite.

We have two analyses of this mineral, one by Bonsdorf, and another by C. G. Gmelin. These analyses gave the following results:

Silica,	46·26	51·75
Magnesia,	19·03	18·97
Lime,	13·96	10·04
Alumina,	11·48	10·93
Protoxide of iron,	3·48	3·97
Protoxide of manganese,	0·36	——
Mixed matter,	0·43	——
Fluoric acid,	1·60	1·83
Water,	0·61	
	97·21*	97·49†

Here it is obvious at once that the quantity of silica is less than in tremolite or actinolite. The atoms deduced from the preceding analyses are as follow:

	Bonsdorf.	Gmelin.
Silica,	23·13 atoms	25·87 atoms
Magnesia,	7·61	7·59
Lime,	3·98	3·12
Alumina,	5·10	4·85
Protoxide of iron,	0·77	0·88
Protoxide of manganese,	0·08	
Fluoric acid,	1·28	

In Bonsdorf's analysis, the atoms of silica and alumina together amount to 28·23, and those of the bases to 12·36. Now these numbers are very nearly to each other as 9 to 4; so that if we admit the substitution of a portion of alumina for silica, the acids and bases in pargasite are to each other very nearly as in tremolite and pargasite, though, if we were to abstract a portion of the lime for the fluoric acid, that ratio would not hold. The lime (abstracting 1·28 atom for the

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* Bonsdorf. † Gmelin, Kong. Veten. Acad. Handl. 1816, p. 158.

fluoric acid) amounts to 2·7 atoms, which is not far from the third of the magnesia, amounting to 7·61 atoms.

In fact pargasite may be considered as a compound of

$$CalS^3+3MgS^2,$$

but it contains also, either combined or mixed,

0·11 atom silica,
2 atoms alumina,
0·3 atom protoxide of iron,
0·5 atom fluor spar.

The Pargas hornblende, so minutely described by Nordenskiöld, in his Bidrag, agrees, as appears from the analysis of Bonsdorf, almost exactly with pargasite in its composition.

The variety of amphibole called *hornblende* occurs pretty abundantly in greenstone and other trap rocks, and also in syenite, and occasionally in granite. Its colour is dark bottle green, or brownish green, or blackish green. Powder greenish grey.

Structure foliated. The primary form of the crystal is the same as that described above, when giving an account of tremolite. Its most common form is a six-sided prism terminated by a low four-sided pyramid, or by three faces. The two additional faces of the prism are produced by the acute edges H of the primary crystal being replaced by tangent planes. Hence the inclination of M′ on the new face is 117° 45′.

The lustre is vitreous, and the crystals are usually opaque, or nearly so. They are uncommonly tough, which was the reason of applying to them the name of hornblende. In other respects hornblende corresponds in its characters with tremolite.

The constituents of hornblende, as determined by Bonsdorf, are as follow:—

Silica,	48·83	42·24	45·69
Magnesia,	13·61	13·74	18·79
Lime,	10·16	12·24	13·83
Alumina,	7·48	13·92	12·18
Protoxide of iron,	18·75	16·26	7·32
Protoxide of manganese,	1·15	0·33	0·22
Fluoric acid,	0·41	trace	1·50
Water,	0·50	—	—
	100·89*	98·73†	99·53‡

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* Black hornblende from Nordmark.

† Black hornblende from Vogelsberg, in Wetteran.

‡ Hornblende from Pargas. It was at first called *basalt*.

If these hornblendes be constitutionally the same as white tremolite, it is obvious that they must be mixed with a great deal of foreign matter.

If the first specimen consist of $CalS^3+3MgS^2$, there must be present in it besides,

Silica, .	4·47 atoms
Alumina, .	1·47
Protoxide of iron,	2·24
Fluor spar, .	0·32
Lime, .	0·42
	8·92

These foreign bodies constitute almost 9 atoms, or $\frac{9}{22}$ of the whole atoms in the mineral. It will be observed, that the atomic weight of the surplus silica is equal to that of all the surplus bases. Hence they are all simple silicates, with the exception of the lime, which is a bisilicate, and as all these silicates exist, we have no reason to be greatly surprised at finding them mixed, or combined in hornblende with the substance which constitutes white tremolite.

If the second specimen consist essentially of $CalS^3+3MgS^2$, there must be present in it besides

Silica, .	2·5 atoms
Alumina, .	3·37
Protoxide of iron,	1·97
Lime, .	0·91
	8·75

Here also the foreign matter amounts almost to 9 atoms, or to $\frac{9}{22}$ of the whole number of atoms in the crystal. But as the atoms of silica are little more than one-third of the atoms of bases, and as we know no trisilicates of alumina or iron, we cannot consider this foreign matter in any other light than as partly a silicate of alumina, and partly an aluminate of iron and lime, in which the alumina acts the part of an acid.

The third specimen contains hardly any surplus of silica; but

Alumina, .	2·15 atoms
Protoxide of iron,	0·64

The mineral from Sardinia, well known by the name of *amianthus*, of which incombustible cloth was made by the ancients, is merely a variety of amphibole.

It has a white colour with a slight shade of green, and a silky lustre, and is composed of fine soft flexible threads, easily separable from each other, and admitting of being spun into thread. The specific gravity is 1·551. Before the blowpipe it melts into a white bead. Its constituents, as determined by an analysis in my laboratory, were

Silica,	55·908
Magnesia,	27·068
Lime,	14·632
Alumina,	1·820
Protoxide of iron,	6·528
	105·956

The excess is probably owing to the formation of a double salt of magnesia during the analysis. A bare comparison of these constituents with those of white tremolite, will satisfy the reader that the two minerals belong to the same species.

Common asbestus in general belongs rather to pyroxene than to amphibole.

Sp. 29. *Norwegian Tremolite.*[*]

This mineral was found by M. Nelson in large rocks in the Isle of Tiotten, near the shore of Helgoland, in Norway.

It was in amorphous masses, having a white colour passing into bluish grey. Its lustre is pearly. It is translucent on the edges. Structure foliated, and giving by mechanical division an oblique prism, with angles of 74° and 106°.

Hardness about 6; specific gravity 3·2.

Before the blowpipe melts with difficulty on the edges.

The constituents of this mineral, as determined by the analysis of C. G. Retzius, are as follow:—

		Atoms.	
Silica,	63·7	31·85	8·94
Lime,	27·2	7·77	2·18
Magnesia,	8·9	3·56	1
	99·8		

This corresponds very nearly with

9 atoms silica,
2 atoms lime,
1 atom magnesia.

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[*] Ann. des Mines, vi. 250.

Hence the constitution of the mineral must be
2 atoms tersilicate of lime,
1 atom tersilicate of magnesia.

Sp. 30. *Retinalite.*[*]

I received this mineral some years ago from Dr. Holmes of Montreal. Its locality is Granville, in Lower Canada. It was considered in Canada as a variety of serpentine.

Colour brownish yellow.

The specimens as I got them were amorphous masses, having exactly the appearance of lumps of resin. Hence the the reason of the name (from ῥετινη, resin.)

Texture compact; fracture splintery.

Translucent.

Lustre resinous, shining.

Hardness 3·75; specific gravity 2·493.

Before the blowpipe becomes white and friable, but it does not fuse.

With borax it forms a clear colourless glass, a white matter (doubtless silica) occupying the interior of the globule. With biphosphate of soda it fuses into a glass transparent while hot, but becoming white and opaque on cooling. With carbonate of soda it fuses into an opaque bead.

Its constituents were found to be

			Atoms.
Silica,	40·550	20·275	8·62
Magnesia,	18·856	7·54	3·2
Soda,	18·832	4·70	2
Peroxide of iron,	0·620	0·12	0·05
Alumina,	0·300	0·12	0·05
Water,	20·000	17·77	8·41
	99·158		

The constitution is $3MgS^2+2NS+8\frac{1}{2}Aq$.

It is therefore totally different from serpentine. It often contains mixed with it a quantity of carbonate of lime.

Sp. 31. *Hypersthene.*[†]

Labradore hornblende—paulite.

The first specimen of this mineral came from the Island of St. Paul, on the coast of Labradore. Hence it was called *paulite* by Werner, when he constituted it a distinct species

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[*] Ρετινη, *resin*, from its great resemblance to resin.

[†] From ὑπερ, above, and σθενος, strength, because it possesses greater lustre and hardness than *amphibole*, with which it was confounded.

in 1812. In that island it occurs chiefly in rolled masses. In that part of the Isle of Skye, called Cuchullin, there is a range of mountains environing a small lake, and composed entirely of hypersthene and felspar. These mountains are uncommonly steep, and quite barren. Hypersthene is found also at Baffin's bay. I have specimens from that locality, for which I am indebted to the kindness of a surgeon of a whale ship, an old pupil.

Colour greyish, or greenish black; sometimes nearly copper red.

It is always crystallized in rhombic prisms, with angles of 93° 30′ and 86° 30′. The base of the prism is wanting in all the crystals that I have seen; nor can any cleavage be observed transverse the axis of the prism. But Mr. Brooke informs us, that he possesses a fragment of a crystal which indicates an oblique termination, inclining upon the acute edge of the prism. Hauy makes the prism a right oblique, and says, that he was able to observe the cleavage parallel to the base by presenting it at night to the light of a candle.

Lustre eminently metallic upon the faces of cleavage; in other directions vitreous.

Opaque, or at most very slightly translucent on the edges.

Hardness 4·75; very difficult to break, nor does it seem to have any tendency to fall to powder, even after long exposure to the atmosphere. The barrenness of the Cuchullin mountains is owing to the entire absence of soil.

The specific gravity of the Isle of Skye hypersthene is 3·338, that of paulite is 3·385, and that from Baffin's Bay 3·355.

Before the blowpipe it is infusible per se, but melts upon charcoal into a greenish grey opaque globule. Dissolves easily in borax.

The constituents of Isle of Skye hypersthene, as determined by the analysis of it by Dr. Thomas Muir in my laboratory, are as follow:—

		Atoms.	
Silica,	51·348	25·67	11·56
Magnesia,	11·092	4·44	2
Protoxide of iron,	33·924	7·54	3·39
Lime,	1·886	0·52	0·23
Water,	0·500		
	98·700		

The atoms of silica are very nearly twice as many as those of the bases. Hence the Isle of Skye hypersthene is composed of bisilicates. If we unite the lime to the magnesia, the atoms of magnesia are to those of protoxide of iron almost exactly as 2 to 3. Consequently the constitution of this mineral is

2 atoms bisilicate of magnesia,
3 atoms bisilicate of iron.

The formula will be $2MgS^2+3\underline{f}S^2$.

Labradore hypersthene, or paulite, was also analyzed by Dr. Muir, who found the constituents,

		Atoms.
Silica, . .	46·112	. 23·05
Magnesia, . .	25·872	. 10·35
Protoxide of iron, .	12·701	. 2·82
Protoxide of manganese,	5·292	. 1·18
Lime, . .	5·380	. 1·54
Alumina, . .	4·968	. 1·76
Water, . .	0·480	
	99·905	

If we unite the lime and magnesia, and the protoxide of manganese with the protoxide of iron, the atoms of the former will be to those of the latter very nearly as 3 to 1. There is a deficiency of silica to constitute these bases into bisilicates. But Klaproth, in his analysis of paulite, states the quantity of silica which he found at 54·25 per cent., which, if we add to it the alumina, would furnish the requisite quantity. Paulite from this would seem to be composed of

3 atoms bisilicate of magnesia,
1 atom bisilicate of iron.

So that it differs essentially in its constitution from Isle of Skye hypersthene. If this difference hold in future analyses, it will be necessary to constitute each a peculiar species.

The specimen from Baffin's Bay not being so pure as the other two, no dependence can be placed upon it as constituting a type of the species. It was subjected to analysis by the same accurate experimenter, and found composed of

		Atoms.
Silica, ...	58·272	. 29·13
Magnesia, . .	18·960	. 7·58
Protoxide of iron,	14·416	. 3·20
Protoxide of manganese,	6·336	. 1·40
Alumina, . .	2·000	. 0·88
	99·984	

The silica is more than sufficient to convert the whole bases into bisilicates. Uniting the oxides of iron and manganese, their atoms are to those of the magnesia very nearly as 3 to 5. Hence the composition of the mineral is

5 atoms bisilicate of magnesia,
3 atoms bisilicate of iron,

with a surplus of

3·11 atoms silica,
0·57 atom alumina.

Probably the specimen contained interspersed grains of quartz, though they could not be distinguished by the eye.

Sp. 32. *Humboldilite.*[*]

This mineral occurs in the lava of Mount Vesuvius, and was described and named by Messrs. Monticelli and Covelli.

The colour is brown, inclining slightly to yellowish or greenish yellow.

Fracture conchoidal.

Primary crystal a right square prism. The lateral edges are frequently replaced by tangent planes, or by two planes converting the crystal into a six, eight, or sixteen-sided prism.

Lustre vitreous; translucent, and in thin laminæ transparent; hard enough to scratch glass; specific gravity 3·104.

Melts before the blowpipe with effervescence, but without forming a globule. With borax it melts into a transparent glass. With biphosphate of soda or carbonate of soda it melts with extreme difficulty into a brown opaque enamel.

Pulverized and treated with nitric acid, it gelatinizes.

Its constituents, according to the analysis of Monticelli and Covelli, are

		Atoms.
Silica,	54·16	27·08
Lime,	31·67	9·04
Magnesia,	8·83	3·53
Alumina,	0·50	0·22
Protoxide of iron,	2·00	0·44
	97·16[†]	

The atoms of silica being very nearly twice as many as

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[*] Silliman's Jour. ii. 251. The mineral was named, by the Italian mineralogists, in honour of M. Humboldt.

[†] Berzelius in his Jahresbericht for 1833 (p. 169), gives the following analysis of this mineral by Kobell :

those of the bases, it is clear that the mineral is composed of bisilicates. And leaving out the small quantities of bisilicates of alumina and iron, the proportions approach

3 atoms bisilicate of lime,
1 atom bisilicate of magnesia.

The formula will be $3CalS^2+MgS^2$.

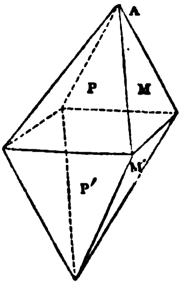
It usually occurs in a lava composed of grains of *zurlite*[*] and pyroxene, both amorphous and having together a greenish brown colour.

Sp. 33. *Hyalosiderite.*[†]

This mineral was observed by Dr. Walchner in an amygdaloid in the Kaiserstuhl, near Sasbach in Brisgau. He published a description and analysis of it in 1823.[‡]

Colour yellowish or reddish brown; streak cinnamon brown; fracture small conchoidal.

It is usually crystallized. The primary form is an octahedron with a rectangular base. The summits A are commonly replaced by planes parallel to the base, and cutting the pyramids so deep, that the crystals have the appearance of thin plates with bevelled edges.



P on P′ 99° 22′
M on M′ 77° 50′

Internal lustre vitreous; of the surfaces metallic; translucent on the edges.

Hardness 5·5; specific gravity 2·875.

		Atoms.
Silica,	49·36	24·68
Alumina,	11·20	5
Lime,	31·96	9·13
Magnesia,	6·10	2·14
Protoxide of iron,	2·32	0·51
Soda,	4·28	1·07
Potash,	0·38	0·06
	105·60	

This would give the mineral quite a different position. But the great excess renders the result doubtful.

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[*] *Zurlite* is a name given by Ramondini to a mineral which occurs in the lava of Mount Vesuvius, along with Humboldilite.

Its colour is asparagus green; its fracture granular; crystalline form the same as that of humboldilite; lustre dull; scratched by the knife, does not scratch glass: specific gravity 2·274. When pulverized and put into nitric acid, it effervesces and then subsides into a greenish imperfect jelly.

It is probably only a variety of humboldilite, or rather a mixture of humboldilite, pyroxene and carbonate of lime.

[†] From ὕαλος, glass, and σίδηρος, iron. [‡] Schweigger's Jahrbuch, ix. 65.

Before the blowpipe it becomes black and then melts into a black bead, which is attracted by the magnet. With borax it fuses easily into a clear glass, greenish yellow while hot; but nearly colourless when cold. With biphosphate of soda it forms a greenish glass leaving a silica skeleton.

Its constituents, according to the analysis of Walchner, are

		Atoms.	
Silica, . . .	31·634	15·81	3
Protoxide of iron, .	29·711	6·61	1·25
Magnesia, . . .	32·403	12·96	2·46
Alumina, . . .	2·211	0·98	0·12
Protoxide of manganese,	0·480	0·10	0·02
Potash, . . .	2·788	0·46	0·08
Chromium, a trace,			
	99·227		

The atoms of silica being 15·81, those of the bases amount to 21·11: and 15·81 : 21·11 : : 3 : 4 very nearly. Hence one-half of the base must be in the state of a simple silicate, and the other half in that of a disilicate. From the last column it is evident that the bases are not regular multiples of each other. As no disilicate of magnesia is known, we may presume that it is in the state of silicate. The atoms of protoxide of iron are almost half those of magnesia. Therefore neglecting the other constituents, as amounting to only a small fraction of an atom, we may consider the mineral as composed of

2 atoms silicate of magnesia,
1 atom disilicate of iron,

The formula will be $2\mathrm{MgS}+\underline{f}^2\mathrm{S}$.

Sp. 34. *Anthophyllite.*[*]

Strelite, karstin.

This mineral was first observed at Kongsberg in Norway, in a bed of mica slate, and described by Schumacher. It has been found likewise in Greenland, and is said to occur in granite in Mechlenburg.

Colour between yellowish grey and clove brown, with a kind of false metallic lustre; streak white.

It occurs massive, the mass being composed of crystals or crystalline fibres, often disposed in a radiating form. The crystals may be cleaved parallel to a right rhombic prism, with

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[*] From ανθος, *a flower*, and φυλλον, *a leaf.*

angles of 125° 30′ and 54° 30′, which therefore may be considered as the primary figure. It cleaves also parallel to the axis of the prism.

Fracture uneven; lustre pearly, inclining to metallic, particularly on the perfect face of cleavage.

Translucent, sometimes only on the edges; brittle.

Hardness 5 to 5·5; specific gravity from 2·940 to 3·1558.

Before the blowpipe infusible per se. It fuses, though with difficulty, along with borax, and yields a glass coloured by iron.

We have three analyses of this mineral, one by Vopelius, one by Leopold Gmelin, and one by me. The results of which are as follow:

Silica,	56·74	56	57·12
Protoxide of iron,	13·94	13	13·52
Magnesia,	24·35	23	25·92
Protoxide of manganese,	23·8	4	—
Lime,	—	2	1·32
Alumina,	—	3	trace
Water,	1·67	—	1·36
	99·08*	101†	99·24‡

The first three of the constituents are identical in the three analyses. As the others vary, the probability is, that they are not essential to the constitution of the mineral.

In Vopelius's analysis, the bases are rather less than half the atoms of silica, but in Gmelin's they are rather more, and in mine almost exactly half. The mean of the three gives us very nearly the atoms of silica to those of the bases, as 2 to 1. Hence it is evident, that the mineral is composed of bisilicates. The atoms of oxide of iron are to those of magnesia very nearly as 1 to 3. We may therefore consider anthophyllite as composed of

3 atoms bisilicate of magnesia,
1 atom bisilicate of iron.

Sp. 35. *Mellilite.*§

This mineral was discovered by M. Fleuriau de Bellevue, at Capo del Bove, in the environs of Rome.

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* Vopelius; Poggendorf's Annalen, xxiii. 355. † Gmelin, ibid. p. 358.

‡ Constituents of a specimen in my cabinet analyzed by me. The specimen was I believe from America, and very characteristic.

§ Hauy's Mineralogie, iv. 504. Mohs' Mineralogy, iii. 125. The name of the mineral is derived from *mel, honey,* on account of its colour.

Colour honey yellow.

It occurs in small square prisms having their edges mostly replaced by tangent planes. The crystals are so small that their shape can only be seen distinctly by means of a microscope.

According to Fleuriau, it is hard enough to strike fire with steel. Opaque.

Before the blowpipe it melts with effervescence into a transparent glass.

Its powder when put into nitric acid is converted into a fine transparent jelly.

Its constituents, as determined by Carpi, are

		Atoms.
Silica,	38·0	19
Lime,	19·6	5·6
Magnesia,	19·4	7·76
Alumina,	2·9	1·28
Oxide of iron,	12·1	2·42
Titanic acid,	4·0	0·76
Oxide of manganese,	2·0	0·44
	98·0	

The atoms of silica and titanic acid amount together to 19·76; while those of the bases are 17·5. It is clear from this, that a portion of these bases must be in the state of a bisalt, or combined with two atoms of acid. If we leave out the titaniate as foreign, the constitution of the mineral is probably

3 atoms silicate of magnesia,
2 atoms silicate of lime,
1 atom bisilicate of iron,

The formula will be $3\mathrm{MgS}+2\mathrm{CalS}+\underline{\mathrm{f}}\mathrm{S}^2$.

Sp. 36. *Mountain Cork.*

This mineral occurs occasionally in primary rocks. Though it bears some resemblance to mountain leather, yet its constitution is quite different.

Colour light buff; composed of very fine fibres, only to be distinguished by means of a microscope.

Soft enough to be indented by the nail.

Lustre silky; nearly dull; opaque; tough; specific gravity 2·442.

Before the blowpipe fuses into a black glass. When heated to redness it loses 1·2 per cent. of its weight, and becomes dark nut brown. Its constituents after ignition, are

		Atoms.
Silica,	51·75	25·87
Lime,	14·05	4·61
Magnesia,	10·85	4·34
Protoxide of iron,	18·90	4·20
Protoxide of manganese,	1·85	0·41
Alumina,	1·95	0·86
	99·35	

If we leave out the alumina, the atoms of silica are twice the atoms of the bases. It is evident from this that the mineral consists of bisilicates, and they approach

1 atom bisilicate of lime,
1 atom bisilicate of magnesia,
1 atom bisilicate of iron,

The formula is obviously $CalS^2+MgS^2+\underline{f}S^2$.

It therefore approaches pyroxene in its constitution; and will be reckoned a pyroxene by those chemists who embrace the doctrine of isomorphism.

Sp. 37. *Hydrous Anthophyllite.*

I received the mineral which was distinguished by this name from Dr. Torrey of New York. Its locality was the neighbourhood of New York.

Colour greenish yellow.

Texture diverging fibrous. The whole specimen consisted of a series of plates or very imperfect crystals diverging from various centres, or it was what Werner denominated scopiform. The fibres could be separated from each other, but much more imperfectly than those of asbestus. They were fine, but easily broken, and utterly destitute of elasticity.

Lustre silky; opaque; sectile; feel soft.

Hardness 2·5; specific gravity 2·911.

Its constituents, according to my analysis, are

		Atoms.	
Silica,	54·980	27·49	39·69
Magnesia,	13·376	5·35	7·75
Peroxide of iron,	9·832	1·97	3·85
Protoxide of manganese,	1·200	0·26	0·38
Potash,	6·804	1·13	1·63
Alumina,	1·560	0·69	1
Water,	11·448	10·17	14·73
	99·200		

If we consider the alumina and protoxide of manganese as accidental ingredients, the constituents are in the state of tersilicates, and nearly in the following proportions:

4 atoms tersilicate of magnesia,
2 atoms tersilicate of iron,
1 atom tersilicate of potash,
7½ atoms water.

The formula is $4MgS^3+\underline{f}S^3+KS^3+7\frac{1}{2}Aq$.

The three following minerals do not belong to the tribe of zeolites, but they are placed here on account of the water which they contain.

GENUS IX.—ALUMINUM.

It is scarcely necessary to observe, that hitherto aluminum has not been met with in the mineral kingdom, but only its oxide *alumina*, which possesses the properties of a base or alkaline substance. It is a much more abundant constituent of the earth in this state than any of the other bases; for there are few rocks into which it does not enter as an ingredient.

The number of mineral species into which alumina enters as the most abundant base, amount to about 138. In consequence of this great number of species, it will be of importance to subdivide the genus, and an obvious chemical division suggests itself, founded on the relative simplicity of the constitution of the aluminous minerals. This subdivision is as follows:

Section 1. Alumina pure or combined with a base.
2. Simple salts of alumina.
3. Double anhydrous aluminous salts.
4. Double hydrous salts soluble in water.
5. Double hydrous aluminous sulphates and phosphates insoluble in water.
6. Double hydrous aluminous silicates, or zeolites.
7. Triple aluminous salts.
8. Quadruple aluminous salts.

We shall describe the mineral species belonging to each of these sections in succession.

Section 1. *Alumina pure or combined with a base.*

This section contains 6 species of aluminous minerals; namely,

1 Sapphire,
2 Spinell,
3 Automalite or Gahnite,
4 Sapphirine,
5 Candite,
6 Dysluite.

The first of these when pure is composed of alumina in a crystallized state. In the other six the alumina acts the part of an acid, being combined with a base. In spinell the base is magnesia, in automalite it is oxide of zinc. In ceylanite (a subspecies of spinell), it is magnesia and oxide of iron. In sapphirine and candite it is magnesia and oxide of iron, and in dysluite it is oxide of zinc, oxide of iron, and oxide of manganese. It is curious, that the crystalline form of all the minerals in which alumina acts the part of an acid, so far as it has been observed, is the regular octahedron.

Sp. 1. *Sapphire.**

Oriental amethyst, corundum, diamond spar, emery, telesia, oriental topaz, salamstein, asteria of Pliny.

There are two varieties of this mineral, which were long considered as constituting distinct species; namely, *sapphire* and *corundum*. The *sapphire* constitutes the precious stone, formerly distinguished by the names of *oriental ruby*, *sapphire*, and *topaz*. The *corundum* is commonly grey, or brown, or red, and being opaque and destitute of beauty, cannot be employed as a precious stone; though in other respects it agrees with the first variety. It was at last discovered, that the chemical composition and crystalline form of the two are identical. This induced mineralogists to class them under one species.

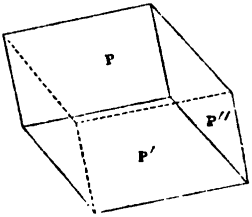
The colour of sapphire varies considerably. When *red*, it is called by jewellers *ruby*; when *blue*, *sapphire*; when *yellow*, *topaz*; when *green*, *emerald*; and when *violet*, *amethyst*.

It is harder than any other mineral except the diamond, and in the table of hardness, that of sapphire is denoted by 9.

It occurs crystallized, and the primary form is an acute rhomboid.

P on P′ 86° 4′

The lateral edges of this rhomboid are frequently replaced by planes parallel to the perpendicular axis of the rhomboid. When these new faces increase so much in size as to obliterate



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* Theophrastus employs the word *σαπφειρος*, and Pliny describes the *sapphirus*; but it is obvious from his description that the name was applied to a very different stone; seemingly the *lapis lazuli*.

the primary faces, a regular six-sided prism is produced, which is the common form of the corundum. Not unfrequently the terminal solid angles of the rhomboid are replaced by six planes. These often increase so as to obliterate the primary faces, in which case a dodecahedron is produced, consisting of two six-sided pyramids applied base to base. These pyramids differ in their lengths and in their angles.

Structure foliated, but this is more evident in the corundum than in sapphire.

Fracture conchoidal, uneven.

Lustre vitreous; transparent to opaque.

Refracts doubly.

Specific gravity 3·9511.

The first good analysis of this mineral was by Klaproth in 1795. He states its constituents to be

Alumina, . . .	98·5
Oxide of iron, . .	1·0
Lime, ...	0·5
	100·0[*]

But the alumina actually found by him was only 95·08. For he converted it into alum crystals, which weighed 85·6, and of course contained 95·08 alumina. There was therefore a loss in his analysis of 3·42 per cent.

Chenevix[†] analyzed both the precious stone and corundum in 1802. The following table shows the results of his investigations.

	Blue Sapphire.	Red Sapphire.	Corundum from					
			Carnatic.	Malabar.	China.	Ava.	China.	Bengal.
Alumina, . .	92	90	91	86·5	86·9	87	89·5	84
Silica, . . .	5·25	7	5	7	5·25	6·5	5·5	6·5
Oxide of iron, . .	1	1·2	1·5	4	6·5	4·5	1·25	7·5
	98·25	98·2	97·5	97·5	98·65	98	96·25	98

But there is reason to suspect, that the silica found by Chenevix was at least chiefly abraded from the agate mortar, in which the mineral was pounded. For Dr. Thomas Muir, at my request, analyzed a very fine white crystal of this species having the form of a six-sided prism, and found it composed of pure alumina. For the silica found was only 1·54 per

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Beitrage, i. 81.

[†] Phil. Trans. 1802, p. 327.

cent., which was just the quantity that had been abraded from the mortar. From this analysis we are entitled to conclude, that pure colourless sapphire is composed of alumina and nothing else.

The sapphire has been occasionally found in the sand of rivers. The finest specimens came from Pegu, where they occur in the Capelan mountains near Syrian. It has been found also at Hohenstein in Saxony, at Biblin in Bohemia, and at Puy in France. The corundum occurs in imbedded crystals in a rock which consists, according to Count Bournon, of Indianite, and contains felspar, fibrolite, several varieties of augite, and also octahedral iron ore. The hair brown or reddish brown varieties, are called *adamantine spar*. They occur with fibrolite and octahedral iron ore in a sort of granite containing no quartz.

The substance called *emery*, which is brought to this country from the island Naxos in the Archipelago, is considered from its composition and hardness, to be a variety of this species.

Its colour is grey; its lustre shining and adamantine; its fracture small grained uneven, or sometimes splintery. It is opaque, and so hard that it scarcely yields to the file. Specific gravity about 4. Reduced to a fine powder it is much used for polishing hard bodies. Its constituents, according to the analysis of Mr. Smithson Tennant, are

Alumina, . . .	86
Silica, . . .	3
Oxide of iron, . .	4
	93[*]

Sp. 2. *Spinell.*

Balass ruby, spinell ruby, ceylanite, pleonast, rubicelle, almandine ruby.

This mineral had been long employed by the jewellers; but it was first distinguished as a peculiar species by Romé de Lisle.

Its colour is most commonly *red;* but it is found also *blue*, and not unfrequently of a fine *green*. It occurs also yellow, brown and black. Sometimes nearly white.

Its crystals are regular octahedrons. Sometimes the edges are replaced by tangent planes. It occurs also in dodecahe-

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[*] Phil. Trans. 1802, p. 400.

drons with rhomboidal faces, the figure which it assumes when the planes replacing the edges become so large as to obliterate the primary faces of the crystals. Sometimes the octahedral and dodecahedral faces occur together, while at the same time each solid angle of the primary octahedron is replaced by four planes.

Fracture conchoidal; lustre vitreous, sometimes splendent, sometimes dull; varies from transparent to opaque.

Hardness 8; specific gravity of the red transparent variety 3·523; of the black opaque variety, called ceylanite, 3·575.

Before the blowpipe per se undergoes no alteration. With borax fuses slowly into a transparent glass with little colour. Fuses also with difficulty in biphosphate of soda. Does not fuse, but swells up with carbonate of soda.

The following table exhibits the constituents of this mineral according to the most modern and best analyses hitherto made:—

	*	†	‡	§	‖
Silica, . . .	—	5·48	5·620	5·596	2
Alumina, . .	82·47	72·25	73·308	61·788	68
Magnesia, . .	8·78	14·63	13·632	17·868	12
Protoxide of iron, .	—	4·26	7·420	10·564	16
Lime, . . .	—	—	trace	2·804	—
Chromic acid, . .	6·18	1·83[¶]	—	—	—
Water, . . .	—	—	—	0·980	—
	97·83	98·45	99·980	99·6	98

The specimen of spinell which I analyzed was in pure transparent crystals of a fine green colour. Its atomic constituents are,

		Atoms.
Silica, . .	2·81	. 0·51
Alumina, . .	32·13	. 5·9
Magnesia, . .	5·45	. 1
Protoxide of iron,	1·65	. 0·3

It is probable that the protoxide of iron is in combination

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[*] Red transparent spinell. Vauquelin, Jour. des Mines, vii. 1.

[†] Berzelius.

[‡] A dark green variety from the United States. By my analysis.

[§] Black spinell or ceylanite from the United States. By my analysis.

[‖] Ceylanite analyzed by Collet Descotils. Ann. de Chim. xxxiii. 11.

[¶] Undetermined matter.

with the silica, and only an accidental constituent, as it is not always present. If the magnesia and alumina be the essential constituents, as is probable, then spinell is a compound of

6 atoms alumina,
1 atom magnesia.

It was shown long ago by Chenevix, that alumina and magnesia have a strong affinity for each other. If we throw down a mixture of alumina and magnesia dissolved in muriatic acid by caustic ammonia, the precipitate after being washed and dried will be found to contain both alumina and magnesia. If we digest it in muriatic acid after ignition, there will remain a white insoluble powder composed of six atoms alumina and one atom of magnesia, and consequently analogous to spinell.

The atomic proportions of ceylanite, deduced from my analysis, are as follow:—

		Atoms.
Silica,	2·79	0·6
Alumina,	27·45	6
Magnesia,	7·15	1·56
Protoxide of iron,	2·34	0·51

The silica and protoxide of iron seem to be united atom to atom. But the atoms of alumina are to those of magnesia as 4 to 1. It seems clear from this, that ceylanite constitutes a species different from spinell. If the magnesia and alumina are the only essential constituents, then it is a compound of

4 atoms alumina,
1 atom magnesia.

If the silicate of iron be also essential, then it is

2 atoms quater aluminate of magnesia,
1 atom silicate of iron.

And the formula will be $2MgAl^4+\underset{.}{f}S$.

The finest crystals of spinell come from Ceylon, where they occur in alluvial deposites. In Sweden spinell is scattered through a primitive limestone. It is similarly situated in North America.

It must not be concealed that the analyses of spinell and ceylanite, lately published by Hermann Abich,* differ considerably in their result from those on which I have founded my opinion respecting the constitution of this mineral. The spinell was found by him composed of

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* Poggendorf's Annalen, xxiii. 305.

	*	†
Silica,	2·25	2·02
Alumina,	68·94	69·01
Magnesia,	25·72	26·21
Protoxide of iron,	3·49	0·71
Protoxide of manganese,	trace	—
Oxide of chromium,	—	1·10
	100·40	99·05

He ascribes the different results of preceding chemists to their not having taken into account the silica abraded from the agate mortar during the process of pulverizing. It is obvious at a glance that the quantity of magnesia relatively to the alumina is doubled. For the atomic constituents of red spinell are

		Atoms.
Silica,	1·01	0·09
Alumina,	30·67	2·92
Magnesia,	10·5	1
Protoxide of iron,	0·15	0·01
Oxide of chromium,	0·55	0·05

If we neglect the other constituents as insignificant and inconstant, the composition of red spinell will be

3 atoms alumina,
1 atom magnesia.

We have four analyses of ceylanite by the same chemist, made apparently with every attention to accuracy. The results of these analyses will be seen in the following table:—

	‡	§	‖	¶
Silica,	2·50	1·23	2·38	1·79
Alumina,	65·27	68·79	67·46	59·66
Magnesia,	17·58	23·61	25·94	17·70
Protoxide of iron,	13·97	8·07	5·06	19·29
Oxide of chromium,	—	—	—	0·73
Protoxide of manganese,	—	—	—	trace
	99·32	102·80	100·84	99·17

From the great variation in the quantity of protoxide of

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* Blue spinell from Aker, in Sweden.

† Red transparent spinell, from Ceylon.

‡ Ceylanite from the Ural.

§ Ceylanite from Monzoni.

[illegible]om Vesuvius.

¶ Ceylanite from Iserweisc.

iron, we can hardly consider it as an essential constituent; though undoubtedly the mineral is indebted to it for its black colour. The atomic constituents of the third variety, which is the freest from iron, are as follow:—

	Atoms.
Silica, . . .	1·19
Alumina, . .	30
Magnesia, . .	10·37
Protoxide of iron, .	1·12

It is obvious at a glance that it consists of

3 atoms alumina,
1 atom magnesia,

and is therefore, according to Abich's investigations, chemically the same as spinell.

Sp. 3. *Automolite*,* *or Gahnite.*

This mineral was discovered in 1805, by Assessor Gahn, in Eric Matt's mine, near Fahlun, where it is interspersed in small crystals in a talc slate. Its constitution was ascertained in 1806, by Ekeberg.†

The colour is a dark dirty green; streak white.

It is always crystallized either in regular octahedrons, or in the *octoedne transposé* of Hauy. So that it has the same crystalline shape as the spinell.

Cleaves parallel to the faces of the regular octohedron.

Cross fracture conchoidal; opaque, or only translucent on the edges.

Hardness 7·25; but very easily frangible.

Specific gravity, as determined by Ekeberg, 4·261. When heavier it contains, interspersed, galena; when lighter it is not free from a mixture of talc.

Infusible per se before the blowpipe. With borax it fuses with difficulty into a clear glass, greenish while hot, but colourless when cold. With biphosphate of soda it fuses into a clear glass bead. With carbonate of soda it does not enter into fusion.

Besides the original analysis of this mineral by Ekeberg, we have an analysis of it by Vauquelin, and two by Abich.

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[*] From αυτομολος, a deserter. Named on account of the presence of oxide of zinc in a mineral not resembling an ore.

[†] Afhandlingar, i. 84.

The following table exhibits the result of these researches:

	*	†	‡	§
Silica, ...	4·75	4	3·84	1·22
Alumina, . . .	60	42	55·14	57·09
Magnesia, . . .	—	—	5·25	2·22
Oxide of zinc, . .	24·25	28	30·02	34·80
Protoxide of iron, .	9·25	5	5·85	4·55
Sulphur, . . .	—	17	—	—
Undecomposed, . .	—	1	—	—
	98·25	97	100·10	99·88

In these analyses, the silica, magnesia, and even oxide of iron, differ so much from each other that we can hardly consider them as essential ingredients. Ekeberg's analysis gives us the atomic ratio of the alumina to the oxide of zinc as 6 to 1. But Abich's, which, from the care with which they were made, seem entitled to confidence, give us the atoms of alumina to those of oxide of zinc as 4 to 1.

It is probable, therefore, that in Gahnite, the essential constituents are

4 atoms alumina,
1 atom oxide of zinc.

Sp. 4. *Sapphirine.*

This mineral was discovered by Sir Charles Giesecke, in Greenland, at Fiskenaes or Kikertarsoeitsiak. He sent specimens of it to Stromeyer, who described its characters, and ascertained its composition.

It has a pale sapphire blue colour.

The specimen in my possession (for which I was indebted to the kind liberality of Sir Charles Giesecke), consists of foliated grains interspersed through mica slate, without any distinct crystalline shape.

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[*] Ekeberg, Afhandlingar, i. 84.

[†] Vauquelin, Gehlen's Jour. (second series), ii. 38.

[‡] Abich. Poggendorf's Annalen, xxiii. 332. The specimen analyzed was from Fahlun.

[§] Abich, ibid. The specimen was from the United States. It occurs in a rock composed of quartz, hornblende, calcareous spar, and albite. Abich found a trace of manganese and of cadmium in the American

Lustre vitreous and splendent.

Translucent, at least on the edges.

Hardness 7·75; specific gravity, as determined by Stromeyer, 3·4282.

Before the blowpipe quite infusible, even when heated with borax. Not altered by exposure to a strong red heat.

Its constituents, as determined by the analysis of Stromeyer,[*] are as follow:

		Atoms.	
Silica,	14·507	7·25	3·22
Alumina,	63·106	28·04	12·49
Magnesia,	16·848	6·74	3
Lime,	0·379	0·10	0·04
Protoxide of iron,	3·924	0·87	0·38
Protoxide of mangan.,	0·528	0·12	0·05
Loss by ignition,	0·492		
	99·784		

If the alumina and magnesia were to be considered as the only essential constituents of this mineral, it would be a compound of

4 atoms alumina,
1 atom magnesia.

If the silica be deemed essential, the mineral might be considered as composed of

2 atoms sexaluminate of magnesia,
1 atom tersilicate of magnesia.

Sp. 5. *Candite.*

This is a very hard black massive mineral from Candy, in Ceylon, for the analysis and description of which we are indebted to Dr. C. G. Gmelin, of Tubingen.[†]

The colour is velvet black. It is massive, has a conchoidal fracture, a glassy lustre, and a hardness equal to that of spinell.

Its specific gravity is 3·617.

It is infusible without addition by the blowpipe. With biphosphate of soda it fuses readily into a translucent green glass. With borax it melts and forms a greenish glass. With carbonate of soda it swells up, but does not melt.

Its constituents, as determined by Gmelin, are

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[*] Untersuchungen, p. 391.

[†] Edinburgh Phil. Jour. ix. 384.

		Atoms.	
Alumina,	57·200	25·42	27·84
Protoxide of iron,	20·524	4·56	5
Magnesia,	18·240	7·30	8
Silica,	3·154	1·52	1·66
	99·118		

If we admit the silica to be combined with alumina in the state of silicate of alumina, and to be accidentally present, which is the opinion entertained by Gmelin, then candite is composed of

5 atoms binaluminate of iron,
8 atoms binaluminate of magnesia,

and its formula will be $8MAl^2+5\underline{f}Al^2$.

Sp. 6. *Dysluite.*

This mineral occurs at Sterling, New Jersey, in a dark-coloured limestone, along with octahedral iron ore, and various other minerals. It seems to have been discovered and named about ten years ago, by Mr. Keating. But so far as I have had an opportunity of knowing, no description or analysis of it has been hitherto published. The name *dysluite* was imposed, I presume, in consequence of the difficulty of decomposing this mineral by fusing it with carbonate of soda.

It is scattered through the limestone in small crystals, which have the form of regular octahedrons.

The colour is yellowish brown; and the shade varies somewhat in intensity in different crystals.

Texture foliated; opaque.

Hardness 4·5; specific gravity 4·551.

Lustre splendent and vitreous when the faces of the crystals are smooth, which is generally, but not always the case; easily frangible.

Before the blowpipe it assumes a red colour, which it loses on cooling, and the assay remains unaltered in its appearance. When heated on charcoal it becomes darker coloured, but does not melt. With carbonate of soda it does not fuse; but the soda, while in fusion, has a fine red colour, which it loses on cooling. With biphosphate of soda no fusion. While the biphosphate is in a melted state it has a fine red colour, which changes to a yellow on becoming solid, and when cold the salt resumes its white colour and transparency, the assay remaining [illegible] the centre. In borax it dissolves very slowly.

The bead is transparent, and has a very deep garnet red colour.

The constituents of this mineral, determined by my analysis of it, are as follow:

		Atoms.
Alumina, . .	30·490 .	13·55
Oxide of zinc, .	16·800 .	3·2
Peroxide of iron,	41·934 .	8·38
Protoxide of manganese,	7·600 .	1·69
Silica, . .	2·966	
Moisture, . .	0·400	
	100·22	

The silica was probably accidental, for in some cases I found hardly any traces of it in the mineral. The constituents are obviously

5 atoms aluminate of iron,
2 atoms aluminate of zinc,
1 atom aluminate of manganese.

The constitution of this mineral is not a little remarkable. The alumina, as in all the other species belonging to this section, acts the part of an acid, but it is the only example of a congeries of simple aluminates which has hitherto been met with in the mineral kingdom.

Sect. 2. *Simple Salts of Alumina.*

The minerals belonging to this section amount to 24 species. In them the alumina is united simply to an acid, or to some substance which acts the part of an acid. These acid substances are water, mellitic acid, sulphuric acid, fluoric acid, phosphoric acid, and silicic acid. No fewer than 15 of the 24 species are silicates.

Sp. 1. *Gibbsite,* or Hydrate of Alumina.*

This mineral was discovered by Dr. Emmons, in an iron mine at Richmond, Massachusetts. Its nature was first determined by Dr. Torrey.†

It occurs in irregular stalactites and tuberose masses.

Structure fibrous, fibres radiating from the centre; lustre vitreous, nearly dull.

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* Named from Colonel Gibbs.

† New York Medical and Physical Journal, No. i. p. 68.

Colour white, with a slight shade of green or grey; slightly translucent.

Hardness 2·75; specific gravity, by my trials, 2·091. Dr. Torrey states it to be 2·400.

Before the blowpipe whitens and gives out water, but is infusible.

I found its constituents to be

			Atoms.
Silica,	8·73	4·36	4·39
Alumina,	54·91	24·40	24·51
Peroxide of iron,	3·93	0·78	0·78
Water,	33·60	29·86	30
	101·17		

It is obvious that the atoms of water very nearly correspond with those of the other constituents. Hence it consists of a congeries of hydrates. We may consider the constitution of the mineral as

25 atoms hydrate of alumina,
5 atoms hydrate of silica,
1 atom hydrate of iron.

Probably it exists in a purer state than in the specimen analyzed by me. Dr. Torrey obtained

		Atoms.
Alumina,	64·8	28·8
Water,	36·7	30·8
	99·5	

This approaches

1 atom alumina,
1 atom water.

There is a mineral which exists in considerable quantity on the hill of Beaux, near Arles, which approaches gibbsite very closely in its chemical composition, though it differs in its external characters. It consists of round or amorphous pieces about the size of a pea, agglutinated in a paste of the same nature. The colour is blood red, and the fracture compact and shining. The specific gravity is inconsiderable, though it varies a good deal in different specimens. The constituents, as determined by the analysis of Berthier, are

			Atoms.
Alumina,	52·0	23·11	5
Water,	20·4	18·13	3·92
Peroxide of iron,	27·6		
Oxide of chromium,	trace		
	100·0[*]		

Berthier has shown that the peroxide of iron is only mechanically mixed with the hydrated alumina. It is obvious that the alumina and water are nearly in the proportion of

1¼ atom alumina,
1 atom water.

The probability is that the mineral was originally a simple hydrate of alumina, but that it had lost a portion of its water before it was analyzed.

Sp. 2. *Bihydrate of Alumina.*

This mineral was found in 1786, by M. Lelievre, on the sides of the gallery of a lead mine in the mountain of Esqueme, situated on the left bank of the Oo, in the Pyrenées.

It has a white colour, with sometimes a shade of yellow and apple green in the centre; opaque, or only slightly translucent. It has a resinous fracture; its hardness is 3·25. It adheres to the tongue, and when put into water absorbs the sixth of its weight of that liquid.

Before the blowpipe it is infusible per se, and gives out no phosphorescent light. Nitric and sulphuric acid attack it without the assistance of heat, and convert it into a saline magma. Its constituents, according to the analysis of Berthier, are

			Atoms.	
Alumina,	44·5	19·77	2·63	1
Water,	40·5	36	4·8	1·81
Silica,	15·0	7·5	1	0·37
	100·0[†]			

If we neglect the silica, as probably not chemically combined, the mineral is very nearly a compound of

1 atom alumina,
2 atoms water.

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[*] Ann. des Mines, vi. 531.

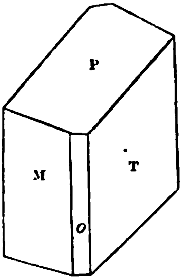
[†] Ann. de Chim. et de Phys. vi. 333.

Sp. 3. *Diaspore,*[*] *or Dihydrate of Alumina.*

This mineral was accidentally found many years ago, by M. Lelievre, in the hands of a dealer, and nothing whatever was known for many years about its locality. Another piece of it came into the possession of Mr. Sowerby of London, in 1822, and he was of opinion that he would be able to discover the place from which it had come,[†] but I am not aware that any thing farther has been published on the subject. Mr. W. Phillips informs us that a third specimen of it is in the mineral cabinet of Mr. S. L. Kent.[‡] Very lately M. Fiedler has announced that the locality of diaspore is a primary limestone not far from Ekatherinburg, in the Marmorbruch, at the back of the Koroibrod.[§]

Colour greenish grey.

Texture foliated and crystallized. The primary crystal, according to the measurement of Mr. Phillips, is a doubly oblique prism, with the following angles:



M on T 65° 0′
P on M 108° 30′
P on T 101° 20′

The plane *o*, though well defined, is not brilliant enough for measurement. It is probably a tangent plane, in which case M on *o* will be 122° 30′.

Lustre vitreous; translucent on the edges; scratches glass; specific gravity 3·4324, according to Hauy.

Before the blowpipe it decrepitates most violently, and splits into many small scaly particles, having the appearance of boracic acid. Berzelius says that these particles restore the blue colour of reddened litmus paper, but Mr. Children did not find this to be the case in the specimen in the possession of Mr. Sowerby. The constituents of diaspore, according to Vauquelin's analysis, are

Alumina, . .	80
Protoxide of iron, .	3
Water, . . .	17·3
	100·3[‖]

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[*] So called from διασπειρω, I disperse, because it divides into small scaly particles before the blowpipe.

[†] [illegible]phy (second series), iii. 433. [‡] Ibid. iv. 17.

[§] [illegible], xx. 322. [‖] Ann. de Chim. xlii. 113.

Mr. Children analyzed another specimen, and states its constituents:

		Atoms.
Alumina,	76·06	33·8
Protoxide of iron,	7·78	1·72
Water,	14·70	13·06
	98·54*	

From the very different proportions of protoxide of iron in the two specimens, it is likely that it is merely an accidental ingredient. Were we to admit the 1·72 atoms of protoxide of iron to be combined with alumina in the ratio of 1 atom oxide to 5 atoms alumina, then the diaspore would consist of

2 atoms alumina,
1 atom water,

or would be a dihydrate. If this supposition be inadmissible, then diaspore must be a compound of

2½ atoms alumina,
1 atom water.

Sp. 4. *Mellate of Alumina*, or *Honeystone*.

Mellite.

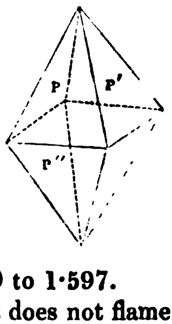
This mineral was discovered a good many years ago, in an earthy brown coal at Artern, in Thuringia, and was first recognised and described as a peculiar species by Werner; but it existed in cabinets, being considered as a variety of amber, at least as early as 1791. Klaproth analyzed it in 1797, and ascertained its nature.

Colour honey yellow, inclining often to red or brown; streak white.

It is always crystallized. Primary form an octahedron, with a square base.

P on P′ 118° 3′
P on P″ 93°

Sometimes all the solid angles of the octahedron are replaced by tangent planes; sometimes the crystal assumes the form of the rhomboidal or garnet dodecahedron.



Hardness 2·75; specific gravity from 1·550 to 1·597.

Before the flame of a candle it whitens, but does not flame. It dissolves in nitric acid, and is decomposed when boiled in water, the alumina being separated nearly pure, and the acid, still retaining a little alumina, being dissolved in the water.

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* Annals of Philosophy (second series), iv. 146.

The constituents, according to the analysis of Klaproth, are

Mellitic acid, .	46
Alumina, . .	16
Water, . .	33
	95*

This is probably equivalent to

1 atom mellitic acid, .	6·5
1 atom alumina, . .	2·25
4 atoms water, . .	4·5
	13·25

If this be the constitution, it is a simple hydrous mellate of alumina.

Sp. 5. *Aluminite.*

Hallite, websterite, trisulphate of alumina.

This mineral was observed many years ago in the environs of Hallé, and about the year 1813, it was detected by Mr. Webster in the chalk rocks at New Haven in Sussex.

Colour snow-white. It occurs in reniform pieces of greater or smaller magnitude.

Fracture fine earthy; dull; streak glistening; opaque; adheres feebly to the tongue; soils very slightly; hardness 2; feels fine, but meagre; specific gravity, as determined by Stromeyer, 1·7054.

We are indebted to Stromeyer for an analysis of three varieties of this mineral, and to Lassaigne for a fourth. The following table exhibits the result of these analyses:

	†	‡	§	‖
Sulphuric acid, .	23·370	23·365	23·554	20·06
Alumina, . .	29·868	30·263	30·807	39·70
Water, . . .	46·742	46·372	45·639	39·94
Sulphate of lime,	—	—	—	0·30
	100	100	100	100

It is obvious that the three specimens analyzed by Stromeyer, are identical, and composed of

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* Beitrage, iii. 116.

† From New Haven, Sussex. Untersuchungen, p. 99.

‡ From Halle on the Saale. Ibid.

§ From Marle near Halle. Ibid.

From Epernay. Lassaigne, Ann. de Chim. et de Phys. xxiv. 97.

1 atom sulphuric acid,
3 atoms alumina,
9 atoms water.

The specimen analyzed by Lassaigne approaches the others in its composition. Though there is an excess of alumina and rather a deficiency of water. The atomic proportions are,

1 atom sulphuric acid,
3·29 atoms alumina,
8·85 atoms water.

Sp. 6. *Sulphate of Alumina.*

This salt occurs in nests in the transition (alum) slate of the Andes. Specimens of it were sent to this country by Sir Ralph Woodford, late governor of Trinidad, and they were put into my hands by the kindness of Charles Macintosh, Esq. of Crossbasket.

Colour white, except where here and there tinged yellow by external impurities.

It is in fine crystalline scales; lustre silky; translucent; specific gravity 1·6606.

It has the astringent and sweet taste of alum, but is rather stronger. Soluble in water.

Before the blowpipe behaves like alum.

Its constituents, determined by a careful analysis, were found as follows:

		Atoms.
Water,	46·375	41·22
Alumina,	14·645	6·51
Peroxide of iron,	0·500	0·10
Soda,	2·262	0·56
Sulphuric acid,	35·872	7·17
Mechanical impurities (being very ferruginous silica,)	0·100	
	99·754	

The sulphuric acid amounts to 7·17 atoms, and the atoms of alumina, soda, and peroxide of iron, are exactly the same. Hence the mineral consists of simple sulphates with a quantity of water. The constituents are as follow:

1 atom sulphate of alumina,
0·07 atom sulphate of soda,
0·0125 atom sulphated peroxide of iron,
6 atoms water.

The quantity of sulphate of soda and sulphated peroxide of iron is so small that it may be overlooked as an accidental impurity. If so, the salt is composed of

1 atom sulphate of alumina,
6 atoms water.

There is a manufacture of alum at Campsie, near Glasgow. The alum is extracted from the shale of the coal beds in the neighbourhood. At first this shale gave alum when simply lixiviated in water. This process had been continued for a number of years, and a great accumulation of washed shale was made in the neighbourhood of the work. It was found that by burning this washed shale it might be made to yield a new crop of alum. In this burnt shale sulphate of alumina makes its appearance in thin bands.

Its colour is greyish white, interspersed with portions having a yellow colour.

Fracture earthy; opaque; friable; specific gravity 1·887.

Taste acid, astringent, and sweet.

When digested in water it dissolves, with the exception of a white powder amounting to 15·31 per cent., and which is a subsulphate of alumina.

When heated it melts somewhat like alum, and gives out pure water. When heated to redness it swells up like alum, and finally leaves a yellowish white porous tasteless matter, nearly similar to what would be left by alum treated in the same way, only making allowance for the colour.

The constituents of this salt were found by analysis to be as follow:—

Insoluble matter 15·31, composed of

		Atoms.
Alumina,	5·11	2·27
Sulphuric acid,	10·2	2·04
	15·31	

The portion dissolved in water consisted of

		Atoms.
Sulphuric acid,	30·225	6·045
Alumina,	5·372	2·38
Peroxide of iron,	8·530	1·70
Potash,	1·172	0·19
Water,	36·295	32·26
	81·594	
Insoluble matter,	15·310	
	96·904	

There is a loss of 3·096 per cent., which I consider as water. For the whole water cannot be separated from sulphate of alumina, without at the same time driving off a portion of the acid.

The atoms of sulphuric acid are 8·085, while those of the bases are only 6·54. Hence 1·54 atoms of the bases must be in the slate bisulphates. The water, if we include the loss, is 35 atoms.

The composition of the salt is very nearly

24 atoms sulphate of alumina,
9 atoms bisulphated peroxide of iron,
1 atom bisulphate of potash,
180 atoms water.

If we leave out the bisulphates, and consider the water as united with the sulphate of alumina, then the constituents of the salt will be

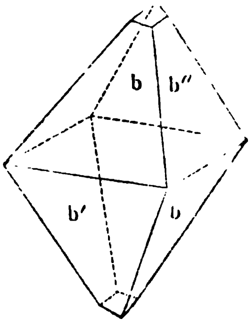
1 atom sulphate of alumina,
7 atoms water.

Sp. 7. *Fluellite*, or *Fluate of Alumina*.

This name was given by Dr. Wollaston to some minute white transparent crystals detected by Mr. Levy on a specimen of Wavellite from Cornwall. The form of the crystal is an acute rhombic octahedron, having its summits replaced by a plane. According to Dr. Wollaston's measurement,

b on b′ 144°
b on b″ 109°
b on b 82°

Hence the primary form may be assumed to be a right rhombic prism the lateral planes of which are inclined to each other at about 105°.



Dr. Wollaston found the index of refraction of fluellite to be 1·47, and that of wavellite 1·52.

He analyzed the mineral on a minute scale, and could detect nothing in it but fluoric acid and alumina. It cannot be a simple fluate of alumina, because that salt is soluble in water. But it may be a difluate of alumina, which Berzelius has shown to be insoluble in water.

Sp. 8. *Tourquois*, or *Trisphosphate of Alumina*.

Calaite, agaphite, johnite, birousa of the Persians.

This mineral has hitherto been found only in Persia, not far from Nichabour, in a mountainous district. Agaphi, the only naturalist who has been on the spot, informs us that the tourquoises occur in thin veins which penetrate the mountain in all directions. We neither know the nature of the mountains nor of the veins in which the tourquoises are found. But they occur either in very thin pieces, or in nodules seldom so large as a nut. They are very much valued by the eastern nations, and the king of Persia is said to reserve all those which have a tolerable size and a good colour for his own use.

Tourquois seems to have been known to the ancients, and is probably the mineral described by Pliny under the name of *calais*.[*] The first tolerably accurate description of it was published by Dr. Fischer of Moscow.[†] Fossil bones coloured by copper had been distinguished by the same name, though they are essentially different.

Colour a peculiar bluish green very pleasant to the eye. It is this colour which gives the mineral its value.

Fracture small conchoidal, sometimes splintery, sometimes uneven.

Lustre dull, or merely glimmering. It admits of a polish, but even then the lustre is inconsiderable. It is vitreous.

Opaque; sometimes, though rarely, translucent on the edges.

Rather softer than quartz; powder white; specific gravity from 2·6296 to 3·25. It is evident from this that various substances are at present confounded under the name of tourquois.

Its constituents, as determined by the analysis of John, are

			Atoms.
Alumina,	44·50	19·77	3
Phosphoric acid,	30·90	6·86	1·04
Oxide of copper,	3·75	0·75	0·11
Protoxide of iron,	1·80	0·40	0·06
Water,	19·00	16·88	2·56
	99·95[‡]		

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[*] Lib. xxxvii. c. 8.

[†] Annals of Philosophy, xiv. 406.

[‡] Ann. des Mines (second series), iii. 231.

If we omit the small quantity of oxides of copper and iron, the mineral is a compound of

1 atom phosphoric acid,
3 atoms alumina,
$2\frac{1}{2}$ atoms water.

It is therefore a hydrous trisphosphate of alumina.

Berzelius informs us that he analyzed tourquois, and found it to consist of phosphate of alumina, phosphate of lime, silica and oxides of iron and copper.[*] It is probable that the specimen, analyzed by Berzelius, differs essentially from that analyzed by John, as the latter chemist detected neither lime nor silica in his specimen.

Sp. 9. *Andaluzite*,[†] or *Disilicate of Alumina.*

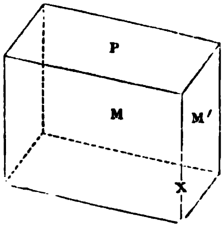
Micaphyllite, Stanzaite.

This mineral was first observed by Count Bournon in a primitive granite mountain in Forez, and described by him in the Journal de Physique for 1789. It was afterwards discovered in Andalusia.[‡] It occurs near Braunsdorf, in Saxony, and in other parts of Germany. Crystals of large size are found in the valley of Lisenz, near Inspruck, in the Tyrol. It has been observed also in the granite near Aberdeen, and in the granite mountains of Glen Malor, in the County of Wicklow, both in crystals and in amorphous masses.

Colour flesh red, passing into pearl grey, also brownish red; streak white.

In the granite of Wicklow it occurs in large amorphous masses, having a brownish red colour and a granular structure. But it is most commonly crystallized. The primary form is a right rhombic prism in which

M on M′ 91° 20′



The edge X is often replaced by two planes, making with each other an angle of 125°. The acute solid angles are also sometimes replaced by one or two triangular planes, making an angle of 140° with the base of the prism. In large crystals the angle M on M′ is not constant. I measured several from Spain an inch in diameter, and several inches in length. M on M′ varied from 92° to

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[*] Ann. des Mines, vii. 223.

[†] Because it was first found in Andalusia.

[‡] Hence the name *andalusite.*

94°. But the faces were not quite smooth, nor he edges of the prisms perfect.

Fracture uneven; lustre vitreous; translucent on the edges.

Hardness 4·25; specific gravity of a specimen from the Linzenz Alps in the Tyrol 3·314; of a specimen from the west of Dublin 3·13.

Infusible before the blowpipe, but becomes covered with white spots. Fuses with extreme difficulty with borax and biphosphate of soda.

Its constituents, as determined by analysis, are as follow:—

	[*]	[†]	[‡]	[§]	[‖]
Silica, . . .	34·000	36·5	32	35·304	30·92
Alumina, . . .	55·750	60·5	52	60·196	64·60
Potash, . . .	2·000	—	8	—	1·75
Protoxide of iron, .	3·375	4·0	2	1·324	—
Protoxide of manganese,	0·625	—	—	—	0·50
Lime, . . .	2·125	—	—	—	—
Magnesia, . . .	0·375	—	—	1·000	0·96
Water, . . .	1·000	—	6	2·032	0·90
	99·25	100·1	100	99·856	99·63

The atomic constituents deduced from my analysis are,

		Atoms.
Silica, . .	17·65 .	1·31
Alumina, . .	26·75 .	2
Protoxide of iron,	0·29 .	0·02
Magnesia, . .	0·40 .	0·08

If we consider the protoxide of iron and the magnesia as silicates, and as accidental ingredients, we see that andaluzite approaches pretty nearly to a compound of

1 atom silica,
2 atoms alumina.

It is therefore a disilicate of alumina.

Sp. 10. *Hydrous Trisilicate of Alumina.*

This mineral was discovered in 1786 by M. Lelievre while

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[*] Brandes, Schweigger's Jour. xxv. 113. The specimen was from the Tyrol.

[†] Bucholz, as quoted by Haidinger, Mohs' Mineralogy, ii. 295.

[‡] Vauquelin, Brogniart's Mineralogie, i. 36.

[§] By my analysis. The specimen was from the Tyrol, and in crystals.

[‖] [illegible] of Dublin, not crystallized. By the analysis of Dr. Covervisiting a lead mine on the mountain Esquerre, in the French Pyrenees. Some years later, (or in 1794,) a substance of the same nature was discovered in the shaft of Stephanus at Schemnitz, in Hungary, the nature of which was determined by Klaproth in 1795. Berthier analyzed the specimens brought by Lelievre from Esquerre in 1810, and found the composition identical with that of the mineral from Schemnitz.

Colour snow-white; it is light; very friable; hardly stains the fingers, but adheres to the tongue; opaque.

The centre has sometimes an apple green colour. It is then translucent, has a resinous lustre, and a hardness of 3·25. When put into water it absorbs the sixth part of its weight of that liquid. When ignited in a crucible it cracks, becomes very friable, and loses rather more than 40 per cent. of its weight.

Before the blowpipe it does not melt, nor emit a phosphorescent light, nor give out a white dust as calamine does. It is attacked even cold by nitric and sulphuric acid, which convert it into a saline magma without crystals.

The following table exhibits the composition of this mineral according to the analyses of Klaproth and Berthier:—

	*	†
Silica,	14	15
Alumina,	45	44·5
Water,	42	40·5
	101	100

The atomic proportions, deduced from Klaproth's analysis, are,

		Atoms.
Silica,	7	1
Alumina,	20	2·86
Water,	37·33	5·33

This approaches pretty nearly

1 atom silica,
3 atoms alumina,
5 atoms water.

It is therefore a hydrous trisilicate of alumina.

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[*] Klaproth, Beitrage, i. 257.

[†] Berthier Ann. des Mines, ii. 476.

Sp. 11. *Scarbroite.**

Hydrous pentesilicate of alumina.

This mineral was first noticed by the Rev. W. H. Vernon. It occurs in a calcareous rock on the coast of Scarborough, between double laminæ of oxide of iron.

Colour pure white; no lustre.

Massive; fracture conchoidal.

Highly adhesive to most surfaces, and polished by the nail.

When breathed upon it emits a strong earthy smell.

When immersed in water neither becomes transparent nor falls to pieces, but gains considerably in weight.

Specific gravity 1·48; easily scratched with a knife.

Its constituents, as determined by the analysis of Mr. Vernon, are as follow:—

		Atoms.
Silica, . .	7·90	. 3·95
Alumina, . .	42·75	. 19
Water, . .	48·55	. 43·15
Peroxide of iron,	0·80	
	100·00	

This approaches pretty nearly

1 atom silica,
5 atoms alumina,
11 atoms water.

It is therefore a hydrous penesilicate of alumina. Its formula will be $Al^5S+11Aq$.

Sp. 12. *Bucholzite*,† or *Anhydrous Silicate of Alumina.*

The first account of this mineral appeared in the twenty-fifth volume of Schweigger's Journal, for the year 1819, written by Dr. Brandes. He had obtained the specimen which he examined from Professor Weiss, and its locality was the Tyrolese Alps. Brandes analyzed it, and published a very imperfect description of it. About the year 1824, I found specimens of it in a collection of American minerals which Mr. Nutall was so obliging as to send me for analysis. The locality was Chester, on the Delaware, south-west from Philadelphia. In 1826, I got larger and better characterized specimens from the same gentleman, which put it in my

[illegible]hical Magazine (second series), v. 178.

[illegible]ucholz, a celebrated German chemist.

power to subject it to analysis, and to draw up a description of it.

Colour greyish white, with a very slight tinge of yellow, not recognisable in every specimen.

Structure fibrous. The fibres are sometimes bent, and when viewed through a microscope, assume the appearance of plates, or imperfect prismatic crystals.

Lustre silky.

Hardness 6; specific gravity 3·193.

I found its constituents,

		Atoms.
Silica, . .	46·40 .	23·2
Alumina, . .	52·92 .	23·52
	99·32	

It is therefore a simple anhydrous silicate of alumina.

The constituents obtained by Brandes are the following:

Silica, . . .	46
Alumina, . .	50
Protoxide of iron,	2·5
Potash, . .	1·5
	100

The American mineral contained no sensible quantity of iron. I did not search for potash. Should any exist, the quantity cannot exceed two-thirds of a per cent., and of course cannot affect the constitution of the mineral.

Sp. 13. *Gilbertite.*[*]

The mineral to which I have given this name was very abundant about thirty years ago in the lode of Stonagwyn, near St. Austle, Cornwall, when it was known by the name of *talc.* I place it here, though scarcely entitled to the name of a simple aluminous salt, on account of its very close connexion with bucholzite.

The mass of gilbertite in the specimens in my possession, is mixed with dark purple fluor spar, and with specks of another mineral, which has the aspect of apatite.

Colour white, with a slight shade of yellow.

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[*] Named from Davies Gilbert, Esq., late president of the Royal Society.

Composed of plates lying irregularly on each other. It has occasionally a certain approximation to a crystalline form; but the exact shape cannot be determined.

Lustre silky; translucent; sectile.

Easily cut with a knife; hardness 2·75.

Specific gravity 2·648.

Its constituents, as determined by the analysis of Captain Lehunt, in my laboratory, are as follow:

		Atoms.	
Silica,	45·155	22·57	8·86
Alumina,	40·110	17·82	7
Lime,	4·170	1·19	0·47
Magnesia,	1·900	0·76	0·3
Protoxide of iron,	2·430	0·54	0·21
Water,	4·250	3·77	1·48
	98·015		

If we allow that the lime, magnesia, and protoxide of iron are in the state of bisilicates, then gilbertite will be a compound of

7 atoms silicate of alumina,
1 atom bisilicate of lime, magnesia, and iron,
$1\frac{1}{2}$ atom water.

And the formula will be

$$7AlS+(\tfrac{4\cdot75}{10}Cal+\tfrac{5}{10}Mg+\tfrac{2\cdot25}{10}f)S^2+1\tfrac{1}{2}Aq.$$

The difference between the properties of this mineral and bucholzite is doubtless owing to the presence of this triple bisilicate and the water.

Some years ago I got from Mr. Peneluna, a mineral dealer in Helston, a specimen of a Cornish mineral (locality unknown), which is intimately connected with gilbertite, if it be any thing else than a variety of that mineral.

Colour snow-white.

Structure foliated, composed of small plates diverging from a centre.

Lustre pearly, splendent; slightly translucent on the edges.

Hardness 2·25; specific gravity 2·801.

Before the blowpipe does not fuse, but it assumes a vitreous lustre. With carbonate of soda fuses into an opaque bead, yellow while hot, but becoming white on cooling. With borax fuses slowly into a translucent glass, leaving silica floating through it. With biphosphate of soda the same, but the fusion is very imperfect. Its constituents, on analysis, proved to be

		Atoms.	
Silica,	47·796	23·89	21·43
Alumina,	32·616	14·49	13·00
Magnesia,	1·600	0·64	0·57
Protoxide of iron,	5·176	1·15	1·03
Soda,	9·232	2·31	2·07
Water,	4·000	3·55	3·11
	100·420		

This is equivalent to

13 atoms silicate of alumina,
2 atoms bisilicate of soda,
1 atom tersilicate of iron,
½ atom bisilicate of magnesia,
3 atoms water.

The formula will be

$$26AlS+4NS^2+2\underline{f}S^3+MgS^2+6Aq.$$

We see that the greater part of the mineral (as is the case with gilbertite), is silicate of alumina. The other salts differ from those in gilbertite. Is it not probable that gilbertite in a state of purity, would be merely a hydrous silicate of alumina?

Sp. 14. *Hydrous Bucholzite.*

I give this name to a mineral which I found in possession of Charles M'Intosh, Esq., of Crossbasket. Unfortunately we are quite ignorant of the locality, except that it was brought from the island of Sardinia.

Colour light bluish green; streak white; powder white.

Structure granular, being composed of small scales; brittle.

Lustre vitreous; translucent.

Hardness 3; specific gravity 2·855.

Before the blowpipe becomes snow-white, and falls into powder, from the loss of water.

With carbonate of soda effervesces, and forms slowly an opaque white frit; or an enamel, if the quantity of soda be more considerable. With borax it fuses immediately into a transparent bead, leaving a portion of silica undissolved. With biphosphate of soda it effervesces and melts into a globule, transparent and colourless while hot, but becoming opal coloured, and cracking in every direction when cold.

Its constituents were found to be as follow:

			Atoms.
Silica,	41·35	20·67	5
Alumina,	49·55	22	5·32
Sulphuric acid,	2·01	0·40	0·09
Lime,	1·105	0·31	0·07
Water,	4·85	4·31	1·04
	98·865		

If we allow for a little sulphate of lime, undoubtedly accidental, and a small excess of alumina, the constitution of the mineral is

5 atoms silicate of alumina,
1 atom water.

Hence the formula is $5\mathrm{AlS}+\mathrm{Aq}$.[*]

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[*] I think it exceedingly probable that the mineral discovered by Nordenskiöld, in a granite rock, at Helsingforss, in Finland, and to which he gave the name of *pyrargyllite*, is nothing else than an impure specimen of hydrous bucholzite. It is described as sometimes black, light, and shining, like sordawalite; and sometimes bluish, granular, and destitute of lustre. It sometimes occurs in pieces which have the aspect of a four-sided prism, with the edges truncated. It is often penetrated by scales of chlorite. Its specific gravity is 2·505. Its hardness from 3 to 3·5. Muriatic acid decomposes it completely. Its constituents, according to the analysis of Nordenskiöld, are:

		Atoms.
Silica,	43·93	21·96
Alumina,	28·93	12·85
Protoxide of iron,	5·30	1·18
Magnesia, with some manganese,	2·90	1·16
Potash,	1·05	0·17
Soda,	1·85	0·46
Water,	15·47	13·75
	99·43[*]	

This is equivalent to

1 atom protoxide of iron, magnesia, potash, and soda,
4·3 atoms alumina,
7·39 atoms silica,
4·66 atoms water.

So that the mineral consists of

4·3 atoms silicate of alumina,
4·66 atoms water,
1 atom tersilicate of iron, magnesia, potash, and soda.

[*] Berzelius' Jahr-Bericht, 1833, p. 174.

Sp. 15. *Halloylite.*

This mineral was first observed by M. Omalius d'Halloy, at Angleure, where it occurs in nodules, amid the collection of ores of iron, zinc and lead, which fill the cavities in the transition limestone of that country.

Halloylite is compact, and has a white colour; fracture conchoidal; lustre waxy. Soft enough to be scratched by the nail; slightly translucent on the edges; adheres strongly to the tongue.

When small pieces of it are put into water they become transparent, like the hydrophane, air is disengaged, and the weight is increased about a fifth part.

When calcined it loses from 26·5 to 28 per cent. of its weight, and becomes milk-white. When dried, but not calcined, it rapidly absorbs water when plunged into that liquid, or left in a humid atmosphere.

It is rapidly decomposed by sulphuric acid, which dissolves the alumina, and leaves the silica in a gelatinous state. Berthier analyzed it, and found its constituents as follow:

			Atoms.
Silica,	39·5	19·75	4
Alumina,	34·0	15·11	3·05
Water,	26·5	23·55	4·79
	100·0*		

The constituents are

4 atoms silica,
3 atoms alumina,
$4\frac{3}{4}$ atoms water.

We may perhaps consider halloylite as a compound of

2 atoms silicate of alumina,
1 atom bisilicate of alumina,
4 atoms water.

For when dried on the stove it loses a portion of its water, and retains rather less than 3 atoms, united to 4 silica and 3 alumina.

Sp. 16. *Pholerite.*

This is another hydrous silicate of alumina, which occurs in

Supposing these tersilicates to be foreign (as is probable) to the constitution of the mineral, it will be obviously composed of

1 atom silicate of alumina,
1 atom water.

* Ann. de Chim. et de Phys. xxxii. 332.

the coal formation of Fins (Allier) in France, occupying some fissures in the sandstone, slate, clay and ironstone.

It has a fine white colour, and is formed of small convex scales, having a pearly lustre. It is soft to the touch, and may be crushed between the fingers.

It adheres to the tongue. When plunged into water it disengages some air-bubbles; but does not exhibit the appearance of lenzinite. It forms a paste with water.

When heated it gives out water, but is infusible before the blowpipe per se.

According to the experiments of M. Guillemin,* to whom we are indebted for the only description of pholerite hitherto published, its composition in three different specimens analyzed, was as follows:

Silica,	42·925	41·65	40·750
Alumina,	42·075	43·35	43·886
Water,	15·000	15·00	15·364
	100	100	100

If we take the mean of these three analyses, the atomic constituents will be

		Atoms.
Silica,	20·72	1·54
Alumina,	19·15	1·42
Water,	13·44	1

These numbers approach pretty nearly

$1\frac{1}{2}$ atom silica,
$1\frac{1}{2}$ atom alumina,
1 atom water,

or 1 atom water united to $1\frac{1}{2}$ atom silicate of alumina. The formula will be $1\frac{1}{2}AlS+Aq$.

Sp. 17. *Worthite.*

This mineral was discovered in 1830 by M. Von Wörth, secretary to the mineralogical society of St. Petersburgh, in one of his mineralogical excursions. For the only account of it which I have had an opportunity of seeing, we are indebted to Dr. Hess.†

It has a considerable resemblance to diaspore in its external character.

[illegible]ite and translucent; has a foliated crystalline tex-

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[illegible]es, xi. 489.

† Poggendorf's Annalen, xxi. 73.

ture; but has hitherto been found only in rolled pieces destitute of any regular crystalline shape. Its plates have a lustre similar to that of cyanite. Specific gravity at least 3; hardness 7·25.

When heated in a glass it becomes opaque, and gives out water, which has no reaction on vegetable blues, and when evaporated leaves no residue. With biphosphate of soda there is no distinct action. With borax it dissolves very slowly. With carbonate of soda it effervesces, but the assay does not melt completely in the strongest heat; the soda sinks into the charcoal and leaves a white frit. When moistened with nitrate of soda and strongly heated, it gives a beautiful dark blue.

Its constituents, as determined by the analysis of Dr. Hess, are as follow:

Silica, . . .	40·58	. 41·00
Alumina, . . .	53·50	. 52·63
Magnesia, . . .	1·00	. 0·76
Water, . . .	4·63	. 4·63
Peroxide of iron, . .	trace	
	99·71	99·02

Taking the mean of these two analyses, we have the atomic constituents of the mineral as follow:

		Atoms.
Silica, ...	20·39	. 5
Alumina, . . .	23·58	. 5·78
Magnesia, . . .	0·35	. 0·08
Water, ...	4·11	. 1

This approaches very nearly (including the magnesia with the alumina) to

5 atoms silicate of alumina,
1 atom hydrate of alumina.

Sp. 17. *Cyanite,** or *Subsesquisilicate of Alumina.*

Disthene, kyanite, rhœtizite, sappare.

This mineral was first observed in Aberdeenshire in Scotland. Specimens of it were sent to Saussure by a Scottish mineral dealer, under the name of *sapphire.* Saussure read the name *sappare,* which was the origin of that appellation by which the mineral was at first distinguished. It has been observed only in primary rocks, and usually in mica slate.

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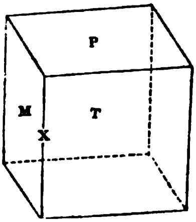
* From *κυανος*, *blue,* on account of its blue colour.

The colour is most commonly white, often passing into blue, sometimes inclining to green or grey. Frequently exhibits spots of Berlin blue elongated in one direction on a paler ground. Streak white.

It is usually crystallized in four or eight-sided prisms, which are mostly terminated irregularly. Its primary form is a doubly oblique prism.



P on M 93° 15′
P on T 100° 50′
M on T 106° 15′

as measured by Mr. W. Phillips on cleavage planes.

The obtuse edge of the prism X, is often replaced by a plane, which makes with M an angle of 140° 55′, and with T an angle of 145° 16′.

Texture foliated; transparent to translucent; hardness 6; specific gravity from 3·618 to 3·675.

Infusible before the blowpipe per se. With borax it fuses slowly into a transparent colourless glass.

It was analyzed by M. T. Saussure,[*] by Laugier[†], and by Klaproth.[‡] But the specimens selected for analysis by Arfvedson, seem to have been purest. He did not succeed in decomposing it by heating it with four times its weight of carbonate of potash, but caustic potash answered the purpose. He analyzed four specimens, the two last of which were from Norway. His results were as follow:[§]

Silica,	34·33	36·9	36·4	37·0
Alumina,	64·89	64·7	63·8	62·5
	99·22	101·6	100·2	99·5

The mean of these four analyses gives

			Atoms.
Silica,	36·66	18·33	1
Alumina,	63·97	28·43	1·55
	100·63		

This is obviously

1 atom silica,
1½ atom alumina.

The formula will be $Al^{1\frac{1}{2}}S$.

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[*] Jour. de Phys. 1793, ii. 13.

[†] Gehlen's Jour. iv. 538.

[‡] Beitrage, v. 10.

[§] Kong. Vetensk. Acad. Handl. 1821, p. 147.

Sp. 18. *Allophane.*[*]

This mineral was first observed about the end of 1815, by Messrs. Riemann and Roepert, at Saalfield in Thuringia. It was described and analyzed by Hoffmann and Stromeyer in 1816.[†] Since that period it has been met with at Sneeberg in Saxony, and in other places.

Allophane lines irregular cavities in a kind of marl. Its colour is commonly a light sky blue; sometimes it is green, brown, or yellow.

Fracture small conchoidal, or approaching to even; lustre waxy and splendent, internally; but externally the lustre is less.

From semi-transparent to translucent; very brittle.

Hardness 3; specific gravity from 1·852 to 1·889.

It has often a thin outer coating which has a greenish or bluish white colour, and is dull. It is occasionally accompanied by blue or green copper ore.

Before the blowpipe it speedily loses its colour and becomes white and opaque, while the flame is tinged green. Its bulk is a little diminished, but it does not melt per se. But by the heat produced by passing a stream of oxygen gas through a spirit lamp, it may be melted into a white opaque glass bead. With borax it fuses, with some frothing, into a transparent and almost colourless glass, having however, a slightly bluish green shade.

Its constituents, as determined by Stromeyer in three successive analyses, are as follow:

		Atoms.	
Silica,	21·922	10·96	3
Alumina,	32·202	14·31	3·91
Lime,	0·730	0·20	0·05
Sulphate of lime,	0·517		
Carbonate of copper,	3·058		
Hydrated peroxide of iron,	0·270		
Water,	41·301	36·71	10·005
	100·000		

The sulphate of lime, carbonate of copper, and hydrated peroxide of iron, are doubtless foreign bodies. We may (includ-

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[*] Probably named from αλλος, *high*, and φαινω, *to shine;* on account of its great internal lustre.

[†] Gilbert's Annalen, liv. 120.

ing the lime with the alumina) consider allophane as composed of

3 atoms silica,
4 atoms alumina,
10 atoms water.

Perhaps the constitution of the mineral may be represented by

2 atoms silicate of alumina,
1 atom disilicate of alumina,
10 atoms water.

The formula will be $2AlS+Al^2S+10Aq$.

If this be the true constitution, perhaps it would have been better to have referred allophane to the section which contains the zeolites or hydrous double salts of alumina.

Sp. 19. *Tuesite*.

This name has been given to a mineral from the new red sandstone on the banks of the Tweed, described and analyzed by my nephew, Dr. Robert D. Thomson.

Colour milk-white; opaque; lustre resinous, nearly dull; sectile.

Hardness 2·5; specific gravity 2·558 to 2·624.

Before the blowpipe assumes a light blue colour and becomes brittle. With carbonate of soda fuses into an opaque mass. With borax or biphosphate of soda fuses into a colourless glass bead.

Its constituents, as determined by the analysis of Dr. R. D. Thomson and Mr. Richardson, are

				Atoms.		
Silica,	44·300	43·80	22·15	2	2	6
Alumina,	40·400	40·10	17·95	1·62	—	—
Protoxide of iron,	—	0·945	—	—	—	—
Lime,	0·755	0·64	0·21	·014	1⅔	5
Magnesia,	0·500	0·55	0·20	·012		
Water,	13·500	14·21	12·	1·08	1	3
	99·455	100·245				

Including the lime and magnesia with the alumina, it is $3AlS+2AlS^{1\frac{1}{2}}+3Aq$.

It makes excellent slate pencils.

Sp. 20. *Nacrite*,[†] or *Anhydrous Bisilicate of Alumina*.

Talcite, earthy talc.

This mineral occurs usually in mica slate, taking the place

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[*] Named from the river Tweed, in Latin *Tuesa*.

[†] Named from its pearly lustre.

of the mica; so that the rock in which it occurs constitutes a mixture of nacrite and quartz. The rock in which *nacrite* occurs at Brunswick, Maine, North America, is a compound of nacrite, granular quartz, and iron pyrites. In the county of Wicklow, it is found crystallized in granite.

Colour silvery white or light greenish white.

It usually consists of small scales which are very soft, flexible but not elastic. In the county of Wicklow it occurs in long four-sided prisms, with angles of about 89° and 91°. These crystals are intermixed with scales of uncrystallized nacrite.*

Lustre splendent, silky; translucent.

Hardness 2·75; specific gravity from 2·788 to 2·793.

After ignition it becomes silvery white; but still retains its splendid lustre.

The following table exhibits the constituents of various specimens of nacrite which have been subjected to analysis.

	†	‡	§
Silica,	64·440	46·000	60·20
Alumina,	28·844	35·200	30·83
Lime,	—	9·608	—
Protoxide of manganese,	—	3·944	—
Protoxide of iron,	4·428	2·880	3·55
Water,	1·000	2·000	5
	98·712	99·632	99·58

The atomic proportions in the crystals which constitute the second analysis in the table, are as follows:

	Atoms.
Silica,	23
Alumina,	11·2
Lime,	2·74
Protoxide of manganese,	0·87
Protoxide of iron,	0·64
Water,	1·77

As neither of the other specimens contain lime or protoxide

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* These crystals were brought to me by Mr. Doran, an Irish mineral dealer, as crystals of Andaluzite. A slight examination showed that they could not be andaluzite, and a chemical analysis ascertained their identity with nacrite.

† The specimen was from Brunswick, Maine. By my analysis.

‡ The crystals from Wicklow. Analyzed by Dr. Short.

§ Yellow earthy talc from Merowitz, analyzed by John. Jour. des Mines, xxiii. 384.

of manganese, there can be little doubt that these bodies in the crystals are accidental. Nor can we admit the iron or water to enter as essential constituents, on account of their great difference in quantity in the various specimens examined. Hence nacrite must consist essentially of silica and alumina, and the proportions are very nearly

2 atoms silica,
1 atom alumina,

or nacrite seems to be a bisilicate of alumina.

Sp. 21. *Fuller's Earth*, or *hydrous Bisilicate of Alumina.*

Walkerde.

This mineral has got its name from being employed by fullers in scouring woollen cloths. It occurs in the green sand and oolitic formations in beds, often of considerable thickness. It varies somewhat in its characters, and probably also in its composition. But that variety, which from its chemical composition I place here, possesses the following characters:

Colour dull greenish grey.

Texture earthy; fracture uneven; opaque; rather tough; sectile; feel soapy; lustre dull; hardness 1; specific gravity 2·4448; adheres very slightly to the tongue. When put into water it falls to powder.

Before the blowpipe fuses into a grey opaque enamel. With carbonate of soda it effervesces and melts into a bead; transparent and nearly colourless while hot, but becoming opaque and buff coloured when cold. With borax it does not unite nor tinge the transparent globule of borax with any colour. With biphosphate of soda it forms an opaque frit, half fused.

Its constituents, determined by my analysis, are as follow:

			Atoms.
Water,	24·95	22·17	2·16
Silica,	44·00	22	2·14
Alumina,	23·06	10·25	1
Lime,	4·08	1·16	0·11
Magnesia,	2·00	0·80	0·07
Protoxide of iron,	2·00	0·44	0·04
	100·09		

If we allow that the lime, magnesia, and protoxide of iron the state of silicates, and if from their small quantity they be considered as only accidental constituents, then the specimen of fuller's earth here described, is a compound of

2 atoms silica,
1 atom alumina,
2 atoms water;

or it is a hydrous bisilicate of alumina. Its formula will be $AlS^2 - 2Aq$.

I received from Dr. Holme of Montreal, in 1833, a mineral, which he informed me constitutes a rock in Magdalen islands, situated in the Gulf of St. Lawrence.

It has a good deal of resemblance to fuller's earth. Its colour is greenish grey, with here and there an admixture of brownish yellow. It is opaque; soft enough to be scratched by the nail; texture earthy; dull; specific gravity 2·517. Its constituents were found to be:

			Atoms.
Silica,	47·65	23·82	5·81
Peroxide of iron,	20·50	4·10	1
Alumina,	17·70	7·84	1·91
Lime,	2·20	0·62	0·15
Water,	11·05	9·82	2·4
	99·10		

This is very nearly

2 atoms bisilicate of alumina,
1 atom bisilicated peroxide of iron,
2½ atoms water.

It is therefore fuller's earth, combined with half an atom of bisilicated peroxide of iron. Its symbol is

$$2AlS + \underset{.}{f}S^2 + 2\tfrac{1}{2}Aq.$$

Sp. 22. *Davidsonite.*

This mineral was discovered by Dr. Davidson, Professor of Natural History in the Marischal College, Aberdeen, in the granite quarry of Rubislaw, near Aberdeen, constituting a detached mass in the granite.

Colour greenish yellow.

Texture foliated; cleaves in the direction of the faces of a four-sided prism, with angles of 86° and 94°. The base of the prism is oblique, and inclined at an angle of about 100°, but it is not smooth enough to admit of accurate measurement.

Translucent; easily frangible; brittle.

Hardness 6·5; specific gravity 2·3629.

Before the blowpipe per se, becomes white, but does not fuse. With carbonate of soda fuses imperfectly into a white enamel. With borax it fuses into a transparent colourless glass, having a silica skeleton in the centre. With biphosphate of soda the same. It is intimately mixed with thin plates of mica, from which it is difficult to free it. Hence the lime, oxide of iron, and magnesia, which are found in variable proportions on analyzing it. When pure the constituents seem to be:

			Atoms.
Silica,	66·59	33·29	2·33
Alumina,	32·12	14·27	1
Water,	1·30		
	100·01		

It is a compound of

2⅓ atoms silica,
1 atom alumina.

Sp. 23. *Lenzinite.*

This mineral was first described and analyzed by John, who named it after Lenzius, a German mineralogist of his acquaintance.* It was first observed at Kall, in Eifeld. It was afterwards found in the neighbourhood of St. Sever, and this variety was described by M. Leon Dufour, and analyzed by Pelletier.† It is this last variety which, from its chemical constitution, is placed here.

It is most commonly met with in amorphous masses, from the size of the fist to that of the head. It is much lighter than limestone, and covered externally with a yellowish brown coating of oxide of iron. Internally it is of a fine dead colour.

It is an opaque, homogeneous, compact substance, having a fine grain, soft and soapy to the touch. It is capable of receiving a polish by being rubbed with the finger.

Specific gravity from 1·8 to 2·1, according to John.

Adheres strongly to the tongue; sectile; fracture conchoidal; dull.

When dipt into water and then held near the ear, it crackles remarkably, but does not split like the argillaceous lenzinite of John.

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* Ann. des Mines, iv. 145.

† Annals of Philosophy (second series), viii. 391.

When heated it becomes hard, but not sufficiently so to scratch glass.

Its constituents, according to Pelletier, are

		Atoms.	
Silica,	50	25	2·55
Alumina,	22	9·77	1
Water,	26	21·95	2·34
	98		

The constituents are

2½ atoms silica,
1 atom alumina,
2⅓ atoms water.

But the specimens of lenzinite analyzed by John were composed of

Silica,	37·5	39
Alumina,	37·5	35·5
Water,	25·0	25
Lime,	trace	0·5
	100	100

The mean of these two analyses give us

	Atoms.	
Silica,	19·12	1·17
Alumina,	16·22	1
Water,	22·22	1·37

This nearly comes to

1 atom silica,
1 atom alumina,
1 atom water;

so that John's lenzinite is a simple hydrous silicate of alumina.

From this it is obvious that either the two minerals are essentially distinct, or lenzinite is not a chemical compound. Indeed, I think there can be little doubt that the *lenzinite* of John is merely a variety of Halloylite.

Sp. 24. *Quatersilicate of Alumina.*

In the year 1826, among a number of minerals sent me from Mexico, there was one which was ticketed "Piedraen Barras? Dipiro de Hauy? De cimophan." This ticket, without giving us any information about the locality of the mineral, gives us the views of the gentlemen who sent it respecting its nature.

Its colour is yellowish white.

Its structure is radiated; for it is composed of imperfect oblique four-sided prisms, diverging slightly, as if from a centre. The surface of the prisms is streaked longitudinally, but no cleavage is perceptible by which information might be got respecting its primary form.

Lustre pearly. When pounded it separates into pearl coloured flakes, having somewhat the appearance of talc; lustre shining.

Opaque, or only very slightly translucent on the edges, when in very thin fragments.

Hardness at present 5; but when it was first put into my cabinet it was softer than calcareous spar, or under 3.

Specific gravity 2·688.

Infusible before the blowpipe per se.

The specimen was much mixed with iron pyrites.

Its constituents were found to be

		Atoms.	
Silica,	72·52	36·26	3·99
Alumina,	20·44	9·08	1
Peroxide of iron,	2·40	0·48	0·05
Water,	3·40	3·02	0·33
	98·76		

The peroxide of iron and water, from the minuteness of their quantity, are probably only accidental ingredients. The mineral is composed of

4 atoms silica,
1 atom alumina,

or it is a quatersilicate of alumina. Its formula will be AlS^4.

Claystone is not unfrequently a quatersilicate of alumina, more or less pure. This will be evident from the following analysis of a specimen from Germany.

Its specific gravity was 2·451. Its constituents were found to be

		Atoms.	
Silica,	72·920	36·46	5·17
Alumina,	15·852	7·04	1
Protoxide of iron,	3·080	0·68	0·09
Lime,	2·000	0·57	0·08
Potash,	0·504	0·08	0·01
Soda,	1·640	0·41	0·06
Water,	4·000	3·55	0·50
	99·996		

It is obviously composed of

1 atom quatersilicate of alumina,
$\frac{1}{4}$ atom quatersilicates of iron, lime, potash and soda.

Sect. 3. *Double Anhydrous Aluminous Salts.*

These saline minerals are very numerous, amounting to no fewer than thirty-seven. They are easily distinguishable from the hydrous double aluminous silicates or *zeolites*, as they have been called, by not frothing when exposed to the action of the blowpipe.

Sp. 1. *Cryolite*, or *Soda Fluate of Alumina.*

This mineral has been hitherto found only at Arksat, an arm of the sea, about thirty leagues from the colony of Juliana Hope, in West Greenland. From this spot it was brought to Copenhagen, where it lay for eight or nine years unnoticed, till it was analyzed by Abilgaard, about the end of the last century.

Colour white, sometimes reddish or brownish; streak white.

It has not been observed in crystals; but it cleaves parallel to the faces of a right rectangular prism, which constitutes its primary form.

Translucent, or semitransparent.

Lustre vitreous, slightly inclining to pearly upon the faces corresponding to the base of the prism; brittle.

Hardness 2·25; specific gravity 2·949.

Melts when held to the flame of a candle.[*]

It was analyzed by Klaproth[†] and Vauquelin,[‡] and more recently by Berzelius,[§] who showed it to be anhydrous. From 100 parts of cryolite he obtained 24·4 alumina, and 101 fused sulphate of soda, equivalent to 44·89 grains of soda. As the mineral is neutral, these bases must be saturated with fluoric acid (the only acid found in it). Hence it is composed of

Fluate of alumina,	37·055
Fluate of soda,	58·915
	96·870

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[*] Hence the name from *κρυος*, *cold*, because it melts like *ice* when applied to the flame of a candle.

[†] Beitrage iii. 207.

[‡] Hauy's Mineralogie, ii. 158.

[§] Kong. Vet. Acad. Handl. 1823, p. 315.

Now this approaches very nearly to
1 atom fluate of alumina,
1 atom fluate of soda.

The fluate of alumina and fluate of soda, when separate, are each soluble in water, but when mixed they combine and become insoluble. Hydrate of alumina, when mixed with fluate of soda in solution, carries off the whole acid and one-half of the soda, leaving the other half in a caustic state.

Sp. 2. *Topaz*, or *Fluosilicate of Alumina.*

Physalite, pyrophysalite.

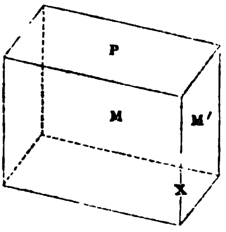
The name *topaz*, derived from an island in the Red Sea,[*] where the ancients used to find topazes, was applied by them to a mineral quite different from the modern topaz. Our topaz they seem to have distinguished by the name of *chrysolite.*

The *topaz* of the moderns is found only in primary rocks; most commonly granite. The finest crystals come from the Uralian and Altai mountains, and Kamschatka; from Brazil, where they usually occur in loose crystals; from Mucla, in Asia Minor. They occur also at Botany Bay, in Germany, in Cornwall, in the mountainous tract at the western extremity of Aberdeenshire, and in the Down mountains, in Ireland.

Colour white,[†] yellow, green, blue; generally pale.

It occurs both massive and crystallized. The primary form of the crystal is a right rhombic prism.

M on M′ 124° 22′, according to the measurement of Mr. W. Phillips. The angles of the base P are usually replaced by tangent planes causing the prism to terminate in a four-sided pyramid. Sometimes the obtuse angles are replaced by two planes, in which case the terminal plane P is not quite obliterated; so that the crystal terminates in a truncated six-sided pyramid. The faces of the prism are usually striated longitudinally. The lateral edges are frequently replaced by one or more planes.



Structure foliated; the foliæ at right angles to the axis of the prism; fracture small conchoidal, or uneven.

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[*] It got its name from τοπαζω, *to seek*, because the island was often surrounded with fog, and therefore difficult to find. See Plinii, lib. 37, c. 8.

[†] The Mina Nova topaz, from Brazil, is as colourless as rock crystal.

Lustre vitreous; from splendent to glimmering, or even dull.

Transparent, to translucent on the edges.

Hardness 8; specific gravity, as determined by Mr. Lowry, 3·641. Haidinger states it at 3·499.

In a strong heat the faces of crystallization, but not those of cleavage, become covered with small blisters, which, however, immediately crack. With borax it melts slowly into a transparent glass. Its powder gives a green colour to the tincture of violets.

Those crystals which possess different faces of crystallization at opposite ends of the crystal, acquire different kinds of electricity at the two extremities, when heated. By friction topaz acquires positive electricity.

The variety called *pyrophysalite*, which occurs at Finbo, three-quarters of a Swedish mile from Fahlun, embedded in gneiss, has a white colour with a slight shade of green. It is found in very large crystals. Its structure is foliated in one direction, and splendent. The cross fracture is uneven and glimmering. It is translucent on the edges. In its other properties it agrees with topaz.

Klaproth first ascertained the true composition of this mineral. It was afterwards analyzed with much care by Berzelius. The following table exhibits the constituents according to the analysis of these chemists:

	*	†	‡	§	‖
Silica, . : .	35	44·5	34·24	34·01	34·36
Alumina, . . .	59	47·5	57·45	58·38	57·74
Fluoric acid, . .	5	7	7·75	7·79	7·77
Oxide of iron, . .	—	0·5	—	—	—
	99	99·5	99·44	100·18	99·87

If we take the mean of Berzelius's three analyses, which correspond so closely with each other, we have the atomic proportions of these constituents, as follow:

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[*] Klaproth, Beitrage, iv. 166. The Saxon topaz.

[†] Klaproth. Ibid. The Brazilian topaz.

[‡] Berzelius, Afhandlingar, iv. 236. The Saxon topaz.

[§] Berzelius. Ibid. The Brazilian topaz.

[‖] Berzelius. Ibid. The pyrophysalite.

		Atoms.
Silica, . .	17·1 .	2·66
Alumina, . .	25·71 .	4
Fluoric acid, .	6·21 .	0·96

The silica is rather less than three atoms; but if we take into account the difficulty of obtaining the whole silica in a mineral containing fluoric acid, and that the amount obtained by Klaproth exceeds that of Berzelius, we may perhaps, without much hesitation, admit that topaz is a compound of

3 atoms silicate of alumina,
1 atom fluate of alumina.

Sp. 3. *Pycnite*, or *Schorlous Beryl.*

Schorlite, stangenstein.

This mineral was originally considered by Werner as a variety of beryl. Hauy united it with topaz; but without sufficient reason. It is found at Altenberg, in Saxony, forming one of the constituents of a rock composed chiefly of quartz and mica. Other localites have been pointed out in Bavaria, Bohemia, France, Norway, and Siberia.

Colour dull yellowish, or reddish white.

It is found in long six-sided prisms, which are striated longitudinally. The prisms are often closely aggregated laterally, and exhibit transverse rents but do not appear to possess a regular structure.

Translucent.

Brittle, and may be easily broken across the prism. This renders it difficult to determine its hardness; but it scratches quartz.

Lustre shining, resinous.

Specific gravity, as determined by Bucholz, from 3·503 to 3·530.

Before the blowpipe on charcoal it does not fuse. With borax it melts slowly into a transparent glass. It becomes electric by exposure to heat.

Its constituents, as determined by the analysis of Berzelius, are as follow:—

			Atoms.
Silica, . .	38·43 .	19·21 .	5·93
Alumina, . .	51·00 .	22·66 .	7
Fluoric acid, .	8·84 .	7·08 ·	2·18
	98·27[*]		

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[*] Afhandlingar, iv. 251.

These atomic proportions correspond with
6 atoms silicate of alumina,
1 atom bifluate of alumina.
Which must therefore be considered as exhibiting the constitution of this mineral.

Sp. 4. *Amblygonite.*[*]

This mineral has been hitherto observed only at Chursdorf, near Penig, in Saxony, where it occurs in a granite along with tourmaline and topaz. It was first recognised as a peculiar species by Breithaupt.

Colour greenish white, passing into light mountain and celandine green; streak white.

It occurs in rhombic prisms of 106° 10′ and 73° 50′, which are rough externally. It cleaves parallel to the faces of the prism with brilliant surfaces. But the position of the base of the prism, whether right or oblique, has not been ascertained.

Fracture uneven.

Lustre vitreous, inclining to pearly.

Semitransparent to translucent.

Hardness 6; specific gravity, as determined by Breithaupt, from 3 to 3·04.

Before the blowpipe it is easily fusible, intumesces, and is converted into a white enamel.

Breithaupt sent a specimen of it to Berzelius, who analyzed it, and in a letter to Breithaupt, says, that it contains 11 per cent. of lithia, and that the other constituents are alumina, and phosphoric acid, with a little fluoric acid;[†] and in his paper on the Mineral System, published in 1824,[‡] he states the constituents to be $L^2P+Al^4Ph^3$. This formula turned into numbers, and using Berzelius's atomic weights, gives us

		Atoms.	
Phosphoric acid, .	35·69	. 7·93	. 1·52
Alumina, . .	25·69	. 11·41	. 2·19
Lithia, . . .	9·11	. 5·20	. 1
	70·49		

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[*] Named probably from *αμϐλυς*, *blunt*, and *γωνη*, *an angle*.

[†] Gilbert's Annalen, lxv. 322.

[‡] Kong. Vet. Acad. Handl., 1824, p. 136.

This is obviously

2 atoms diphosphate of alumina,
1 atom diphosphate of lithia.

Hence the formula will be $2Al^2\dot{P}h+L^2\dot{P}h$.

Sp. 5. *Fibrolite.*[*]

This mineral is found accompanying crystals of corundum in the Carnatic, and is a component part of the granite, which is the matrix of the corundum of China. It was first distinguished as a peculiar species by Count Bournon.

Colour white, or dingy grey.

Texture fibrous. Hence the name.

Cross fracture compact.

Seldom crystallized. But Count Bournon met with it in right prisms with rhombic bases, having angles of 100° and 80°.

Rather harder than quartz.

Specific gravity, according to Bournon, 3·214.

Internal lustre vitreous.

It acquires negative electricity by friction. When two pieces are rubbed they give out a dark red phosphorescent light.

Its constituents, as determined by the analysis of Chenevix, are

			Atoms.
Silica,	38	19	3
Alumina,	58·25	25·88	4·08
Trace of iron.			
	96·25		

These atomic numbers correspond with

2 atoms silicate of alumina,
1 atom disilicate of alumina.

The formula is $2AlS+Al^2S$.

Sp. 6. *Nepheline.*

Sommite, davyne,[†] covellinite, beudontite.

This mineral has been hitherto found only in the cavities of a

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[*] Named by Bournon from its *fibrous* structure.

[†] [illegible] experiments of Mitcherlich it appears, that the davyne of [illegible]elli agrees in the crystalline form, and in its chemical [illegible]heline, if we except the presence of a little chloride [illegible] des Mines (third series), iv. 213.

granular limestone in that part of Vesuvius called Monte Somma, and in the lava of Capo di Bove, near Rome.

Colour greyish, or greenish white; streak white.

It occurs in grains, or in small regular six-sided prisms, of which the terminal edges are sometimes replaced. The regular six-sided prism is considered as the primary form.

Fracture conchoidal; surface smooth and even.

Lustre vitreous; transparent to translucent; brittle.

Hardness 2·5; specific gravity, as determined by Roget and Dumas, 3·270.*

Before the blowpipe on charcoal the edges are rounded off. It yields a colourless and vesicular glass, but cannot be melted into a perfect globule.

Fragments of it thrown into nitric acid lose their transparency and assume a nebulous appearance. This suggested to Hauy the name *nepheline*.†

Its constituents, by the analysis of Arfvedson, are the following:—

		Atoms.	
Silica,	44·11	22·05	4·31
Alumina,	33·73	15	2·93
Soda,	20·46	5·11	1
Moisture,	0·62		
	98·92‡		

This corresponds with

3 atoms silicate of alumina,
1 atom silicate of soda.

The formula is 3AlS+NS.

Sp. 7. *Sodalite.*

Hauyne, noseane, spinellane.

This mineral was discovered by Sir Charles Giesecké at Kanerdluersuk, a narrow tongue of land in latitude 61°, West Greenland, where it occurs in a mica slate. It was afterwards observed on the slope of Mount Vesuvius by Count Borkowsky.

Colour green, greenish white, passing into greyish and snow white; streak white.

Massive and crystallized in rhomboidal dodecahedrons,

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* Annals of Philosophy (second series), iii. 392.

† From νεφιλη, a cloud.

‡ Kong. Vetens. Acad. Handl., 1821. p. 150.

which has been considered as the primitive form. But the sodalite of Vesuvius when crystallized has usually 18 faces; namely, those of the cube (elongated) and those of the dodecahedron; and in some of the crystals all the edges are replaced by tangent planes.*

Fracture conchoidal, uneven.

Lustre vitreous; translucent; brittle; hardness 5·75; specific gravity from 2·295 to 2·378.

Before the blowpipe it melts with intumescence, and the development of air bubbles into a colourless glass bead. With borax it melts with difficulty, and only when added in small proportions.

Soluble in muriatic acid and in nitric acid.

The constituents of this mineral, according to the different analyses hitherto made, are as follow:—

	†	‡	§	‖	¶
Silica,	38·52	36·00	44·87	33·75	50·98
Alumina,	27·48	32·00	23·75	35·50	27·64
Lime,	2·70	—	—	—	—
Protoxide of iron,	1·00	0·25	0·12	—	—
Soda,	25·50	25·00	27·50	26·23	20·96
Muriatic acid,	3·00	6·75	—	5·30	1·29
Volatile matter,	2·10	—	—	—	—
	100·30	100	96·24	100·78	100·87

If we take the mean of Ekeberg's results and my own, we find sodalite is composed of the following atomic quantities:—

		Atoms.
Silica	18·63	3
Alumina,	13·21	2·12
Soda,	6·31	1·01
Muriatic acid,	1·08	0·17

It is obvious that the constituents are

2 atoms silicate of alumina,
1 atom silicate of soda,
$\frac{1}{8}$th atom muriate of alumina.

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[*] See Haidinger's description, Edinburgh Journal, xiii. 222.

[†] By my analysis. Specimen from Greenland.

[‡] Ekeberg. Specimen from Greenland.

[§] Borkowski, Gilbert's Annalen, lxiii. 382. The loss was doubtless muriatic acid. From Vesuvius.

[‖] Arfvedson, Kong. Vet. Acad. Handl., 1821, p. 153. From Vesuvius.

[¶] [illegible]eister, Ann. des Mines, xii. 284.

Probably the last ingredient is only accidentally present. If so, the formula will be $2AlS+NS$.

The mineral analyzed by Wāchtmeister seems to have been a nepheline, or at least to approach the nature of that mineral. Arfvedson's analysis approaches the first two. Borkowski's differs from all the rest.

Sp. 8. *Idocrase.*[*]

Egrane, loboite, vesuvian, wiluite, frugordite.

This mineral was first observed in the lava from Vesuvius and Etna; but it was afterwards found in primary rocks in various parts of the world. That found at Egra, in Bohemia, which is in much larger prisms and less perfectly crystallized, got the name of *egrane*. Nordenskiöld gave the name of *frugordite* to a variety occurring in a lime quarry at Frugord, in Finland.

Colour various shades of brown, passing into leek green, pistachio green, olive green, and oil green; streak white.

It is found occasionally massive, but most commonly crystallized. The primary form is a right square prism. The lateral edges of the prism are frequently replaced by tangent planes, which sometimes increase so much as nearly to obliterate the primary planes of the prism. These new faces make angles of 135° with the primary faces of the prism. The terminal edges of these new faces of the prism are often replaced by new planes making angles of about 127° with these lateral faces. These new faces when they obliterate the base of the prism, constitute a four-sided pyramid with which the prism terminates. But I have never observed this pyramid complete. A portion of the base of the prism always remains.

Lustre vitreous, but often inclining to resinous, especially in the variety called *egrane*; fracture uneven.

Semitransparent to translucent on the edges; refracts doubly.

Hardness 6; specific gravity from 3·349 to 3·399.

Before the blowpipe fuses with ebullition into a yellowish transparent glass.

Idocrase was analyzed by Klaproth,[†] Borkowski,[‡] and

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[*] From ειδω, *I see*, and κρασις, *mixture*. Because its crystalline forms have a considerable resemblance to that of several other minerals.

[†] Beitrage, ii. 32.

[‡] Annals of Philosophy, xv. 146.

Nordenskiöld.* But the most elaborate analyses are those made by Magnus in 1831.† The following table exhibits the result of these analyses :—

	‡	§	‖	¶
Silica, ...	37·359	37·178	38·519	37·658
Alumina, . . .	23·530	18·107	20·063	17·695
Protoxide of iron, .	3·992	4·671	3·420	6·489
Lime, . . .	29·681	35·791	32·411	31·896
Magnesia, . . .	5·208	0·773	2·987	4·537
Protoxide of manganese,		1·495	0·018	0·499
Potash, . . .	—	—	—	trace
	99·770	98·015	97·418	98·774

The mean of these four analyses gives us the following atomic proportions of the constituents :—

	Atoms.
Silica, . .	18·77
Alumina, . .	8·82
Protoxide of iron,	1·03
Lime, . .	9·27
Magnesia, . .	1·10
Protoxide of manganese,	0·15

The bases amount to 20·37 atoms, and therefore exceed the silica by 1·6 atom. But the magnesia and protoxide of manganese vary so much in the different analyses that we cannot avoid considering them as accidental. If so idocrase consists of simple silicates, and including the protoxide of iron along with the alumina, it is obviously

1 atom silicate of alumina,
1 atom silicate of lime.

Its formula is $AlS+CalS$.

Sp. 9. *Grossularite*,** or *Green Garnet*.

This mineral was first observed in Siberia in the year 1790, by Councillor Laxman, during his journey through that

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[*] Bidrag, p. 80.

[†] Poggendorf's Annalen, xxi. 50.

[‡] The specimen was from Vesuvius.

[§] The specimen was from Slatoust in the Uralian mountains.

[‖] The specimen was from the Bannat.

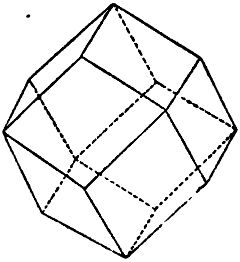
[¶] The specimen was from Egg. The analysis was conducted by fusing the mineral which renders it soluble in acids. It was then dissolved in muriatic acid.

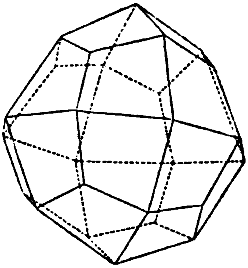
[**] From its resemblance in colour to a green gooseberry.

country, and was first made known to mineralogists by Pallas in the fifth volume of his *New Nordische Beytrage*, published in 1793. It was named by Werner from some resemblance which he fancied he perceived between it and a *green gooseberry*.

Colour asparagus green.

Always in crystals. The primary form, is the rhombic dodecahedron, the faces of which are inclined to each other at angles of 120°. But hitherto that primary form has scarcely been observed in the grossularite. The form which it usually assumes is a twenty-four-sided almost spherical crystal, usually known among mineralogists by the name of *leucite crystal*. It will be obtained when the edges of the primary dodecahedron are replaced by tangent planes, and when these planes increase in size so much as to obliterate the original faces of the primary crystal. In general the original faces are not quite obliterated.





Lustre resinous, dull to shining.

Fracture between conchoidal and uneven.

Translucent.

Hardness 6·75; specific gravity 3·372, as determined by Klaproth, to 3·64, as determined by Trollé Wāchtmeister.

It loses no weight, nor does it change its appearance after ignition. Before the blowpipe thin splinters of it have their edges rounded off, but it does not completely fuse.

The following are the constituents of a specimen of grossularite from Kamtschatka, analyzed by Trollé Wāchtmeister:

		Atoms.
Silica,	40·55	20·27
Alumina,	20·10	8·93
Protoxide of iron,	5·00	1·11
Protoxide of manganese,	0·48	0·10
Lime,	34·86	9·95
	100·99*	

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* Kong. Vet. Acad. Handl., 1823, p. 141.

The atoms of the bases amount to 20·09, while those of silica are 20·27. It is evident from this that grossularite consists of simple silicates. Uniting the protoxide of iron to the alumina it becomes very nearly equal to the atoms of lime. Hence the mineral must be a compound of

1 atom silicate of alumina,
1 atom silicate of lime.[*]

This is precisely the constitution of idocrase. Yet the crystalline shape, and the hardness of the two minerals differ as much as those of arragonite do from calcareous spar.[†]

Sp. 10. *Melanite*,[‡] or *Black Garnet*.

This mineral was observed first at Frescati near Rome, and at Monté Somma near Naples, and was arranged sometimes with garnet and sometimes with tourmalin, till Werner gave it the name of melanite (from its colour), and constituted it a peculiar species. Since that time it has been observed in various other localities, particularly in Bohemia and the United States of America.

Colour velvet black; sometimes inclining to greyish black.

It is usually crystallized. The primary form is the rhomboidal dodecahedron or garnet crystal. But in every specimen which I have seen, the edges of the dodecahedron are replaced by tangent planes, making a twenty-four sided figure similar to that of grossularite.

The lustre is rather inclined to resinous. When the sur-

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[*] Cyprine from Tellemarken, in Norway, is merely a variety of grossularite. Its colour is green, and its specific gravity 3·2278. The colour has been ascribed to copper, but I could not detect a particle of that metal in it. Mr. Richardson analyzed it in my laboratory, and obtained,

		Atoms.
Silica, . .	38·80 .	19·4
Alumina, . .	20·40 .	9·06
Protoxide of iron,	8·35 . .	1·85
Lime, . .	32·00 .	9·14
	99·55	

These numbers approach so nearly to the analysis of Trollé Wächtmeister, that no doubt can exist respecting the identity of the two minerals analyzed.

[†] Were we to adopt the cube as the primary form we might deduce from it the crystals of both species. But the suite of crystals belonging to each is very different.

[‡] From *μελας*, *black*.

face is smooth it is shining, when rough it is dull, or at most only glistening.

Fracture flat and imperfect conchoidal; opaque.

Hardness 6·75; specific gravity from 3·157 to 3·730.

Not altered by ignition. Before the blowpipe the edges are rounded off, but it cannot be fused into a globule. The constituents of a very pure specimen of melanite from Arendal analyzed by Trollé Wāchtmeister, are as follow:

		Atoms.
Silica,	42·450	21·22
Alumina,	22·475	9·99
Protoxide of iron,	9·292	2·06
Protox. of manganese,	6·273	1·39
Magnesia,	13·430	5·37
Lime,	6·525	1·86
	100·445*	

The atoms of the bases amount to 20·67, while the atoms of silica are 21·22. Hence the mineral consists of simple silicates. Of these bases the alumina constitutes very nearly one half. Hence the constituents are

1 atom silicate of alumina,

1 atom ($\frac{23}{46}$ magnesia + $\frac{9}{46}$ oxide of iron + $\frac{8}{46}$ lime + $\frac{6}{46}$ oxide of manganese) combined with one atom of silica. The formula is

$$AlS + (\tfrac{23}{46}Mg + \tfrac{9}{46}\underline{f} + \tfrac{8}{46}Cal + \tfrac{6}{46}\underline{mn})S.$$

The magnesia, oxide of iron, lime, and oxide of manganese, are to each other nearly as the numbers 4, 1$\frac{1}{2}$, 1$\frac{1}{3}$, 1.

Dark reddish brown garnet (what is usually distinguished by the name of *common garnet*) is perhaps a more decided chemical compound than the melanite, and the true type of this species.

Its colour is dark red or reddish brown. Its specific gravity varies from 4·236 to 3·90. It has the regular rhomboidal dodecahedral form which characterizes the garnet. Its constituents, determined by the analysis of Wāchtmeister,† are

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* Kong. Vet. Acad. Handl., 1833, p. 138. Its specific gravity was 3·157.

† Kong. Vet. Acad. Handl., 1823, p. 122.

	*	†	‡
Silica, . .	40·60 .	42·51 .	39·66
Alumina, . .	19·95 .	19·15 .	19·66
Protoxide of iron,	33·93 .	33·57 .	39·68
Protox. of manganese,	6·69 .	5·49 .	1·70
Lime, . .	— .	1·07 .	—
	101·17	101·79	100·70

Taking the mean of these three analyses, we have the atomic proportions of the constituents of common garnet as follow:

	Atoms.
Silica, . .	20·46
Alumina, . .	8·70
Protoxide of iron, .	7·94
Protoxide of manganese,	1·02
Lime, . .	0·30

The atoms of silica are 20·46, while those of the bases amount only to 17·96. Thus there is an excess of 2½ atoms of silica. This excess is probably accidental, for it does not hold with garnets in general. If we include the oxide of manganese along with the oxide of iron, the atoms of oxide of iron are very nearly equal to those of alumina. Hence the constituents of common garnet are

1 atom silicate of alumina,
1 atom silicate of iron.

Sp. 11. *Garnet.*

Precious garnet, almandine, aplome, greenlandite, pyrenaite, carbuncle of the ancients.

This important mineral varies so much in its colour, specific gravity, and chemical constitution, that there cannot be a doubt that it is for the most part a mixture of various minerals having the same crystalline form but a different chemical constitution. The minerals, by the mixture or combination of which it is formed, are three, namely,

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* The specimen from Engsö. The colour dark red, inclining to violet and muddy. Leucite crystal. Specific gravity 4·236.

† From New York. In regular rhombic dodecahedrons. Colour violet red; specific gravity 3·90.

‡ From Fahlun. Colour dark reddish brown. Occurs in very large crystals, weighing sometimes 10 or 12 pounds. Specific gravity 4·2, analysis by Hisinger. Afhandlingar, 4·385.

1 Grossularite, composed of $\mathrm{AlS+CS}$.
2 Common garnet, composed of $\mathrm{AlS+\underline{f}S}$.
3 Colophonite, of . . $\mathrm{CS+\underline{f}S}$.

The consequence of this mixture is, that garnet consists of three different silicates in various proportions; namely,

1 Silicate of alumina,
2 Silicate of lime,
3 Silicate of iron,

And in some cases there is a fourth silicate present, namely,

4 Silicate of manganese.

The colour of the precious garnet (*almandine*, or *greenlandite*) is always red; of the common garnet, reddish, yellowish, greenish, or blackish brown; of pyrope, blood red.

Garnet occurs most commonly crystallized, and the primary form is the rhomboidal dodecahedron, figured in page 261. The edges are often replaced by tangent planes, which produce ultimately the leucite crystal of 24 trapezoidal faces. These two shapes often appear together constituting a crystal with 36 faces.

Structure foliated and the cleavage faces parallel to those of the primary form. Fracture uneven or conchoidal.

Lustre vitreous, in some varieties inclining to resinous.

Transparent to translucent; sometimes opaque or nearly so.

Hardness from 6·5 to 7·5.

Specific gravity from 4·208 to 3·157.

Before the blowpipe it fuses easily into a dark-coloured globule.

A great number of analyses (at least 30) of different varieties of garnet have been made, especially by Trollé Wāchtmeister,* Klaproth,† Bucholz, Hisinger,‡ Rothoff,§ and Laugier;|| but the only conclusion that can be safely drawn from these analyses, is, that garnet is a mixture in various proportions of the three minerals above specified, which having the same primary form, are capable of mixing and of producing crystals, having always the same shape or some modification of it.

Sp. 12. *Essonite.*

Cinnamon stone, kanelstein.

This mineral has been hitherto found only in Ceylon and

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* Kong. Vet. Acad. Handl., 1823, p. 122.

† Beitrage, ii. 16, 22 : v. 168.

‡ Afhandlingar, iv. 385 : ii. 153.

§ Afhandlingar, iii. 324.

|| Hauy's Mineralogie, ii. 538.

the United States. It is usually associated with table spar and quartz, and occurs in primary rocks, most commonly gneiss.

Colour intermediate, between hyacinth red and orange yellow.

It has never been observed in crystals but only in granular masses.

Lustre between vitreous and resinous.

Fracture flat conchoidal; no distinct cleavage perceptible.

Semitransparent to translucent.

Hardness 6·5; specific gravity 3·631.

Captain Lehunt analyzed it several times in my laboratory. The result of his investigations was as follows:

		Atoms.
Silica,	39·826	19·91
Lime,	30·574	8·73
Alumina,	20·141	9·07
Protoxide of iron,	9·459	2·10
	100·000	

The atoms of bases are 19·90, and those of silica 19·91 Hence the mineral consists of simple silicates.

The constituents being the same as in garnet and in the same proportions, it is probable that cinnamon stone is merely a mixture of the three minerals which constitute garnet. If we were to consider it as a peculiar species, it would be

6 atoms silicate of iron,
25 atoms silicate of lime,
26 atoms silicate of alumina;

Or very nearly

1 atom silicate of iron,
4⅙ atoms silicate of lime,
4⅓ atoms silicate of alumina.*

Sp. 13. *Brown Manganese Garnet.*

The locality of this mineral is Franklin, Sussex County, New Jersey. The only specimen which I have seen was sent me by Dr. Torrey from New York.

Colour tombac brown.

Texture granular. The specimen consists of a congeries of imperfect crystals. The crystals have the aspect of four-sided

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* The result of other analyses hitherto made of essonite approaches so

oblique prisms, with angles of about 111° and 69°, terminated by four-sided pyramids.

Hardness 6·75.

Brittle, and very easily frangible.

Lustre resinous, glistening.

Opaque, or only translucent on the edges. Specific gravity 3·829.

I found the constituents

		Atoms.
Silica,	33·716	16·86
Lime,	25·884	7·39
Alumina,	7·972	3·54
Protoxide of iron,	15·840	3·52
Protoxide of manganese,	16·704	3·71
Water,	0·080	
	100·196	

The atoms of the bases are 18·16, while those of silica are only 16·86. This excess makes it possible that one of the bases may be in the state of subsesquisilicate. But if we admit the excess to be accidental, then the mineral will be composed of

2 atoms silicate of lime,
1 atom silicate of alumina,
1 atom silicate of iron,
1 atom silicate of manganese.

It is therefore of a more complicated nature than any of the different garnets hitherto analyzed, and may probably be entitled to rank as a peculiar species.

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near that given in the text, that I did not think it necessary to introduce them. The following table will show the most important of these analyses:

	*	†	‡	§
Silica,	38·8	41·87	40·006	41·24
Alumina,	21·2	20·57	22·996	24·08
Lime,	31·25	33·94	30·573	24·76
Peroxide of iron,	6·50	3·93	3·666	7·02
Potash,	—	—	0·589	—
Magnesia with Manganese,	—	0·39	trace	0·92
Water,	—	—	0·326	0·91
	97·75	100·70	98·156	98·93

[*] Klaproth, Beitrage, v. 138.

[†] Arfvedson, Kong. Vet. Acad. Handl., 1822, p. 87.

[‡] C. G. Gmelin, Edin. Jour. xi. 129.

[§] Nordenskiöld, Bidrag, p. 14.

Sp. 14. *Pyrope.*[*]

Bohemian garnet.

The term *pyrope* was applied by Werner to what had been previously known by the term *Bohemian garnet*, because it occurs in the mountains on the south side of Bohemia, especially Meronitz, Podsedlitz, Chrastian, Trziblitz, and Scheppenthal, where it is imbedded in trap tuff and wacke. A mineral also occurs at Ely, in Fife, in trap tuff, which has been considered as pyrope, though I am not aware that it has ever been subjected either to a rigid mineralogical or chemical examination.

Colour dark blood red, which when held between the eye and the light falls strongly into yellow.

It occurs usually in roundish or angular grains, but it has been found also crystallized; and M. Zippe informs us that M. Moteglek has a regular crystal of it in his museum from the Isergebirge. The primary form is the cube, or at least a right prism with a square base.[†]

No cleavages can be perceived in it.

Fracture conchoidal; streak white.

From transparent to translucent.

Lustre vitreous, slightly inclining to resinous; splendent.

Hardness 7·5; specific gravity 3·78.

It is much more difficultly fusible before the blowpipe than the precious garnet. The bead is black and nearly opaque.

Its constituents, as determined by the analyses of Kobell, and Trollé Wächtmeister, are as follow:

Silica,	42·080	43·70
Alumina,	20·000	22·40
Magnesia,	20·199	5·60
Protoxide of iron,	9·096	11·48
Peroxide of iron,	1·507	—
Protoxide of manganese,	0·320	3·68
Chromic acid,	3·013	7·68
Lime,	1·993	6·72
	98·208[‡]	101·26[§]

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[*] From πυρ, *fire*, and οπτομαι, *I see*. From the peculiar lustre, like *fire*, which it exhibits.

[†] Poggendorf's Annalen, xxvii. 692.

[‡] Kobell, Kastner's Archiv. viii. 447, and ix. 344.

[§] Wächtmeister, Kong. Vet. Acad. Handl., 1825, p. 216.

These two analyses do not correspond. That of Wăchtmeister, being made on the Meronitz pyrope, we have every reason to consider it as exhibiting the constituents of the true pyrope. Now this analysis gives us the following as the atomic proportions of these constituents:

	Atoms.
Silica, . .	21·85
Alumina, . .	9·95
Protoxide of iron, .	2·55
Chromic acid, .	1·18
Lime, . .	1·92
Magnesia, . .	2·24
Protoxide of manganese,	0·81

If we suppose the chromic acid to exist in the mineral in the state of oxide, as is most probable, the atoms of bases will amount to 18·65, while those of the silica are 21·85; so that the atoms of silica exceed those of the bases by 3·23. Hence it is probable that the protoxides of iron and manganese, amounting together to 3·36 atoms are in the state of bisilicates. The atoms of lime, magnesia, and oxide of chromium, approach to half of those of alumina; hence the constitution of pyrope seems to be

10 atoms silicate of alumina,
5 atoms silicates of lime, magnesia, and chromium,
3 atoms bisilicates of iron and manganese.

The magnesia, lime, and oxide of chromium, are to each other nearly as 10, 8, 5; while the oxide of iron to the oxide of manganese nearly as 3 to 1. Hence the formula for pyrope may be

$$10\mathrm{AlS}+5\left(\tfrac{10}{23}\mathrm{Mg}+\tfrac{8}{23}\mathrm{Cal}+\tfrac{5}{23}\underset{\cdot}{\mathrm{C}}\mathrm{hr}\right)\mathrm{S}+3\left(\tfrac{3}{4}\underline{\mathrm{f}}+\tfrac{1}{4}\underline{\mathrm{mn}}\right)\mathrm{S}^2.$$

Sp. 15. *Amphodelite.*[*]

This is a name given by Nordenskiöld to a mineral found by him in the limestone quarry of Lojo, in Finland.

Colour light red.

Its crystalline form resembles that of felspar. It has two cleavages which meet at an angle of 94° 19′. Its fracture resembles that of the scapolite.

Hardness 4·5; specific gravity 2·763. Its constituents, as determined by Nordenskiöld's analysis, are

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[*] Berzelius, Jahresbericht, 1833, p. 174.

		Atoms.
Silica,	45·80	22·9
Alumina,	35·45	15·75
Lime,	10·15	2·9
Magnesia,	5·05	2·02
Protoxide of iron,	1·70	0·37
Water and loss,	1·85	1·64
	100·00	

If we allow for a slight excess of silica, the mineral consists of simple silicates. The formula is

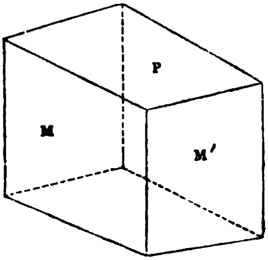
$$3\mathrm{AlS}+(\tfrac{11}{21}\mathrm{Cal}+\tfrac{8}{21}\mathrm{Mg}+\tfrac{2}{21}\mathrm{f})\mathrm{S}.$$

Sp. 16. *Zoisite.*

This mineral was discovered by Baron von Zois,* in Carinthia, partly in a granite, in which the zoisite takes the place of felspar, and partly in a quartz rock, where it is associated with cyanite, garnet, and foliated pyroxene. It was analyzed and described by Klaproth in 1807.†

The colour is usually grey; yellowish, greenish, or bluish grey; and sometimes, it is said, brown. It is always light coloured and the tints are not well defined.

It is usually crystallized in oblique prisms, which are rarely perfect, owing to deep longitudinal striæ. According to Mr. Brooke, the primary form is an oblique rhombic prism.



M on M′ 116° 30′

The face P is oblique but not sufficiently distinct for measurement.

Structure foliated. Lustre pearly, shining; translucent.

Hardness 6·25; specific gravity from 3·320 to 3·3207.

Before the blowpipe it swells up and melts on the edges to a yellow glass. With borax swells and fuses into a diaphanous glass. With biphosphate of soda it is decomposed with effervescence, leaving a silica skeleton. With a very small portion of carbonate of soda, it fuses into a slightly greenish glass. With the usual quantity of that flux, gives an intumescent, white, infusible mass.

The following table exhibits the constituents of this mineral, according to the different analyses hitherto made:

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* Hence the name.

† Beitrage, iv. 179.

	*	†	‡	§	‖
Silica, . . .	45	47·5	40·25	39·300	40·208
Alumina, . .	29	29·5	30·25	29·488	25·588
Lime, . . .	21	17·5	22·50	22·956	23·280
Protoxide of iron, with trace of manganese,	3	4·5	4·50	6·480	7·680
Water, . .	—	0·75	2·00	1·360	1·708
	98	99·75	99·584	99·584	98·464

The result obtained by Bucholz and my first analysis, correspond so closely, that the specimens must have been nearly identical. The mean of the two gives the following atomic proportions of the constituents:

		Atoms.
Silica, . .	19·88	3·06
Alumina, . .	13·27	2·04
Lime, . .	6·49	1
Protoxide of iron, .	1·22	0·19
Water, . .	1·48	0·22

If we consider the protoxide of iron and the water as only accidental ingredients, it is evident that zoisite is a compound of

2 atoms silicate of alumina,
1 atom silicate of lime.

Its formula is $2\mathrm{AlS}+\mathrm{CalS}$.

Sp. 17. *Meionite,*[¶] or *Scapolite.*[**]

Paranthine, wernerite, arctizite, bergmannite? chelmsfordite? micarelle rapidolite, spreustein? dipyre.

The different varieties of minerals belonging to this species were discovered at different times; and having but little apparent resemblance to each other, were naturally distinguished by different names. It was only by careful crystallographical

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[*] Klaproth, Beitrage, iv. 179. The specimen from Carinthia.

[†] Klaproth, ibid. p. 183. From the same locality, but of a yellowish brown colour, and having a specific gravity of 3·265.

[‡] Bucholz, Gehlen's Jour. (2d series), i. 197. Locality not specified.

[§] By my analysis. Specimen from Carinthia.

[‖] By my analysis. Specimen from Williamsburgh, Massachusetts. Specific gravity 3·2707.

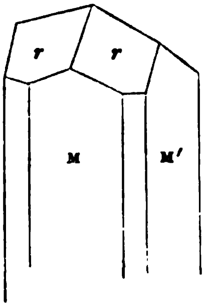
[¶] From *μειων*, *less*; so named from the lowness of the pyramid with which the crystal is usually terminated.

[**] This name was imposed by D'Andrada, from the rodlike appearance of the crystals.

examinations and chemical analyses that their identity was made out. *Meionite* is described by Romé de Lisle, and was constituted into a particular species, and named by Hauy. *Wernerite*, or foliated scapolite, was discovered and described by Andrada, and named by him in honour of Werner. *Paranthine*, or radiated scapolite, was first observed at Arendal, in Norway, and was named by Werner from the rod like appearance of the crystals.

This species, when pure, has a white, or greyish-white colour, which is the colour of *meionite*. Frequently there is a shade of green or yellow superadded to the white. This is the case with the varieties arranged under the name of *scapolite*. Frequently the colour is red, or brownish, or yellowish red, doubtless from the admixture of foreign matter. The green colour seems owing to an admixture of augite, the red to an admixture of peroxide of iron. Streak greyish white.

It occurs occasionally massive, but much more frequently crystallized. The primary form obtained by cleavage is a right square prism. Most commonly the prism is terminated by a low four-sided pyramid, the faces of which, *r*, *r*, are inclined to each other at an angle of 136° 22′, and *r* on M 112° 5′. The lateral edges of the prism are most frequently replaced by one, two, or even three small planes, making the prism eight, twelve, or sixteen-sided. The edges of the terminating pyramid are also often replaced by tangent planes. Sometimes the pyramid is incomplete, leaving a small portion of the primary terminal face of the prism at its apex.



Surface of the prism often streaked longitudinally.

Structure foliated; fracture imperfect conchoidal, or uneven; lustre vitreous.

From transparent to translucent on the edges; brittle.

Hardness 4·25; specific gravity of meionite from 2·612 to 2·650; of scapolite from 2·709 to 2·749.

Before the blowpipe it froths and melts into an enamel or glass, white, except when the colour is altered by the presence of foreign matter.

The following table exhibits the constituents of this mineral according to the best analyses hitherto made of it:

	*	†	‡	§	‖	¶	**	**
Silica,	40·8	40·531	39·915	43.83	41·25	45	45·348	46·300
Alumina,	30·6	32·726	31·970	35·43	33·58	33	31·672	26·484
Lime,	22·1	24·245	23·856	15·96	20·36	17·6	23·952	18·624
Soda with lithia,	2·4	—	—	—	—	1·5	—	3·640
Potash with soda,	—	1·812	0·894	—	—	0·5	—	—
Peroxide of iron,	1	0·182	2·242	—	—	1	—	—
Protox. of mangan.,	—	—	0·174	—	0·54	—	—	—
Water,	—	—	0·949	1·03	3.32	—	—	5·040
Carb. acid & loss,	3·1	—	—	—	—	—	—	—
	100	99·496	100	99·28	99·05	98·6	100·972	100·088

It is obvious, from a bare inspection of this table, that the only essential constituents of this mineral are silica, alumina, and lime. A mean of all the analyses gives us for these constituents the following quantities:

		Atoms.
Silica,	42·871	21·43
Alumina,	31·933	14·19
Lime,	20·837	5·95

The mean gives the proportion of lime too low, and that of alumina too high, owing to the fourth and sixth analyses, which do not well accord with the rest. If we leave them out we shall find the atoms of the bases equal to those of silica, and the atoms of alumina twice as great as those of lime. Hence the constitution of this mineral is

2 atoms silicate of alumina,
1 atom silicate of lime.

And the formula $2AlS+CalS$.

Thus the chemical constitution of zoisite and scapolite is the same. Yet they differ in their specific gravity, zoisite being 3·327, and scapolite 2·740. Zoisite is also harder, being 6·25, while that of scapolite is 4·25. The shape of the crystals is also different, zoisite being an oblique rhombic prism, while that of scapolite is a square prism. These differences makes it requisite, notwithstanding their identity in com-

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* A meionite from Vesuvius. Leopold Gmelin, Schweigger's Jour. xxv. 38.

† A meionite from Monte Somma. Stromeyer, Untersuchungen, p. 378.

‡ A meionite from the Tyrol. Ibid.

§ A scapolite from Finland, white with a shade of green. Nordenskiöld, Bidrag, p. 58.

‖ A white scapolite, with a shade of yellow, from Finland. Nordenskiöld, Ibid.

¶ A scapolite; Laugier, Ann. de Mus. d'Hist. Nat. x. 472.

** By my analysis. Two scapolites from the United States. The first had a specific gravity of 2·717; the second, from Bolton, Mussachusetts, had a specific gravity of 2·709.

position, to constitute them different species. They stand in the same relation to each other that arragonite does to calcareous spar.*

Sp. 18. *Prehnite.*

Koupholite, yu.

This mineral was constituted into a peculiar species by Werner, from specimens brought from the Cape of Good Hope, by Colonel Prehn, about the year 1780. It occurs in veins in primary rocks, and also in trap rocks, both in veins and in amygdaloidal cavities.

Colour sometimes white, but most commonly green of

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* The mineral analyzed by Ekeberg (Afhandlingar, ii. 144), and called by him *natrolite*, is generally considered as a variety of scapolite.

Its colour is light greenish-grey; lustre glistening and waxy; structure imperfect foliated; translucent; hardness about 5; tough; specific gravity 2·723. Before the blowpipe it melts per se into a transparent-green glass. Its constituents, by my analysis, are,

		Atoms.
Silica, . .	43·572 .	21·78
Alumina, . .	24·480 .	10·88
Lime, . .	15·460 .	4·41
Peroxide of iron,	5·540 .	1·11
Soda, . .	9·148 .	2·28
Water, . .	1·800	
	100	

The atoms of silica exceed those of the bases by 4·1.

The constituents seem to be

11 atoms silicate of alumina,
5 atoms silicate of lime,
2 atoms bisilicate of soda,
1 atom bisilicate of iron.

If the bisilicates of soda and iron were accidental, then the natrolite would agree with scapolite in its composition.

At Grenville, in Lower Canada, in an aggregate of table spar, sphene, graphite, &c., there occurs a brown-coloured mineral in small grains, which looks like scapolite. Its specific gravity is 2·7449, and its constituents

		Atoms.
Silica, .	52·85 .	5·21
Alumina, .	24·70 .	2·16
Lime, .	17·75 .	1
Water, .	3·40	
	98·70	

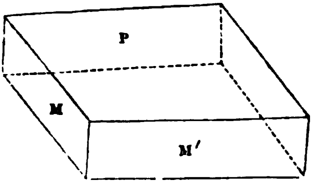
This is $2AlS^2 + CalS$.

It differs from scapolite in containing an additional atom of silica, but the grains were so small that it was difficult to be sure that all the table spar in which they were imbedded was excluded.

various shades, as apple-green, leek-green, sisken-green, &c. Streak white.

It occurs both granular and fibrous. Frequently amorphous, or in various derivative shapes. But it is also crystallized, and the primary form of the crystal is a right rhomboidal prism.

M on M′ 100°.



The face P is usually replaced by two low faces making an angle of 91° 30′. The lateral edges of the prism are frequently replaced by tangent planes.

Lustre vitreous, except that of face P, which is pearly, at least when produced by cleavage.

Semitransparent to translucent on the edges.

Hardness 5; specific gravity from 2·90 to 2·953.

Before the blowpipe it froths and melts into a slag of a light green colour.

When heated it becomes electric.

Does not gelatinize with acids.

The constituents of this mineral, according to the best analyses hitherto made are as follow:

	*	†	‡	‡	§	§	‖
Silica,	43·80	42·5	42·875	43·00	43 60	42·22	43·048
Alumina,	30·33	28·5	21·500	23·25	23 00	23·68	23·840
Lime,	18·33	18·4	26·500	26·00	22·33	23·52	26·164
Protoxide of iron,	5·66	3·0	3·000	2·00	2·00	3·06	0·640
Prot. of manganese,	—	—	0·250	0·25	—	—	0·416
Potash and soda,	—	0·75	—	—	—	—	1·028
Water,	1·16	2·00	4·625	4·00	6·40	5·58	4·600
	99·28	95·15	98·75	98·5	97·33	98·06	99·772

The mean of these analyses gives us

		Atoms.
Silica,	43	21·5
Alumina,	24·97	11·09
Lime,	23·03	6·58
Protoxide of iron,	2·78	0·61
Water,	4·05	3·6

[*] Klaproth; Ann. de Chim. i. 208. It was a foliated prehnite.

[†] Laugier, ibid. lxxv. 78. A fibrous prehnite.

[‡] Gehlen; Schweigger's Jour. iii. 182. Both fibrous prehnites.

[§] By my analyses. The first specimen was light green, the second white; both fibrous, and from the neighbourhood of Glasgow.

[‖] A white prehnite from the Castle Hill of Edinburgh, analyzed by Captain Lehunt. Known in Edinburgh by the name of *Wollastonite*.

The atoms of silica exceed those of the bases by 3·22. Hence the lime must be in the state of sesquisilicate.

Probably the lime from the mean exceeds the true quantity, in consequence of the uncommon quantity obtained by Gehlen and Lehunt in their analyses. I am disposed, therefore, (uniting the protoxide of iron to the alumina,) to consider the constitution of prehnite to be

2 atoms silicate of alumina,
1 atom sesquisilicate of lime,
$\frac{1}{2}$ atom water.

The oxide of iron is never wanting altogether, but it varies so much in its quantity that it can scarcely be considered as an essential constituent.

Sp. 19. *Anhydrous Scolezite.*[*]

This mineral occurs in the large masses of scapolite at Ersby, in Finland. It was taken for scapolite till the analysis of Nordenskiöld ascertained its true nature, and induced him to constitute it a peculiar species.

Colour white.

Occurs in crystals, but the shape is not mentioned by Nordenskiöld; only one cleavage perceptible.

Translucent.

Fracture small conchoidal.

Lustre vitreous; hardness 6; difficultly fusible.

Before the blowpipe behaves like common scolezite, only it requires more heat to be fused into a glass with soda.

The specific gravity not determined.

The constituents of this mineral, according to the analysis of Nordenskiöld, are as follow:

		Atoms.
Silica, .	54·13 .	27·06
Alumina,	29·23 .	12·99
Lime, .	15·46 .	4·41
Water, .	1·07 .	0·95
	99·89[†]	

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[*] From σκωληξ, *a worm.* From the appearance which scolezite assumes under the blowpipe.

[†] Bidrag, p. 67.

These constituents are obviously

3 atoms silicate of alumina,
1 atom tersilicate of lime.

The water is doubtless accidental, being too small in quantity to constitute an atomic proportion.

Sp. 20. *Iolite.*[*]

Cordierite, dichroite, peliom, steinheilite, sapphire d'eau.

This mineral was first observed at Capo de Gate, and called *iolite*, from its blue colour, and *dichroite*, from the two colours which it frequently displays, when viewed in two different positions. The variety called *pelium*, or *peliom* (from its blue colour), was first found at Bodenmais, in Bavaria, while *steinhelite* was discovered in the copper mine of Orrijarvi, in Finland. It was the analysis of Stromeyer that demonstrated the identity of dichroite and steinheilite.

Colour various shades of blue, generally inclining to black; streak white.

It occurs generally massive, but is sometimes crystallized. The primary crystal is a regular six-sided prism, most commonly having the lateral edges replaced by tangent planes. The terminal edges are also frequently replaced by planes making angles of 137° 46′ (according to Mr. W. Phillips), with the corresponding lateral faces of the prism.

Fracture conchoidal; lustre vitreous.

Translucent; sometimes transparent. When we view the crystal in the direction of the axis of the prism the colour is blue, but when we look through it in a direction perpendicular to the axis it has a yellowish-grey colour.

Hardness 7; specific gravity from 2·5969 to 2·6643. A Greenland specimen was found by Stromeyer, 2·5969, steinheilite, 2·6003. I found the specific gravity of a fine transparent specimen from Connecticut, in plates, to vary from 2·651 to 2·6643. It was not absolutely free from some very thin plates of mica, which became visible when the specimen was ignited.

When strongly heated before the blowpipe the edges melt with difficulty into a glass equalling the original mineral in colour and transparency.

The constituents of this mineral are as follow:

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[*] From ιον, *a violet*, and λιθος, *a stone.* So called on account of its colour.

	*	†	‡	§	||	¶
Silica, . . .	43·6	49·170	48·352	48·538	48·525	49·620
Alumina, . . .	37·6	31·106	31·706	31·730	31·502	28·720
Magnesia, . . .	9·7	11·454	10·157	11·305	15·000	8·640
Lime, . . .	3·1	—	—	—	—	0·228
Protoxide of iron, .	4·5	6·338	8·316	5·686	1·610	11·580
Protoxide of manganese,	trace	0·037	0·333	0·702	0·243	1·508
Potash? . . .	1·0	—	—	—	—	—
Water, . . .	—	1·204	0·595	1·687	1·705	—
	99·5	99·309	99·458	99·648	98·585	100·296

The mean of these analyses (leaving out the first as differing too much from the others), gives us the following numbers:

		Atoms.
Silica, . . .	48·841 .	24·42
Alumina, . .	31·35 .	13·93
Magnesia, . .	11·31 .	4·52
Protoxide of iron, .	6·306 .	1·40
Protoxide of manganese,	0·564 .	0·12

The atoms of bases are 19·97, while those of silica are 24·42. Thus there is an excess of 4·45 atoms of silica, which corresponds with the atoms of magnesia. We may infer from this that the magnesia is in the state of bisilicate. If we include the manganese along with the iron, we have the ratio of the bases nearly, oxide of iron 1, magnesia 3, alumina 9. Hence the constitution of iolite seems to be

9 atoms silicate of alumina,
3 atoms bisilicate of magnesia,
1 atom silicate of iron.

The formula is $9AlS+3MgS^2+fS$.

Sp. 21. *Hydrous Iolite.*

This mineral occurs in red granite, in the neighbourhood

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* Leopold Gmelin, Hoffman's Mineralogie, iv. 2, 119. The specimen a *peliom.*

† Stromeyer, Untersuchungen, p. 329. The specimen was from Greenland.

‡ Stromeyer, ibid. Specimen from Bodenmais, and consequently a peliom.

§ Stromeyer, ibid. The specimen was a steinheilite.

|| By my analysis. The specimen was steinheilite.

¶ By my analysis. The specimen was in the state of very beautiful transparent blue plates from Connecticut.

of Abo, accompanied by a light bluish-grey dichroite. It was first described and analyzed in 1827, by M. Bonsdorf.*

The colour is greenish-brown, or dark olive-green. When viewed by transmitted light, thin plates of a light-green colour are seen.

It occurs crystallized in six-sided irregular prisms. The lateral edges are usually replaced by so many faces that the prism appears nearly cylindrical.

Structure straight foliated, folia perpendicular to the axis of the prism; cross fracture conchoidal.

Lustre of the fracture talcy, of the surface of the plates waxy.

Hardness 3·75; specific gravity not specified.

When heated in a glass tube it gives out pure water, but undergoes no farther alteration. It cannot be fused by the blowpipe per se.

Its constituents, according to the analysis of Bonsdorf, are as follow:

		Atoms.
Silica, . .	45·05 .	22·52
Alumina, .	30·05 .	13·35
Magnesia, .	9·00 .	3·60
Protoxide of iron,	5·30 .	1·17
Water, . .	10·60 .	9·42
	100·00	

Here the atoms of base exceed those of silica by 4·4, which rather exceeds the atoms of magnesia. The constituents are,

$10\frac{1}{2}$ atoms silicate of alumina,
3 atoms bisilicate of magnesia,
1 atom silicate of iron,
8 atoms water.

Or, taking the oxide of iron along with the magnesia,

3 atoms silicate of alumina,
1 atom bisilicates of magnesia and iron,
2 atoms water.

The fomula will be $3AlS+1(\frac{3}{4}Mg+\frac{1}{4}f)S^2+2Aq$.

It is very nearly an atom of iolite united to two atoms water.

Sp. 22. *Staurotide.**

Grenatite, staurolite.

This mineral occurs in primary rocks, particularly in mica

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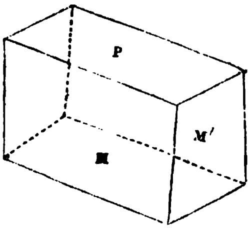
* Kong. Vet. Acad. Handl., 1827, p. 157.

† From σταυροειδης, *like a cross*. So called from the cruciform appearance of its twin crystals.

slate. St. Gothard, the Tyrol, St. Jago de Compostella, and Oporto, are some of the best known localities. It is met with also in Aberdeenshire, and in the United States.



Colour dark reddish brown; streak white.

It is always crystallized, and the primary form is a right rhombic prism.

M on M′ 129° 20′

The acute edges of the prism are commonly replaced by tangent planes, making angles with the adjacent planes of the prism of 115° 20′. The obtuse solid angles of the prism are frequently replaced by a triangular plane, making with M or M′ an angle of 137° 58′. Two of these crystals frequently cross each other either at right angles or obliquely. Hence the name, and the veneration with which they were formerly regarded in Catholic countries.

Fracture conchoidal or uneven.

Lustre vitreous, inclining to resinous.

Translucent, frequently only on the edges.

Hardness 6·75; specific gravity of the opaque and impure specimens, 3·273; that of a pure specimen I found 3·693.

Before the blowpipe it assumes a dark colour, but does not melt.

The following table exhibits the constituents of staurotide, according to the best analyses:

	*	†	‡	§
Silica, . .	37·5	27	50·076	36·696
Alumina, . .	41·0	52·25	35·900	39·880
Protoxide of iron,	15·25	18·5	13·908	18·144
Protoxide of manganese,	0·5	0·25	—	4·046
Magnesia, . .	0·5	—	trace	0·686
Moisture, . .	—	—	1·200	0·080
	97·75	98	101·084	99·550

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[*] Klaproth, Beitrage, v. 80. A dark brownish staurotide from St. Gothard, specific gravity 3·510.

[†] Klaproth, ibid. A brownish red variety from the same place, having a specific gravity of 3·765.

[‡] By my analysis. The crystal was a cross nearly opaque, and having a specific gravity of 3·273.

[§] By my analysis. The specimen was pure, and had a specific gravity of 3·693.

If we take the last of my analyses, which from its purity I consider as very nearly correct, as exhibiting the true constitution of staurotide, it will consist of

	Atoms.
Silica, . .	18·40
Alumina, . .	17·72
Protoxide of iron, .	4·03
Protoxide of manganese,	0·90

The atoms of base are 22·65, exceeding those of silica by 4·25 atoms, nearly the amount of the atoms of oxides of iron and manganese. If we unite the oxide of manganese to that of iron, the mineral will be a compound of

4 atoms silicate of alumina,
1 atom hexasilicate of iron.

The first analysis of Klaproth gives very nearly the same result. In my first analysis the mineral obviously contained an excess of silica, while in Klaproth's second there was too little. The mean of the two would approach pretty near the truth.

Sp. 23. *Gehlenite.**

Stylobite.

This mineral was found on Mount Monzoni, in the valley of Fassa in the Tyrol. It was brought to Munich during the course of the year 1815, by the mineral dealer Frischholtz, and was soon after described and analyzed by Professor Fuchs.

Colour different shades of grey, none of them bright.

It is always crystallized in rectangular prisms, with square bases, but whether the primary form be a cube, or a right square prism, has not been determined.

Fracture uneven, passing into splintery.

Lustre resinous, inclining to vitreous.

Usually opaque; sometimes faintly translucent on the edges; brittle.

Hardness 6·5; specific gravity from 2·9166 to 3·029.

Before the blowpipe fuses with difficulty, and only when in thin splinters. It dissolves slowly when mixed with borax. Gelatinizes when heated in muriatic acid; even dilute muriatic acid acts upon it without the application of heat.

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* Named in honour of the German chemist, M. Gehlen.

Its constituents are as follow :

Silica,	29·64	29·132
Alumina,	24·80	25·048
Lime,	35·30	37·380
Protoxide of iron,	6·56	4·350
Water,	3·30	4·540
	99·60*	100·450†

These two analyses approach each other very closely. The mean of both gives us

		Atoms.
Silica,	29·386	14·69
Alumina,	24·924	11·07
Lime,	36·340	10·38
Protoxide of iron,	5·455	1·20
Water,	3·920	3·48

The atoms of bases amount to 22·65 exceeding those of silica by 7·96, or nearly one-third of the bases. Hence an atom and a half of bases must be combined with every atom of silica. If we unite the oxide of iron to the lime, the atoms of alumina and lime are nearly equal. Hence Gehlenite seems composed of

3 atoms subsesquisilicate of alumina,
3 atoms subsesquisilicates of lime and iron,
1 atom water.

The formula will be $3Al^{1\frac{1}{2}}S+3(\frac{8}{9}Cal+\frac{1}{9}f)^{1\frac{1}{2}}S+Aq$.

Sp. 24. *Weissite.*‡

This mineral was observed in Erik Matt's mine at Fahlun. It was described and analyzed by Trollé Wāchtmeister, in 1827.§

Weissite occurs thinly scattered in a chlorite slate in kidney-shaped pieces about the size of a hazel nut.

Colour ash grey, slightly inclining to brown, sometimes covered with a blackish ochre.

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* Fuchs, Schweigger's Jour. xv. 377.

† By my analysis. The specimen was digested in acetic acid to remove any adhering lime.

‡ Named by Trollé Wāchtmeister, to whom we owe the knowledge of this mineral, in honour of Professor Weiss, of Berlin. See Poggendorf's Annalen, xiv. 190.

§ Kong. Vet. Acad. Handl., 1827, p. 80.

The largest pieces show no regular texture, but give an even and coarse-grained fracture. In some smaller pieces the texture is foliated, and there are indications of a rhomboidal prismatic texture.

Powder pure white; by ignition acquires a slight shade of red.

Scratches glass, but is scratched by steel.

Lustre between pearly and waxy.

Scarcely translucent.

Specific gravity 2·808.

Before the blowpipe becomes pure white, and fuses on the edges. On charcoal gives out a zinc smoke. Heated in a tube it gives out water which at first reddens litmus paper, and finally renders it blue. With borax it fuses slowly into a colourless glass. With biphosphate of soda it behaves in the same way, leaving a silica skeleton. With carbonate of soda it fuses slowly into an opaque slag, which finally melts into a bead.

Its constituents, as determined by Trollé Wāchtmeister, are as follow:

		Atoms.
Silica,	59·69	29·84
Alumina,	21·70	9·64
Magnesia,	8·99	3·60
Protoxide of iron,	1·43	0·31
Protoxide of manganese,	0·63	0·14
Potash,	4·10	0·68
Soda,	0·68	0·17
Oxide of zinc,	0·30	0·05
Water with a little ammonia,	3·20	2·84
	100·72	

The atoms of silica are very nearly double those of the bases. Hence the mineral is composed of bisilicates. While those of the alumina are very nearly double those of all the the other bases.

We may therefore consider weissite as composed of

2 atoms bisilicate of alumina,

1 atom bisilicate of magnesia, iron, manganese, potash, soda, and zinc,

$\frac{1}{2}$ atom water.

If we unite the oxides of iron and manganese, and the potash and soda, then the ratio of the atoms of magnesia, potash, and iron, will be to each other as the numbers 8, 2, and 1. Hence the formula for the constitution of weissite will be $2AlS^2+1(\frac{8}{11}Mg+\frac{2}{11}K+\frac{1}{11}f)S^2+\frac{1}{2}Aq$.

Whether the water was a chemical constituent of the mineral or not must remain doubtful.

Sp. 25. *Fahlunite, Triclasite?*

This mineral occurs at Fahlun, particularly in Erik Matt's mine in chlorite slate. The descriptions of it by Hauy, Hisinger, &c., and the specimens sent me from Sweden differ so much from each other that there is reason to believe that various minerals have been confounded together under the same name. On that account I shall confine myself to the description and analyses given by Trollé Wachtmeister, as from his situation he had the best opportunity of determining the characters of the true fahlunite.

The colour is sometimes coal black, sometimes greyish brown, or blackish brown, and in thin splinters light brown; streak white; powder light grey; when heated to redness it becomes fawn coloured.

The specimens found in the chlorite slate in Erik Matt's mine are always amorphous; but in the Terra Nova shaft at Fahlun, and in the Lovise mine in the same place it is found in crystals, and from the examination of these crystals by Mitcherlich it appears that they have exactly the form of topaz crystals.

Fracture even, passing into fine splintery.

Lustre waxy, but inconsiderable.

Easily scratched by steel.

Specific gravity from 2·62 to 2·79.

Before the blowpipe in thin splinters it becomes white, and fuses on the edges with some effervescence into a glass. With the usual fluxes it gives a glass with a light iron colour. When heated in a glass tube it gives out water.

Its constituents, determined by Trollé Wachtmeister, are as follow:—

	*	†	‡	§
Silica, . . .	43·51	44·60	44·95	51·840
Alumina, . .	25·81	30·10	30·70	24·780
Protoxide of iron, .	6·35	3·86	7·22	10·296
Magnesia, . .	6·53	6·75	6·04	7·704
Protoxide of manganese,	1·72	2·24	1·90	2·248
Soda, . . .	4·45	1·98	—	—
Potash, . . .	0·94		1·38	—
Fluosilicic acid, . .	0·16	—	—	—
Lime, . . .	trace	1·35	0·95	2·684
Water, . . .	11·66	9·35	8·65	0·576
	101·13	100·23	101·79	100·128

The three analyses of Trollé Wachtmeister agree very closely with each other. The mean of them is as follows:—

		Atoms.
Silica, . .	44·35 .	22·17
Alumina, . .	28·71 .	12·76
Magnesia, . .	6·44 .	2·57
Protoxide of iron, .	5·81 .	1·29
Protoxide of manganese,	1·95 .	0·43
Soda, . .	1·48 .	0·37
Potash, . .	1·76 .	0·29
Lime, . .	0·76 .	0·21
Water, . .	9·88 .	8·78

The atoms of the bases being only 17·94, while those of silica are 22·17, it is evident that some of these bases must be in the state of bisilicates. Now the surplus in the silica being 4·23 atoms, and the atoms of magnesia, protoxide of iron, and oxide of manganese being 4·29, it is probable that these last are in the state of bisilicates. The potash, soda and lime amount to the fifth of the atoms of magnesia, iron and manganese, while the atoms of alumina are thrice those of these last. Hence the constitution of fahlunite seems to be

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[*] Trollé Wachtmeister, Kong. Vet. Acad. Handl., 1827, p. 21. The specimen was from Erik Matt's mine, and not crystallized. Sp. gr. 2·68.

[†] Ibid. p. 25. From Terra Nova, and in regular crystals. Sp. gr. 2·74.

[‡] Ibid. p. 27. From Lovise mine. Crystallized. Sp. gr. 2·79.

[§] A specimen analyzed by me. Its colour was yellowish brown, and its specific gravity 2·632. In other respects it agreed with the description in the text. The remarkable difference was the absence of water. It was an anhydrous fahlunite.

15 atoms silicate of alumina,
5 atoms bisilicate of magnesia, iron, and manganese,
1 atom silicate of potash, soda, and lime,
10 atoms water.

Or if the silicates of potash, soda, and lime, (which vary very much in the different specimens,) were considered as only accidental, then the constitution would be

3 atoms silicate of alumina,
1 atom bisilicate of magnesia, iron, and manganese,
2 atoms water.

The formula is $3AlS+(\frac{6}{10}Mg+\frac{3}{10}f+\frac{1}{10}mn)S^2+2Aq$.

The constitution of anhydrous fahlunite deduced from the last analysis in the table, is

15 atoms silicate of alumina,
5 atoms bisilicate of iron,
4 atoms bisilicate of magnesia,
1 atom bisilicate of lime.

Or uniting the magnesia and lime,

3 atoms silicate of alumina,
1 atom bisilicate of iron,
1 atom bisilicate of magnesia and lime.

The formula is $3AlS+fS^2+(\frac{4}{5}Mg+\frac{1}{5}Cal)S^2$.

So that it differs in other respects from hydrous fahlunite, as it contains more silica.

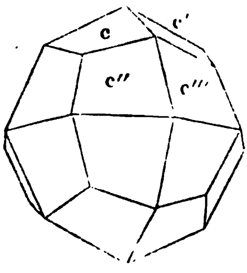
Sp. 26. *Leucite.**

Amphigene, vesuvian, white garnet.

This mineral occurs in imbedded crystals in lava. The lavas of Vesuvius, and the basalts of Italy and Bohemia, abound with it. The road from Rome to Frascati is in many places covered with it.

Colour reddish, yellowish, or greyish white; also ash grey and smoke grey; streak white.

Always crystallized in crystals approaching to a sphere, and consisting of twenty-four trapezoidal faces.



c on c′ 131° 48′ 16″

$$\left.\begin{array}{c} c \text{ on } c'' \\ \text{or} \\ c' \text{ on } c''' \end{array}\right\} 146^\circ\ 26'\ 33''$$

These crystals exhibit joints parallel to the faces of a rhomboidal dodecahedron, and to those of the cube.

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* From λευκος, *white*; c its white colour.

The cube being the simplest of the two has been chosen for the primary form of the crystal. The leucite crystal is formed by each of the angles of the cube being replaced by three planes, which planes by enlargement have enveloped and concealed the primary faces of the cube.

Fracture conchoidal; surface of the crystals sometimes even, but rough for the most part.

Lustre vitreous; from semitransparent to translucent; brittle.

Hardness 7; specific gravity 2·490.

Infusible before the blowpipe per se. It fuses with borax or with carbonate of lime, though with difficulty into a clear globule.

Its powder changes the blue tincture of violets to green.

The following table exhibits the constituents of leucite, according to the best analysis hitherto made:

	*	†	†
Silica,	53·750	58·70	56·10
Alumina,	24·625	19·95	23·10
Potash,	21·350	21·40	21·15
Lime,	—	1·35	—
Peroxide of iron,	—	0·40	0·95
	99·725	101·80	101·3

The mean of these three analyses gives us

		Atoms.
Silica,	56·18	28·09
Alumina,	22·56	10·02
Potash,	21·30	3·55

This approaches pretty nearly to

3 atoms bisilicate of alumina,
1 atom bisilicate of potash.

The formula is $3AlS^2+KS^2$.

Sp. 27. *Pipestone.*

I give this name to a mineral from North America, of which the Indians make their tobacco pipes. I got the specimen in my possession from my friend and old pupil, Dr. Scouler; who spent a summer on the north west coast of America, between Nootka Sound and the Columbia river, and among

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[*] Klaproth, Beitrage, ii. 42.

[†] Arfvedson, Afhandlingar, vi. 255. Arfvedson by inadvertance, has given the name of *meionite* to one of the leucites analyzed by him.

many other natural productions of the country, he brought home a specimen of this pipestone, which he was good enough to put in my possession. It had been given him by the natives, and he was able to learn nothing about the part of the country from which it came, nor of the nature of the rocks with which it is associated.

It constitutes a compact stone through which a few scales are scattered, having some resemblance to *claystone*, but being much softer; fracture earthy.

Colour light greyish blue; powder light blue; sectile; dull; opaque.

Hardness 1·5; specific gravity in different trials, varied from 2·606 to 2·608.

The particles when scraped off with a knife feel gritty between the teeth.

Infusible before the blowpipe.

I made two analyses of it, the result of which was as follows:

Silica,	55·620	56·60
Alumina,	17·208	17·42
Soda,	12·160	12·80
Peroxide of iron,	7·612	6·308
Lime,	2·256	2·076
Magnesia,	0·112	0·292
Water,	4·600	4·566
	99·568	100·062

The mean of these gives us

		Atoms.
Silica,	56·11	28·05
Alumina,	17·314	7·69
Soda,	12·48	3·12
Peroxide of iron,	6·960	1·39
Lime,	2·166	0·61
Magnesia,	0·202	0·08
Water,	4·583	4·07

These numbers approach very nearly

6 atoms bisilicate of alumina,
3 atoms bisilicates of soda, lime, and magnesia,
1 atom quatersilicate of iron,
3 atoms water.

Or if the quatersilicate of iron be considered as accidental, the constitution will be

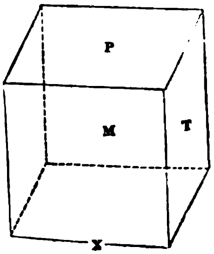
2 atoms bisilicate of alumina,
1 atom bisilicate of soda, lime, and magnesia,
1 atom water.

The formula is $2AlS^2+(\frac{40}{49}N+\frac{8}{49}Cal+\frac{1}{49}Mg)S^2+Aq$.

Sp. 28. *Murchisonite.*

This mineral was discovered by Mr. Levy, interspersed in small crystals in the conglomerate belonging to the new red sandstone, from the neighbourhood of Dawlish and Heavitree, near Exeter.*

The colour of this mineral is not given, but one of the cleavage faces has a pearly lustre, and the mineral presents a golden yellow reflection, generally not uniform but in spots. By cleavage a four-sided prism is obtained of the following dimensions;



P on T 90°, P on M 106° 50′, M on T 90 .

Sometimes the edge X is replaced by a plane, making an angle with P′ of about 120°.

Texture foliated. In thin laminæ, transparent.

Hardness the same as felspar, or 6.

Specific gravity, as determined by Mr. Kent, 2·5091.

Its constituents, according to the analysis of Mr. R. Phillips, are

		Atoms.	
Silica, .	68·6 .	34·3 .	14·11
Alumina, .	16·6 .	7·37 .	3·03
Potash, .	14·8 .	2·43 .	1
	100·0		

This corresponds with

3 atoms tersesquisilicate of alumina,
1 atom tersesquisilicate of potash.

The formula will be $3AlS^{3\frac{1}{2}}+KS^{3\frac{1}{2}}$.

Sp. 29. *Gabronite.*†

Compact scapolite.

This mineral has been found only in a vein of titaniferous iron near Arendal in Norway.

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* Phil. Magazine (2d series), i. 448.

† Phillips' Mineralogy, p. 139.

It is of a bluish or greenish grey colour; also reddish, and red. The bluish variety is found near Arendal along with hornblende; the greenish and red variety at Fredericksvarn, disseminated in a large grained syenite.

Its structure is foliated, being mechanically divisible, though with difficulty parallel to the sides of a rectangular prism.

Translucent on the edges and hard enough to scratch glass, though not to give fire with steel. Specific gravity nearly 3.

Before the blowpipe it fuses with difficulty into an opaque white globule.

Its constitution, according to the analysis of John, are as follow:

		Atoms.
Silica,	54	27
Alumina,	24	10·66
Magnesia,	1·5	0·6
Potash and soda,	17·25	3·45
Protox. of iron and mangan.,	1·25	0·27
Water,	2	1·77
	100	

This corresponds very nearly with

3 atoms bisilicate of alumina,
1 atom bisilicate of potash and soda.

The formula will be $3AlS^2+K,NS^2$.

Sp. 30. *Icespar.*

This mineral occurs at Monte Somma, near Naples, in lava, where it is much mixed with meionite and nepheline.

Colour greyish white, inclining sometimes to yellowish white.

Often massive; sometimes crystallized in thin longish six-sided tables. Primary form a right oblique four-sided prism, the faces of which are inclined at an angle of 129° 40′. The edges of this prism are usually replaced by one or two planes. The angles also are occasionally replaced by tangent planes. Lateral planes longitudinally streaked.

Lustre shining, vitreous; fracture imperfect foliated; strongly translucent; crystals transparent; very easily frangible; specific gravity 2·4365; hardness about 3.

Before the blowpipe on charcoal it becomes vitreous, semitransparent, and white, and fuses with difficulty on the edge into a blebby semitransparent glass; with borax fuses into a diaphanous glass.

Its constituents are

Silica, . . .	63·56
Alumina, . .	24·06
Potash, . . .	10·03
Lime, . . .	0·94
Peroxide of iron, .	0·92
Water, . . .	0·37
Oxide of manganese,	trace
	99·88

This is equivalent to $6AlS^{2\frac{1}{4}}+KS^{2\frac{1}{4}}$.

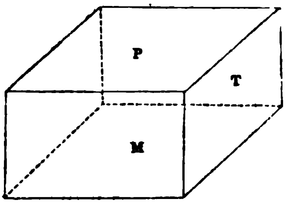
Sp. 31. *Felspar.*

Amausite, amazonstone, adularia, felstein, fusible hornstone, lemanite, lodulite, moonstone, napoleonite, necronite, orthose, fusible petrosilex, sunadin.

This mineral was long confounded with *albite*, from which it was first distinguished by chemical analysis. Being one of the constituents of granite it is a very common mineral. For the first accurate description of it, we are indebted to Mr. Henry Rose.

Colour white or grey; often flesh red; sometimes green; streak greyish white.

Sometimes massive, but most frequently crystallized. The primary form is a doubly oblique prism.



P on M 90°
P on T 67° 15′
M on T 120° 35′

According to the measurement of Mr. W. Phillips. For a description of the crystalline forms, we refer the reader to the Memoir of M. Gustavus Rose,* and to Phillips' Mineralogy.†

Structure foliated; fracture conchoidal; lustre vitreous; transparent to translucent on the edges; hardness 6; brittle.

The specific gravity of seven different specimens was determined by M. H. Rose. The green variety called amazon stone, was the heaviest, being 2·581; the lightest was from Baveno, being 2·394. That of the other specimens was 2·569, 2·574, 2·395, 2·468, and 2·496.‡

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* Ann. de Chim. et de Phys. xxiv. 5.

† P. 114.

‡ Ann. de Chim. et de Phys. xxiv. 14.

Before the blowpipe it fuses with difficulty, and only on the edges. With borax it fuses into a transparent glass. It fuses also with biphosphate of soda, leaving a skeleton of silica. With carbonate of soda it fuses into a glass full of vesicles.

The following table exhibits the constituents of this mineral, according to the best analysis hitherto made:

	*	†	†	‡
Silica, ...	64	64·5	65	64·20
Alumina, ...	20	19·75	20	18·40
Potash, ...	14	11·50	12·25	16·95
Lime, ...	2	trace	trace	trace
Oxide of iron, ...	—	1·75	1·25	—
Water, ...	—	0·75	0·50	—
	100	98·25	99	99·55

I am disposed to take Berthier's analysis as nearest the truth, because it was made on a pure specimen, and his method of determining the potash would be more correct than the methods of Vauquelin or Klaproth. The result of this analysis gives us the following atomic numbers:

		Atoms.
Silica, . .	32·1	. 11·3
Alumina, .	8·17	. 2·9
Potash, . .	2·82	. 1

The atoms of silica are thrice as numerous as those of the bases; while those of potash are to those of alumina, very nearly as 1 to 3. Hence the constituents of felspar are

3 atoms tersilicate of alumina,
1 atom tersilicate of potash.

The formula is $3AlS^3+KS^3$.

Sp. 32. *Glassy Felspar.*

Ryacolite.

This mineral is a very common ingredient in lava, and got its name from the strong vitreous lustre by which it is cha-

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[*] Vauquelin; Hauy, ii. 592.

[†] Klaproth, Beitrage, vi. 242. The first specimen from Carlsbad, having a specific gravity of 2·565; the second from Fredrickswärn in Norway, having a specific gravity of 2·590.

[‡] Berthier; Ann. des Mines, vii. 239. An adularia from St. Gothard.

racterized. The lava of Vesuvius contains abundance of it, and also the lava of the Laucher sea. It is found also in many other localities, as the pitchstone porphyry in the islands of Arran and Rum. It was first distinguished as a peculiar species by G. Rose.

Colour greyish white or grey.

It is always crystallized, and the form is the same as that of felspar, excepting that by M. G. Rose's measurement, the inclination of M on T is very nearly a degree greater than in adularia.[*] The crystals are usually very much cracked. They are generally small and always imbedded.

Fracture uneven or small imperfect conchoidal.

Internal lustre splendent and strongly vitreous; transparent.

Hardness the same as that of felspar.

Specific gravity, as determined by G. Rose, from 2·576 to 2·582.

Mitcherlich tried the optical properties of glassy felspar and found them quite different from those of adularia.

The following table exhibits the constituents of this mineral, as determined by the analyses of G. Rose and Berthier.

	†	‡	§	§
Silica,	65·52	50·31	66·1	66·6
Alumina,	19·15	29·44	19·8	18·5
Lime,	0·60	1·07	—	—
Magnesia,	—	0·23	2·0	1·0
Potash,	14·73	5·92	6·9	8·0
Soda,		10·56	3·7	4·0
Oxide of iron,	—	0·28	—	0·6
Volatile matter,	—	—	—	—
	100	97·81	98·5	98·7

The second of these analyses differs so much from the rest that we must omit it. The mean of the others gives us

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[*] See the usual crystalline forms of glassy felspar, figured by G. Rose in Poggendorf's Annalen, xv. 193.

[†] G. Rose, Poggendorf's Annalen, xxviii. 145. The specimen was from Vesuvius.

[‡] Rose. Ibid. p. 147. The specimen was from Vesuvius.

[§] Berthier's Memoires, ii. 315. The first specimen was from Mont Dore, the second from Drakenfield.

		Atoms.
Silica,	66·00	33
Alumina,	19·13	8·5
Potash,	7·45	1·24
Soda,	3·85	0·96

Glassy felspar agrees with common felspar in being composed of tersilicates, but it contains both potash and soda. The proportion of alkali to alumina is less. Its constitution is very nearly

4 atoms tersilicate of alumina,
1 atom tersilicate of potash and soda.

The formula is $4AlS^3+(\frac{5}{9}K+\frac{4}{9}N)S^3$.

Sp. 33. *Albite.*

Crumbling felspar, kieselspath, cleavelandite, pereklin.

This mineral which had been confounded with felspar, was first described and analyzed in 1806, by Hedenberg.[*] It was afterwards noticed by Gahn and Berzelius in 1814, under the name of *albite*;[†] and in 1815, two varieties of it were analyzed and described under the names of granular and radiated albite, by Eggertz.[‡] Haussmann had received a specimen of it from Chesterfield in Massachusetts, during the year 1817. He drew up a description of it under the name of kieselspath, which was read to the Royal Society of Gottingen during the course of that year, and Stromeyer, at his request, made a chemical analysis of it, which he published in 1821 in his Untersuchungen (p. 300). In 1823, M. Gustav. Rose published an elaborate account of its crystalline form and constitution.[§] At a latter period, Mr. Brooke proposed for it the name of cleavelandite, and Mr. W. Phillips showed that it is a common constituent of the granite rocks of this country.[||]

The colour is generally white, but it is found also bluish and blue, of a dingy red and green, and doubtless of other colours; streak white.

It occurs massive and also crystallized. The primary form is a doubly oblique prism.

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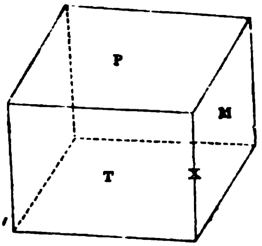
[*] Afhandlingar, i. 118.

[†] Ibid. iv. 180. The name was derived from *albus*, white; from the white colour of the specimens observed by them.

[‡] Ibid. v. 27.

[§] Gilbert's Annalen, lxxiii. 173.

[||] Annals of Philosophy (2d series), vii. 118.



T on M 117° 53′
P on M 86° 24′
P on T 115° 5′

The edge X is often replaced by a plane, making with T an angle of 122° 15′, and with M an angle of 119° 52′. The terminal edges and angles of the prism are also occasionally replaced by planes.*

Albite, when massive, is always radiated, never foliated.

Lustre vitreous, often inclining to pearly on the perfect surfaces of cleavage.

Rarely transparent, and only when it occurs in small crystals; always translucent on the edges.

Hardness 6; brittle.

Specific gravity, by Rose's trials, varies from 2·608 to 2·619. Eggertz found the albite of Finbo 2·612, that of Broddbo 2·619. Nordenskiöld found the red albite from Kimito 2·609.

Before the blowpipe it behaves exactly like felspar.

Does not dissolve by digestion in acids.

The constituents of albite, according to the most accurate analyses hitherto made, are as follow:—

	†	‡	§	‖
Silica, . . .	70·48	70·676	68·46	70·94
Alumina, . .	18·45	19·801	19·30	18·70
Soda, . . .	10·50	9·056	9·27	8·83
Lime, . . .	0·55	0·235	0·68	0·68
Oxides of iron & manganese,	—	0·111	0·28	—
Moisture, . .	—	—	—	0·70
	99·98	99·879	97·99	99·85

These four analyses approach each other very closely; showing that all the specimens analyzed were nearly pure. The mean of the four is as follows:—

		Atoms.
Silica, . .	70·139 .	35·07
Alumina, . .	19·063 .	8·47
Soda, . . .	9·414 .	2·35

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* See a description of the forms by Rose; Gilbert's Annalen, lxxiii. 156.

† Eggertz, Afhandlingar, v. 28. ‡ Stromeyer, Untersuchungen, p. 300.

§ Rose, Gilbert's Annalen, lxxiii. 173.

‖ By my analysis. A beautiful white laminated mass.

The atoms of silica exceed three times the atoms of the bases by 2·61, which rather exceeds the atoms of soda. It would seem from this that the soda is in the state of quatersilicate; but it is more probable that this excess of silica is accidental, and that the constitution of albite is

3 atoms tersilicate of alumina,
1 atom tersilicate of soda.

The formula is $3AlS^3+NS^3$.

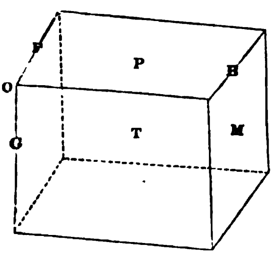
Sp. 34. *Anorthite.*[*]

This species was first recognised and separated from felspar, with which it had been confounded, by Dr. Gustavus Rose in 1823.[†]

The only locality of it at present known is Mount Vesuvius, where it is found lining cavities in limestone along with a greenish variety of pyroxene.

Colour white; streak white.

It occurs sometimes massive, but most frequently crystallized. The primary form of the crystal is a doubly oblique prism.



M on T 117° 28′
M on P 94° 12′
T on P 110° 57′

In general the edge G is replaced by a plane making an angle of 120° 30′ with T. This plane sometimes increases so much as to obliterate the plane M′ altogether. The edges F and B are often replaced by planes, which cause the prism to terminate in three planes. P makes with one of these new planes an angle of 137° 22′, and with the other an angle of 133° 13′. Sometimes the angle O is replaced by a triangular plane.

Fracture conchoidal.

Lustre on cleavage planes pearly; in other directions vitreous.

Varies from transparent to translucent; brittle.

Hardness 6; specific gravity of the massive varieties 2·762, of small crystals not quite free from pyroxene 2·656, as determined by Rose.

Before the blowpipe it fuses on the edges with great diffi-

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[*] The name is derived from the Greek word *ανορθος*, because the primary form exhibits no right angles.

[†] Gilbert's Annalen, lxxiii. 173, or Ann. de Chim et de Phys., xxiv. 1.

culty. With borax it fuses into a transparent glass. With biphosphate of soda we obtain the same result, excepting that a skeleton of silica is left. With carbonate of soda it swells and froths and forms an enamel.

Its constituents, as determined by Dr. G. Rose, are

		Atoms.	
Silica,	44·49	22·24	10·59
Alumina,	34·46	15·31	7·29
Lime,	15·68	4·48	2·13
Magnesia,	5·26	2·10	1
Peroxide of iron,	0·74	0·15	0·07
	100·63		

The number of atoms of silica nearly correspond with those of the bases, showing that the mineral is composed of silicates. The constitution approaches

7 atoms silicate of alumina,
2 atoms silicate of lime,
1 atom silicate of magnesia.

The minute quantity of silicate of iron is doubtless accidental.

Sp. 35. *Labradorite.*

Labradore felspar.

This mineral was first observed on the island of St. Paul, near the coast of Labrador, by Mr. Wolfe. It occurs also in Ingermania, and (as Klaproth informs us) in great abundance. The hills at Campsie, near Glasgow, and on the south side of Paisley contain a great quantity of a peculiar green stone, in which labradorite supplies the place of felspar.

It was arranged as a variety of felspar by mineralogists; but Kirwan was of opinion on account of its difficult fusibility, that it constituted a peculiar species.* And Klaproth proved by analysis that the constituents differ from those of felspar.† Still more lately Dr. G. Rose showed that the crystalline form, as well as the composition, is different. We cannot hesitate then to consider it as a distinct species, though nearly related to felspar.

Colour dark ash and smoke grey, in certain positions it reflects a great variety of colours, as blue, green, yellow, red, and brown. It was these colours that first attracted the

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* Mineralogy, i. 324.

† Beitrage, vi. 250.

attention of the missionaries. When the stone is polished they give it a great deal of beauty.*

Occurs commonly massive, and in rolled pieces, but the labradorite in the neighbourhood of Glasgow, is often in crystals; and Rose informs us that a crystallized specimen of it is placed in the mineralogical cabinet belonging to the University of Berlin. The shape of the crystal is very analogous to that of felspar. But the inclination of the sides and base are a little different. The following are the results of several measurements by Nordenskiöld:—†

P on M 93° 28′
P on T 114° 48′
T on M 119° 16′

Lustre of the sides of the prism vitreous, of the base pearly; translucent when in thin pieces.

Hardness 6; specific gravity of the variety from Labrador, as determined by Klaproth 2·69, as determined by my trial 2·699. Klaproth found that from Ingermania 2·75. Rose found the specific gravity of two specimens from Labrador 2·695 and 2·7025.‡

Before the blowpipe behaves like felspar.

Soluble when in powder, or at least decomposable by muriatic acid.

Its constituents, according to the analyses hitherto made, are as follow:—

	§	‖	¶	**
Silica, . .	55·75	55	55·408	58
Alumina, . .	26·50	24	26·920	27·8
Lime, . .	11·00	10·25	10·892	9·8
Protoxide of iron,	1·25	5·25	1·508	trace
Soda, . .	4·00	3·5	4·392	2·0
Water, . .	0·50	0·5	0·840	1·2
	99	98·5	99·96	98·3

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* Nordenskiöld describes a curious suite of colours displayed by a labradorite found near Ojamo, in Finland. See Poggendorf's Annalen, xix. 179.

† Poggendorf's Annalen, xix. 181.

‡ Ann. de Chim. et de Phys. xxiv. 25.

§ Klaproth, Beitrage, vi. 250. The specimen was from Labrador.

‖ Klaproth, ibid. The specimen was from Ingermania.

¶ By my analysis. The specimen was from Labrador.

** Analyzed by Mr. Bruce in my laboratory. The specimen was from the hills on the south side of Paisley. It was impossible to free it from all

We must omit the fourth of these analyses, because the specimen was not quite pure. The mean of the other three gives us

		Atoms.
Silica,	55·386	27·69
Alumina,	25·810	11·47
Lime,	10·714	3·06
Protoxide of iron,	2·663	0·59
Soda,	3·964	0·99
Water,	0·613	0·54

The atoms of the bases being only 16·11, while those of silica are 27·69, it is obvious that the alumina must be in the state of bisilicate. If we admit the silicate of iron to be accidental, the constitution of the mineral will be

$11\frac{1}{2}$ atoms bisilicate of alumina,
3 atoms silicate of lime,
1 atom silicate of soda;

Or, it may be a simpler view of the compound to consider the silicates of lime and soda as previously united. The constitution of the mineral will then be

3 atoms bisilicate of alumina,
1 atom of silicates of lime and soda.

The formula will be $3AlS^2+(\frac{2}{3}Cal+\frac{1}{3}N)S$.

Sp. 36. *Kaolin.*

Porcelain earth, porcelain clay.

This mineral constitutes an ingredient in a kind of disintegrated granite, where the kaolin or porcelain earth assumes the place of felspar or albite. St. Austle, in Cornwall, and St. Yriez, in France, are well known localities.

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traces of hornblende. A specimen from Canada very like labradorite, and having a specific gravity of 2·461, was analyzed in my laboratory. Its constituents were

		Atoms.
Silica,	50·45	25·22
Alumina,	29·65	13·17
Protoxide of iron,	1·85	0·41
Lime,	9·95	2·84
Soda,	6·00	1·5
Water,	1·65	1·46
	99·55	

This is $10AlS^{1\frac{1}{4}}+CalS+NS^{1\frac{1}{4}}$. It is therefore not labradorite, though it approaches it.

Colour white, often with a shade of yellow or red.

Massive or disseminated in rocks.

Composed of dusty particles cohering slightly; adheres slightly to the tongue; feels meagre.

Specific gravity, as determined by Karsten, 2·216. I found that of St. Austle, Cornwall, 2·484.

Does not fuse per se.

The following table exhibits the constituents of various specimens of kaolin from different localities:

	*	†	†	†	†	†	‡
Silica, . .	52	46·8	58·6	55·8	63·5	50	37·10
Alumina, . .	47	37·3	34·6	26·0	28·0	25	24·48
Potash, . .	—	2·5	2·4	8·2	1·0	2·0	—
Magnesia, . .	—	trace	1·8	0·5	8·0	0·7	—
Lime, . .	—	—	—	—	—	5·5	9·28
Oxide of iron, .	0·33	—	—	1·8	—	8·5	6·98
Water, . .	—	13·0		7·2	—	9·5	19·22
	99·33	99·6	97·4	99·5	100·5	101·4	97·06

From the great difference between these different analyses, it is evident that the specimens were not pure. They were doubtless mixed with quartz, and probably also with felspar.

I consider the probable composition of kaolin to be

$$4(Al+f)S+(Cal+k)S.$$

Sp. 37. *Leelite.*

This mineral, which occurs at Grythittan in Nerike, was named by Dr. Clarke, who subjected it to a chemical analysis.§ It had been previously considered as a compact felspar.

Colour deep flesh red.

Structure compact; fracture splintery and conchoidal.

Has the translucency of horn.

Hardness 6·25; specific gravity 2·606.

Its constituents, by my analysis, are

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* Rose, Karsten's tabellen, p. 37.

† Berthier, Ann. de Chim. et de Phys. xxiv. 107. The first specimen from St. Yriez; the second from Meissen; the third from St. Tropez; the fourth from Mende; and the fifth from Normandy.

‡ By my analysis. The specimen was from St. Austle. The loss was probably potash.

§ Annals of Philosophy, xi. 367.

			Atoms
Silica,	81·91	40·95	28·83
Alumina,	6·55	2·91	2·05
Protoxide of iron,	6·42	1·42	1
Potash,	8·88	1·48	1·04
	103·76		

This is very nearly

2 atoms sepsilicate of alumina,
1 atom sepsilicate of iron,
1 atom sepsilicate of potash.

The formula is $2AlS^7+fS^7+kS^7$; or supposing the silicates of iron and potash previously combined, $AlS^7+(\frac{1}{2}f+\frac{1}{2}K)S^7$.

Berthier has given us the analysis of a mineral from Sahlberg, in Sweden, under the name of *petrosilex*, which has some resemblance to leelite.

It has a deep flesh red colour, is compact and homogeneous, the fracture resembles that of wax, and is very fine grained. It is strongly translucent, is capable of receiving a good polish, and before the blowpipe is fusible into a white enamel, though it is much more infusible than felspar. Its constituents are

		Atoms.
Silica,	79·5	39·75
Alumina,	12·2	5·42
Soda,	6·0	1·50
Magnesia,	1·1	0·44
Oxide of iron,	0·5	0·10
	99·3*	

The atoms of silica are rather more than five times as numerous as those of the bases. If we consider the oxide of iron as accidental, and unite together the magnesia and the soda, the atoms of alumina will be nearly thrice as numerous as those of soda and magnesia together. Hence the constitution of the mineral must be

3 atoms quintosilicate of alumina,
1 atom quintosilicate of magnesia and soda.

The formula will be $3AlS^5+(\frac{3}{4}N+\frac{1}{4}m)S^5$.

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* Ann. de Chim. et de Phys. xxxvi. 20.

Sp. 38. *Spodumene.*[*]

Triphane.

This mineral was first found in the iron mine of Utön, in the province of Södermanland, Sweden, and was described by D'Andrada. It was afterwards discovered by Leonhard, at Sterzing, in the Tyrol; more lately at Killiney, near Dublin; and I have very fine specimens from the United States.

Colour various shades of greyish green, passing into greenish white; streak white.

Texture always foliated. Cleaves in the direction of an oblique prism, with angles of 93° and 87°, but there is no cleavage to determine whether the prism be right or oblique.

Lustre pearly; translucent.

Hardness 6·5; specific gravity, by Leonhard, 3·115;[†] Haidinger states it at 3·170.[‡] I found that from Dublin bay 3·188.

Before the blowpipe it swells to a foliated reddish yellow mass, which on the smallest agitation falls to powder. The outermost portions fuse into small glass globules.

The constituents of this mineral, according to the best analyses hitherto made, are as follow:

Silica, . .	66·40 .	63·288 .	63·812
Alumina, .	25·30 .	28·776 .	28·508
Lithia, . .	8·85 .	5·626 .	5·604
Lime, . .	— .	— .	0·728
Protoxide of iron,	1·45 .	0·794 .	0·828
Protox. of mangan.,	— .	0·204 .	—
Moisture, .	0·45 .	0·775 .	0·360
	102·45[§]	99·463[‖]	99·840[¶]

These analyses approach very near to each other, showing that the specimens examined were pure or nearly so.

The mean of the three gives us

		Atoms.
Silica, .	64·5 .	32·25
Alumina, .	27·528 .	12·23
Lithia, .	6·69 .	3·82

It is obvious that the atoms of silica are twice as numerous as those of the bases. The atoms of lithia are more than a fourth

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[*] From *σποδος, ashes.* So called because it assumes a form like ashes before the blowpipe.

[†] Ann. des Mines, iii. 125.

[‡] Mohs' Mineralogy, ii. 217.

[§] Arfvedson, Afhandlingar, vi. 161.

[‖] Stromeyer, Untersuchungen, p. 426.

[¶] From Killiney, Dublin Bay, analyzed by Captain Lehunt, in my laboratory.

of the atoms of alumina, owing to the excess of that alkali in Arfvedson's analysis. In the other two analyses it approaches very near to a fourth. We may therefore consider spodumene as composed of

4 atoms bisilicate of alumina,
1 atom bisilicate of lithia.

The formula is $4AlS^2+LS^2$.

Sp. 39. *Petalite.*[*]

Berzelite.

This mineral, like the preceding, was first observed by D'Andrada, in the iron mine of Utön, where it is said to constitute a vein. I have seen specimens also from the United States.

Colour milk-white, sometimes with a shade of red or flesh-red. Sometimes it is greenish, probably from an admixture of chlorite. Streak white.

Occurs only massive; lamellar in one direction. It has a two-fold cleavage parallel to the faces of a prism of 100° and 80°, according to Brooke. Mr. Phillips thinks that the summit of the prism is oblique.

Lustre vitreous, inclining to resinous. It inclines to pearly upon the perfect faces of cleavage.

Translucent; brittle.

Hardness 6·5; specific gravity, as determined by Arfvedson 2·42,[†] by Dr. Clarke 2·45,[‡] by C. G. Gmelin 2·426.[§]

Exposed to the heat of the blowpipe on charcoal, it becomes glassy, semitransparent, and white; but melts with difficulty, and only on the edges. With borax it fuses into a clear colourless glass.

When gently heated it emits a blue phosphorescent light.

When boiled in acids it is partly decomposed.

Its constituents, according to the analyses of Arfvedson and Gmelin, are as follow:

Silica,	79·212	74·17
Alumina,	17·225	17·41
Lithia,	5·761	5·16
Lime,	trace	0·32
Water,	—	2·17
	102·198[‖]	99·23[¶]

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[*] From πεταλον, *a leaf*.

[†] Afhandlingar, vi. 147.

[‡] Annals of Philosophy, xi. 198.

[§] Ibid, xv. 341.

[‖] Arfvedson, Afhandlingar, vi. 145.

[¶] C. G. Gmelin, Annals of Philosophy, xv. 343.

There seems to have been an excess of silica in the specimen analyzed by Arfvedson. Gmelin's analysis gives us

		Atoms.
Silica, .	37·08 .	12·6
Alumina, .	7·73 .	2·62
Lithia, .	2·94 .	1

If we were to admit 0·6 of alumina to be combined with 0·6 silica, and to be accidental, petalite would consist of

2 atoms quatersilicate of alumina,
1 atom quatersilicate of lithia.

The formula is $2AlS^4+LS^4$.

The last described eleven species in this section were originally confounded together under the name of felspar, though they all differ in their chemical constitution, and in their crystalline form. It may be worth while to give a synoptical view of the primary crystal, and of the composition of these eleven species, that the student may be enabled to distinguish them readily from each other.

	Murchisonite.	Gabronite	Spodumene.	Anorthite.	Albite.	Labradorite.	Felspar.	Glassy felspar.	Kaolin.	Leelite.	Petalite.
M on T	90°	90°	93°	117°28′	117°53′	119°16′	120°35′	121°35′	Does not crystall.	not crystallized.	100°
P on M	106°50′	99°	—	94°12′	86°24′	93°28′	90°	Unknown.			Unknown.
P on T	90°	90°	—	110°57′	115° 5′	114°48′	67°15′				

The constituents are as follow:

Murchisonite,	$3AlS^{3\frac{1}{4}}+KS^{3\frac{1}{4}}$.
Gabronite,	$3AlS^2+(K,N)S^2$.
Spodumen,	$4AlS^2+LS^2$.
Anorthite,	$7AlS+2CS+MS$.
Albite,	$3AlS^3+NS^3$.
Labradorite,	$3AlS^2+(\frac{2}{3}C+\frac{1}{3}N)S$.
Felspar,	$3AlS^3+KS^3$.
Glassy felspar,	$4AlS^3+(\frac{5}{9}K+\frac{4}{9}N)S^3$.
Kaolin,	$4(Al+f)S+(C+K)S$.
Leolite,	$2AlS^7+fS^7+KS^7$.
Petalite,	$2AlS^4+LS^4$.

Sect. 4. *Double hydrous Aluminous Salts soluble in Water.*

These salts are not numerous, as they amount only to three, constituting the different species of *alkaline alum* known in commerce.

Sp. 1. *Ammonia-Alum.*

This alum, which approaches very nearly in its properties to the common potash-alum of this country, occurs at Tackermig, in Bohemia, and was described by Von Herder, in the year 1818.*

It has a greyish-white colour; occurs amorphous, but by solution and evaporation may be obtained in regular octahedrons.

Lustre resinous and shining.

Structure fibrous; cross fracture conchoidal.

Varies from transparent to translucent.

Soft; specific gravity 1·56 at the temperature of 44°·5.

Has the look of alum, is soluble in water, and when heat is applied exhibits nearly the same phenomena as common alum.

Its constituents, according to the analysis of Mr. mine-commissioner Gruner, are,

Sulphuric acid,	33·682	or	19·24
Alumina, .	10·750		6·31
Ammonia, .	3·619		2·125
Water, .	51·000		29·94
	99·051†		

These approach very nearly to

4 atoms sulphuric acid,	20
3 atoms alumina, .	6·75
1 atom ammonia, .	2·125
25 atoms water, .	28·125

Hence the constituents are doubtless

3 atoms sulphate of alumina,
1 atom sulphate of ammonia,
25 atoms water.

At least these are the constituents of ammonia-alum, when made artificially.

Sp. 2. *Potash-Alum.*

This salt occurs occasionally, though rarely, in pretty regular octahedral crystals. I have specimens of it from the neighbourhood of Whitby, and from Mount Etna.

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* Gilbert's Annalen, lxix. 54.

† Ibid. 218.

It is white and translucent, or transparent. The crystal is the regular octahedron, having frequently all its angles replaced by tangent planes.

Hardness 2·75; specific gravity 1·753.

Taste sweetish, astringent, and acid.

Reddens vegetable blues and is soluble in water.

Melts when heated; before the blowpipe froths up and swells, and at last loses its acid.

Its constituents are

3 atoms sulphate of alumina, .	21·75
1 atom sulphate of potash, .	11·00
25 atoms water, . . .	28·125
	60·875

This is the species of alum usually manufactured in Great Britain.

Sp. 3. *Soda-Alum.*

This species of alum occurs native in the Province of St. Juan, situated to the north of Mendoza, on the east side of the Andes, in about south latitude 30°. The specimens which I examined were sent to Dr. Hooker by Dr. Gillies of Edinburgh, who at that time lived in Mendoza.

It is white, and composed of fibres adhering longitudinally, and having a certain breadth, but very thin. It bears some resemblance to fibrous gypsum, but is harder, not being scratched by the nail.

Sectile; outer fibres white, and only slightly translucent, as if they had lost a portion of their water. But the internal fibres are transparent, and have a glassy, or rather a silky aspect, showing that they retain water of crystallization.

Specific gravity of the transparent portion 1·88; hardness 3.

Tastes precisely like alum; very soluble in water. At 62° 100 parts of water dissolve 377·3 parts of the alum, and boiling water dissolves any quantity whatever. When exposed to heat, it exhibits nearly the same phenomena as common alum.

I found its constituents

Sulphuric acid, .	20·000
Alumina, . .	6·360
Silica, . . .	0·012
Lime, . . .	0·136
Peroxide of iron, .	0·110
Protoxide of iron, .	0·423
Soda, . . .	4·000
Water, . .	22·209
	53·250

The sulphuric acid constitutes 4 atoms.

The alumina wants 0·29 of three atoms, but the quantity of lime and oxides of iron present are just equivalent to 0·29 alumina, and are substituted for it.

The soda constitutes 1 atom.

The water is only 0·291 less than 20 atoms. Hence it is obvious that the true constitution of this salt is

3 atoms sulphate of alumina,	21·75
1 atom sulphate of soda, .	9
20 atoms water, .	22·50
	53·25

It contains 5 atoms of water less than soda-alum, artificially crystallized.

Sect. 5. *Double Hydrous Aluminous Sulphates and Phosphates insoluble in Water.*

These species amount only to three. I place them by themselves, because they do not well agree with the minerals in the other sections of this genus.

Sp. 1. *Alumstone.*

Walnyn.

This mineral was first observed at Tolfa, in the neighbourhood of Rome; afterwards in Hungary; and Cordier has shown that it is very common in volcanic rocks, but that it never occurs any where else.*

Colour white, greyish-white, or sometimes yellowish-white.

Most commonly amorphous, but it is observed also crystallized in rhomboids approaching very near to cubes, the angles being 89° and 91°. In some crystals the apex of the rhomboid is replaced by tangent planes. The size of these crystals varies from 0·03937, to 0·11811 of an inch in length.

Hardness 3·5; specific gravity 2·7517. The amorphous specimens (owing, probably, to cavities) are lighter; Hauy states it as 2·587.

Fracture foliated in a direction perpendicular to the axis of the rhomboid. In all other directions the fracture is conchoidal.

Lustre vitreous; fragments irregular, with blunt edges; Easily pulverized.

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* Ann. des Mines, iv. 205, and v. 303.

Feels harsh, and does not stain.

Decrepitates before the blowpipe. Gives out sulphurous acid when heated on platinum foil, and tastes of alum when applied to the tongue. In a strong heat loses its acid and becomes tasteless.

The constituents of the pure crystals, according to the analysis of Cordier, are

		Atoms.	
Sulphuric acid,	35·495	7·1	4·25
Alumina,	39·654	17·61	10·54
Potash,	10·021	1·67	1
Water and loss,	14·830	13·18	7·96
	100		

These atomic numbers approach pretty nearly

3 atoms trisulphate of alumina,
1 atom sulphate of potash,
8 atoms water.

From the mode of analysis followed, a little of the potash would remain adhering to the alumina. Hence the apparent excess of alumina and of sulphuric acid.

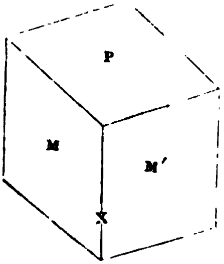
Sp. 2. *Wavellite.*

Devonite, hydrargillite, lasionite, hydrous diphosphate of alumina.

This mineral was discovered a good many years ago by Dr. Wavell, in small veins and in cavities, in a tender clay slate near Barnstaple in Devonshire; and it was named by Dr. Babington from the discoverer.

Its colour is white, passing into various shades of green, grey, yellow, brown, and black.

It is found almost always in minute crystals, which commonly adhere together, forming hemispherical or globular concretions, from a very small size to an inch, or even more, in diameter. The primary form of the crystal is a right rhombic prism, in which M on M′ is 122° 15′.



The base P is usually replaced by a dihedral summit, the faces of which are inclined on each other at an angle of 107° 26′. The edge X is frequently replaced by two, and sometimes by four planes.

Lustre of cleavage planes intermediate between pearly and vitreous.

Hardness 3·25; specific gravity of the variety from Barnstaple 2·337;[*] of the variety at St. Stephens, Cornwall, 2·253;[†] of the Irish variety 2·3616, as determined by Mr. Richardson.

Before the blowpipe it loses its lustre and transparency, but does not melt. With boracic acid and iron wire it yields a globule of phosphuret of iron.

The constitution of this mineral was discovered by Fuchs, and his analysis was confirmed by that of Berzelius. The following table shows the results obtained.

	‡	§	‖
Phosphoric acid, . .	35·12 .	33·40 .	34·65
Fluoric acid, . .	— .	2·06 .	—
Alumina, . .	37·20 .	35·35 .	34·00
Lime, ...	— .	0·50 .	—
Oxides of iron & manganese,	— .	1·25 .	2·15
Water, ...	28·00 .	26·80 .	28·75
	100·37	99·36	99·55

These analyses give us as the constitution of wavellite,

9 atoms diphosphate of alumina,
½ atom bifluate of alumina,
14½ atoms water.

Or doubling the number to get rid of fractions,

18 atoms diphosphate of alumina,
1 atom bifluate of alumina,
29 atoms water.

But Mr. Richardson's analysis, which was made with very great care upon a pure specimen, gives

1½ atom phosphoric acid,
3 atoms bases,
5 atoms water.

Hence the formula will be $3Al^2 \dot{P}h + 5Aq$.

This mineral has been found near Cork in Ireland, in the Shiant Isles, Scotland; in Brazil, Bohemia, Mount Vesuvius, and various other localities.

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[*] Haidinger, Mohs' Mineralogy, iii. 170.

[†] Gregor, Nicholson's Jour. xiii. 249.

[‡] Fuchs, Schweigger's Jour. xxiv. 121.

[§] Berzelius, Ann. de Chim. et de Phys. xii. 12.

[‖] The Irish variety analyzed in my laboratory, by Mr. Richardson.

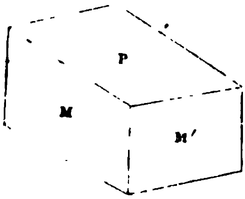
Sp. 3. *Lazulite.*

Azurestone. Hydrous diphosphate of alumina and magnesia.

This mineral occurs near Werfen in Salzburg, in the valleys called Schlamming and Radelgraben, in narrow veins traversing clay slate.

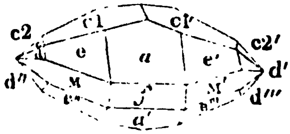
The colour of the mineral is pale blue of various shades; particularly deep and beautiful if viewed in the direction of one line, apparently the axis of the crystal; while perpendicular to it, it is of a pale greenish blue colour; streak white.

It is most frequently granular or in pieces, about the size of a hazel nut, but it occurs also crystallized. The primary form of the crystal is a regular rhombic prism.



M on M′ 121° 30′

According to the measurement of Mr. W. Phillips. In general the edges are replaced by one or more planes. We give a representation of a superb crystal in the possession of Mr. Brooke, with the inclinations of the planes as measured by Mr. William Phillips.



M on e or M′ on e′	138° 45′
M on d, . .	140 30
M or M′ on *f*, .	150 45
a on *a*′, . .	91 30
a on cl or cl′, . .	129 10
a on e or e′ or *a*′ on e″ or e‴,	158 10
cl on cl′, . .	120 40
cl on c2′ or cl′ on c2′	150
e on d or e′ on d′, .	162 36
cl on e or cl on e′, .	139 25
cl on d, . .	141 20

Fracture uneven; surface smooth, all the faces alike.

Lustre vitreous; translucent, at least on the edges; sometimes opaque.

Hardness 5 to 5·5; brittle; specific gravity, as determined by Fuchs, 3·057.

Before the blowpipe it intumesces a little, and assumes a glassy appearance when the heat is highest, but does not melt. With borax it yields a clear colourless globule. Treated with boracic acid and a piece of iron wire, it gives a globule of phosphuret of iron.

Its constituents, as determined by Fuchs, are as follow:

		Atoms.	
Phosphoric acid,	41·81	9·29	2·52
Alumina,	35·73	15·88	4·25
Magnesia,	9·34	3·78	1
Silica,	2·10	1·05	0·28
Protoxide of iron,	2·64	0·58	0·15
Water,	6·06	5·38	1·44
	97·68*		

The atoms of acids (including the silica) amount to half the atoms of the bases. Hence the mineral is composed of disalts. Supposing the silica to be united with alumina and oxide of iron, and that these disilicates are accidental, lazulite will be

4 atoms diphosphate of alumina,
1 atom diphosphate of magnesia,
1½ atoms water.

Whether the mineral which occurs at Vorau in Austria, and described and analyzed by Klaproth in 1792,† be the same with the mineral here described, remains to be determined. From Mr. Brooke's measurement, its crystals are right rhombic prisms with angles of 121° 30′, and 58° 30′.

Sp. 4. *Bluespar.*

Prismatoidal azure spar, feldspath bleu of Hauy.

This mineral occurs in masses and in indistinct crystals imbedded in quartz, and mixed with mica, in the valley of Freschnitz near Krieglach on the Mürz in Upper Stiria.

Colour smalt blue, inclining sometimes to white or green; streak white.

The crystals, by Hauy's description, seem to be right oblique prisms; cleavage indistinct; fracture uneven.

Lustre vitreous, inclining to pearly on faces of cleavage.

Translucent on the edges; often nearly opaque.

Brittle; hardness 5½ to 6; specific gravity 3·024, as determined by Haidinger.

Before the blowpipe it loses its colour but does not melt. It dissolves slowly and with difficulty in borax. With boracic acid and iron wire it yields a globule of phosphuret of iron.

Its constituents, as determined by Brandes, are

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* Schweigger's Jour. xxiv. 373.

† Beitrage, i. 197.

		Atoms.
Phosphoric acid,	43·32	9·62
Silica,	6·50	3·25
Alumina,	34·50	15·33
Magnesia,	13·56	5·42
Lime,	0·48	0·13
Protoxide of iron,	0·80	0·17
Water,	0·50	
	99·66	

There can be no doubt that it is a diphosphate of alumina and magnesia like the preceding species. The silica, lime, and protoxide of iron, are most probably accidental ingredients derived from the rock. The constituents are

3 atoms diphosphate of alumina,
1 atom diphosphate of magnesia.

The difference between lazulite and blue spar lies in the proportion of the two diphosphates which each contains.

Sect. 6. *Double Hydrous Aluminous Silicates*, or *Zeolites.*

The term *zeolite* was first applied by Cronstedt, to a mineral which he describes as frothing and swelling before the blowpipe like borax. The specimens which he describes were from Svappavari in Torneo Lappmark, and from Iceland.* Hauy afterwards divided the zeolite of Cronstedt into 4 species.† Since that time many additions have been made to their number. I mean to class under the common name of zeolites all the double hydrous aluminous silicates. They owe their property of frothing when heated, to the water which they contain. This water is easily driven off by a heat scarcely amounting to ignition, and on its escape, the mineral either falls to powder or melts into a white enamel, according to the nature of the constituents. They occur most frequently in trap rocks, especially amygdaloid, and in lava. The hills in the neighbourhood of Glasgow and in the north of Ireland, are particularly rich in species belonging to this beautiful section of the mineral kingdom. The species belonging to the zeolites amount at present to no fewer than 38.

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* Kong. Vet. Acad. Handl., 1756, p. 120. It was from the frothing before the blowpipe that the word *zeolite* is derived, from the Greek word *Ζεω, to boil.*

† Jour. des Mines, iii. 14, 86.

Sp. 1. *Stellite.**

This mineral has hitherto been observed only in the rifts of a greenstone rock, situated on the banks of the Forth and Clyde Canal, a little to the east of Kilsyth. Quantities of this rock had been blasted and brought to the neighbourhood of Glasgow. My son accidentally observed the stellite on one of these rocks while we were walking along the canal bank.

Colour snow-white.

It consists of a congeries of small crystals issuing like rays from several centres. Each circle of crystals may be about an inch in diameter. The different circles run into each other, so that the termination of each crystal is confused. They seem oblique four-sided prisms; but their inclinations cannot be measured.

Tough, having some slight resemblance to asbestus, or still more to nemalite.

Lustre silky, shining; translucent.

Hardness 3·25; specific gravity 2·612.

Before the blowpipe fuses into a beautiful white enamel. With carbonate of soda fuses with effervescence into a translucent white bead. With borax it fuses into a perfectly transparent glass when the quantity of stellite is small; if it be larger, the bead exhibits a silica skeleton. With biphosphate of soda it fuses very slowly and imperfectly into a colourless bead. But a great deal of white matter remains undissolved.

Its constituents, by my analysis, are

		Atoms.	
Silica,	48·465	24·23	10·84
Lime,	30·960	8·84	3·96
Magnesia,	5·580	2·23	1·0
Alumina,	5·301	2·31	1·03
Protoxide of iron,	3·534	0·78	0·35
Water,	6·108	5·42	2·43
	99·948		

The constituents are very nearly

11 atoms silica,
4 atoms lime,
1 atom magnesia,
1 atom alumina,
2½ atoms water.

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* From *stella, a star,* because the crystals spread in a star-like form on the greenstone.

The constitution of stellite seems to be

4 atoms bisilicate of lime,
1 atom bisilicate of magnesia,
1 atom silicate of alumina,
2½ atoms water.

The formula is $4CS^2+MS^2+AlS+2\frac{1}{2}Aq$.

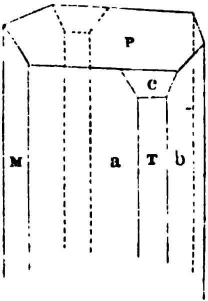
Sp. 2. *Thomsonite.*

Mesotype of Hauy in part—needle zeolite of Werner in part.

This mineral was first recognised as a peculiar species by Mr. Brooke, who determined its characters. It occurs at Lochwinnoch, and near Kilpatrick, both of which localities are within a few miles of Glasgow, and in both places it is imbedded in an amygdaloidal rock.

Colour snow-white.

Occurs usually crystallized; but there is a brown coloured amorphous mineral found at Ballimony, in Ireland, and having a specific gravity of 2·289, which proved upon analysis to be an impure variety of the same species. The primary form of its crystal, as Mr. Brooke has shown,* is a right rectangular prism, with a square base. The usual crystal is that represented in the margin, in which P, M and T are the primary faces. The faces *a*, *b* are tangents to the lateral edges of the prism, and the faces *c* are the result of a decrement of one row on the edge of the terminal plane. The height of the prism is equal to about four times its breadth.



M on a 135° 30′

a on a 90° 40′

Structure foliated; cleaves readily parallel to the faces M, T; fracture uneven.

Lustre vitreous, inclining to pearly.

From transparent to translucent.

Hardness 4·75; brittle.

Specific gravity from 2·29 to 2·36966.

Before the blowpipe it swells up like borax, and becomes opaque and snow-white, but does not melt. When exposed to a red heat it becomes opaque, very white and shining like enamel. The edges are rounded, but it does not altogether lose its shape.

The following table exhibits the constituents of this mineral, according to the best analyses hitherto made:

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* Annals of Philosophy, xvi. 194.

	*	*	†	†	‡
Silica, . . .	36·80	37·560	34·63	37·08	38·30
Alumina, . .	31·36	31·960	32·35	33·02	30·20
Lime, . .	15·40	15·096	18·65	10·75	13·54
Magnesia, . .	0·20	1·080	—	—	—
Protoxide of iron,	0·60	0·720	—	—	—
Soda, . . .	—	—	1·25	3·70	4·53
Water, . .	13·00	13·200	14	13·00	13·10
	97·36	99·616	100·88	97·55	100·07

I consider the first specimen analyzed by me as the purest specimen hitherto examined, and the second analysis as the most correct. It gives us the atomic constituents of thomsonite as follow:

		Atoms.
Silica, .	18·78 .	3·96
Alumina, .	14·20 .	3
Lime, .	4·31 .	0·91
Magnesia, .	0·43 .	0·09
Protoxide of iron,	0·16 .	0·03
Water, .	11·73 .	2·47

These numbers, if we include the magnesia along with the lime, and leave out the oxide of iron as accidental, are very nearly equivalent to

3 atoms silicate of alumina,
1 atom silicate of lime,
2½ atoms water.

The formula is $3\text{AlS}+\text{CalS}+2\frac{1}{2}\text{Aq}$.

Sp. 3. *Natrolite.*[§]

Mesotype, crocalite, edelite, hoganite, feather zeolite.

This mineral was first distinguished from the tribe of zeolites by Hauy, who gave it the name of *mesotype*.[‖] Klaproth analyzed a mamillary matter from Högau, near the lake of Constance, of a light yellowish brown colour, to which he gave

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[*] By my analysis. The specimens were from Lochwinnoch, near Greenock. The first analysis was inserted in the Annals of Philosophy, xvi. 409. The second was made with great care on a specimen from the same locality, to determine whether it contained an alkali.

[†] Also by my analysis. The specimens were from the neighbourhood of Dumbarton.

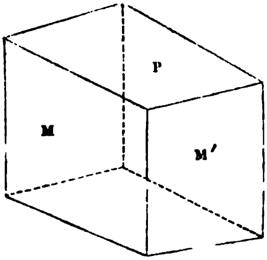
[‡] Berzelius, Edinburgh Journal, vii. 9.

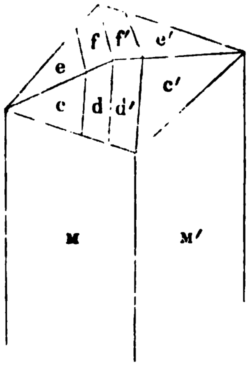
[§] From *natron*, *soda*, on account of the great quantity of soda which it contains.

[‖] Jour. des Mines, xiv. 86.

the name of *natrolite*.* Mr. Smithson sometime afterwards demonstrated by analysis that natrolite and mesotype belong to the same species.† Fuchs and Gehlen soon after showed that the mesotype of Hauy constitutes in fact two distinct species.‡ To the one now under consideration they gave the name of *mesotype*, to the other that of *scolezite*. Still more lately Mr. Brooke, without being aware of what these chemists had done, drew precisely the same conclusion,§ distinguishing *scolezite* by the name of *needlestone*.

Colour white, sometimes with a shade of red or brown; often grey; streak grey.





It occurs pulverulent, fibrous and crystallized. The primary form, obtained by cleavage, is a right rhombic prism.

M on M′ 91° 10′, by the measurement of Gehlen and Fuchs, and also of Mr. Brooke. The crystal is almost always terminated by a four-sided pyramid, or very commonly by eight faces, constituting two four-sided pyramids of different inclinations.

M on c	116°	37′
c on e	126	47
c on d	178	45
c on c′	143	14
d on d′	145	44

These are the measurements of Mr. Brooke. Those given by Mr. William Phillips are slightly different.‖

Lustre vitreous; transparent to translucent; brittle.

Hardness 4·5; specific gravity from 2·139 to 2.2303. The last was a very fine crystallized specimen from Auvergne, the analysis of which is given below.

When heated it becomes electric.

Before the blowpipe froths, gives a phosphorescent light, and melts into a white semitransparent enamel.

Gelatinizes in acids, even after exposure to a red heat.

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[*] Beitrage, v. 44.

[†] Phil. Trans. 1811, p. 171.

[‡] Schweigger's Jour. xviii. 11.

[§] Annals of Philosophy, xvi. 193.

[‖] Mineralogy, p. 123.

Its constituents, by the best analyses hitherto made, are as follow:

	*	†	‡	§	‖
Silica, . .	48	48	48·04	49	47·56
Alumina, .	24·25	26·5	25·03	27	26·42
Protoxide of iron,	1·75	—	—	—	0·58
Soda, . .	16·50	16·2	16·76	17	14·932
Lime, . .	—	—	—	—	1·400
Water, .	9·00	9·3	9·65	9·5	10·440
	99·50	100	99·48	102·5	101·332

The first three analyses very nearly agree. If we take mine, which was that of a very fine and pure specimen, we have the atomic proportions as follow:

		Atoms.
Silica, . .	24·02 .	5·73
Alumina, .	11·12 .	2·65
Soda, . .	4·19 .	1
Water, . .	8·57 .	2·04

The alumina is rather less than three atoms, but the quantity obtained by Smithson, and by Fuchs and Gehlen, was greater than in my analysis. It would seem then that natrolite is composed of

3 atoms silicate of alumina,
1 atom tersilicate of soda,
2 atoms water.

The formula is $3AlS+NS^3+2Aq$.

Sp. 4. *Mesolite.*¶

Perhaps this mineral should rather be considered as a variety of *natrolite*, than as a peculiar species. It possesses the crystalline form of natrolite, but in several of its other characters it approaches much nearer to scolezite. Fuchs and Gehlen first pointed it out as a peculiar species, and gave

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* Klaproth, Beitrage, v. 44.

† Fuchs and Gehlen, Schweigger's Jour. xviii. 11.

‡ By my analysis. A fine specimen from Auvergne.

§ Smithson, Phil. Trans. 1811, p. 171.

‖ By my analysis. The specimen was from Antrim. It was crystallized; but full of holes, through which water containing iron seems to have filtered. Specific gravity 2·139.

¶ From *μεσος, middle*, and *λιθος, a stone.* Because it is intermediate between natrolite and scolezite.

it the name which it bears, because they considered it as intermediate between natrolite and scolezite.

It occurs in the same situations as natrolite and scolezite, in amygdaloidal cavities, and is much more common than either of them. By far the greater number of specimens of zeolite from Iceland and the Faroe islands belong to it. Most of the needlestones found in the amygdaloidal rocks in Scotland belong to it likewise.

Colour white.

Usually crystallized in four-sided prisms terminated by four-sided pyramids. The primary form is a right rhombic prism, M on M′ 91° 25′, according to Fuchs and Gehlen, 91° 10′ according to Brooke.

The lustre, transparency, hardness, electric properties, and the action of acids on mesolite, are the same as in scolezite.

Specific gravity, as determined by Dr. Freysmuth, 2·333.[*] I found it to vary in different specimens from 2·125 to 2·218.

Before the blowpipe it becomes opaque and curls up, but not so much as scolezite, neither does it give out quite so much light. It melts with the extrication of many air bubbles into a porous and almost opaque bead.

Its constituents, as determined by the best analyses hitherto made, are as follow:—

	†	†	†	†	‡	§
Silica,	47·00	46·78	47·46	46·04	48·028	42·188
Alumina,	26·13	25·66	25·35	27·00	26·660	30·412
Lime,	9·35	10·06	10·04	9·61	5·472	4·908
Soda,	5·47	4·79	4·87	5·20	8·320	12·548
Water,	12·25	12·31	12·41	12·36	11·720	10·966
	100·2	99·6	100·13	100·21	100·2	101·018

There are two differences between the constitution of mesolite and natrolite. It contains more water, and part of the soda is replaced by lime. Its constituents may be stated thus:

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[*] Schweigger's Jour. xxv. 426.

[†] Fuchs and Gehlen. The first specimen was from Faroe, and was needleform. The second and third were from Iceland, and were fibrous. The fourth was from the Tyrol, and also fibrous.

[‡] By my analysis. The specimen was from the neighbourhood of Kinross.

[§] By my analysis. The specimen was from Antrim. It was a white coloured mass composed of minute crystals. Specific gravity 2·125. Its constituents deviate a good deal from the rest.

3 atoms silicate of alumina,
1 atom tersilicate of lime and soda,
3 atoms water.

It seems to consist of a mixture or combination of natrolite and scolezite, probably only a mixture, as the proportion between the lime and soda varies a good deal in the different analyses.

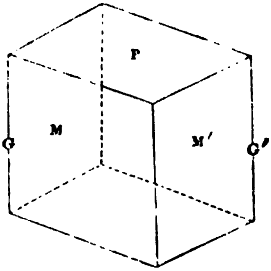
Sp. 5. *Scolezite.*

Needlestone.

This species was first distinguished from mesotype, with which it had been previously confounded, by Fuchs and Gehlen, who pointed out the peculiarity of its crystalline shape, and its composition in 1816.[*] Mr. Brooke described its crystalline form, and recognised it as a peculiar species in 1820,[†] without being aware of what had been already done by Fuchs and Gehlen.

Scolezite occurs in Iceland, the Faroe Islands, Staffa, &c., in the vesicular cavities of amygdaloid. It occurs also in veins in Kilpatrick hills.

Colour white.



Usually crystallized. Primary form a right rhombic prism.

M on M′ 91° 20′, as measured by Fuchs and Gehlen, and by Brooke. The prisms are larger than those of natrolite, and their faces are smoother and more brilliant. The prism is often six-sided by the replacement of the edges G G′ by tangent planes. The prism is frequently terminated by a four-sided pyramid, the faces of which make an angle of 116° 35′ with the corresponding faces of the prism. The needles are often too small to admit of measurement.

Lustre vitreous; scratches glass feebly; specific gravity, as determined by Fuchs and Gehlen 2·214. Mr. Brooke states it at 2·27.

Soluble in nitric and muriatic acid before, but not after ignition.

Becomes electric when heated, the apex of the terminating pyramid being positive, the other extremity negative.

Before the blowpipe in the exterior flame it becomes

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[*] Schweigger's Jour. xviii. 13.

[†] Annals of Philosophy, xvi. 193.

opaque, and then twists itself up like a worm.[*] If the action of the exterior flame be continued for some time, the fragment melts into a very bulky and shining slag. When this slag is exposed to the interior flame, it falls down and is converted into a vesicular and slightly translucent bead.

The constituents of scolezite, as determined by Fuchs and Gehlen, are as follow :—

	†	†
Silica, . .	46·19	46·75
Alumina, . .	25·88	24·82
Lime, . .	13·86	14·20
Soda, . .	0·48	0·39
Water, . .	13·62	13·64
	100·03	99·80

I analyzed a specimen in my cabinet, locality unknown; the result was almost identical with the first analysis of Fuchs and Gehlen. The mean of these two analyses is,

			Atoms.
Silica, . .	46·47	23·23	5·80
Alumina, . .	25·35	11·26	2·81
Lime, . .	14·03	4·00	1
Soda, . .	0·43	0·40	0·10
Water, . .	13·63	12·11	3·03

This approaches sufficiently near

3 atoms silicate of alumina,
1 atom tersilicate of lime,
3 atoms water.

So that it differs from natrolite by the substitution of lime for soda, and by the addition of another atom of water. This is the reason why mesolite, which is a mixture of natrolite and scolezite, contains more water than the former of the minerals, and less than the latter.

Sp. 6. *Zeuxite.*[‡]

The mineral which I distinguish by this name was found in 1814 in considerable quantity in the Huel Unity mine, about three miles east of Redrath, in Cornwall. At that time

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[*] Hence the name *scolezite*, from σκωληξ, a *worm*.

[†] Schweigger's Jour. xviii. 16. The first specimen from Faroe, the second from Staffa.

[‡] From ζευξις, *connexion*, because it occurs in the *united mines*, Cornwall.

I considered it as a variety of *asbestous actinolite* of Werner, and published an analysis of it under that name.* But a more careful examination, and a more accurate analysis of it have satisfied me that it constitutes a peculiar species, which I have called *zeuxite*, in allusion to the Huel Unity where it was found.

Colour brown with a slight shade of green, when we view a considerable mass of it together, but not perceptible in a single crystal.

Composed of very small flat rectangular prisms interwoven in such a way as to leave cavities between them. From this structure the mineral may be called promiscuous fibrous.

Lustre vitreous, glistening; opaque.

Hardness 4·25; but the crystals adhere to each other so loosely that the mineral is easily crumbled between the fingers.

Specific gravity 3·051.

When heated in a glass tube it gives out water containing a trace of muriatic acid, and emits an odour which may be termed bituminous. By this treatment it loses rather more than five per cent. of its weight. Before the blowpipe its colour becomes deeper, and the crystals lose their edges and assume a scoriaceous appearance, but I did not succeed in fusing them into a glass globule. With carbonate of soda it fuses easily into an opaque bottle green glass. With borax it effervesces, and is converted into a dark brown glass so very deep in the colour that it appears opaque.

Its constituents, by my analysis, are,

		Atoms.	
Silica, . .	33·480	16·74	23·9
Alumina, . .	31·848	14·15	20·2
Protoxide of iron,	26·010	5·78	8·25
Lime, . .	2·456	0·70	1
Water, . .	5·280	4·68	6·68
	99·074		

If we admit the atom of lime to be united with 1½ atom protoxide of iron in the state of sesquiferrite of lime, and to be accidental, the mineral will be a compound of

3 atoms silicate of alumina,
1 atom disilicate of iron,
1 atom water.

The formula is $3AlS+f^2S+1Aq$.

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* Annals of Philosophy, iv. 299.

Sp. 7. *Ittnerite.*

This mineral was first described by M. Von Ittner, and it was considered as a variety of sodalite till Dr. C. G. Gmelin analyzed it, and pointed out its peculiar characters. It has hitherto been found only at Kayserstuhl, near Freyburg, in Saxony.

Colour bluish, smoke, and ash grey.

Occurs massive, and seemingly in rhomboidal dodecahedral crystals.

Fracture between imperfect conchoidal and uneven.

Lustre resinous, slightly approaching vitreous.

Hardness 7; specific gravity 2·3854.

Before the blowpipe per se fuses easily with frothing, and the evolution of a gas like sulphurous acid, and forms a vesicular opaque glass, which becomes blue when treated with nitrate of cobalt. With borax it fuses easily into a colourless translucent glass. With biphosphate of soda it is readily decomposed leaving a silica skeleton. With carbonate of soda it fuses into an opaque glass. When heated in a glass tube it gives out much water.

It readily gelatinizes in acids.

Its constituents, by Gmelin's* analysis, are,

		Atoms.	
Silica,	34·016	17·008	11·41
Alumina,	28·400	12·62	8·47
Lime,	5·235	1·49	1
Soda,	11·288	2·82	1·88
Potash,	1·565	0·26	0·17
Peroxide of iron,	0·616	0·12	0·08
Gypsum,	4·891	—	—
Common salt,	1·618	—	—
Water with some sulphuretted hydr.,	10·759	9·56	6·41
	98·388		

The gypsum and common salt are doubtless accidental ingredients. The other ingredients are

8½ atoms silicate of alumina,
2 atoms silicate of soda,
1 atom silicate of lime,
6½ atoms water.

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* Schweigger's Jahrbuch, vi. 74.

If we allow for a small deficiency of silicate of alumina, the constituents might be thus arranged:—

3 atoms silicate of alumina,
1 atom silicate of soda and lime,
2 atoms water.

The formula would then be $3\text{AlS}+(\frac{2}{3}\text{N}+\frac{1}{3}\text{Cal})\text{S}+2\text{Aq}$.

Sp. 8. *Plinthite.**

I give this name to a mineral which occurs in the County of Antrim, in Ireland, from its brick red colour.

Colour brick red.

Texture earthy; fracture flat conchoidal.

Opaque; does not adhere to the tongue.

Hardness 2·75; specific gravity 2·342.

Before the blowpipe per se it blackens, but does not become magnetic; nor can it be fused. With carbonate of soda it does not readily combine. Neither does it fuse with borax or biphosphate of soda.

Its constituents, by my analysis, are,

		Atoms.	
Silica,	30·88	15·44	20·86
Alumina,	20·76	9·22	12·46
Peroxide of iron,	26·16	5·23	7·06
Lime,	2·60	0·74	1
Water,	19·60	17·42	23·54
	100		

These atomic numbers correspond with

12·46 atoms silicate of alumina,
7·06 atoms silicate of iron,
1 atom silicate of lime,
23·54 atoms water.

Or, if we consider the silicates of iron and lime to be previously united, the constitution of the mineral will be

3 atoms silicate of alumina,
2 atoms silicate of iron and lime,
6 atoms water,

And the formula $3\text{AlS}+2(\frac{7}{8}\text{f}+\frac{1}{8}\text{Cal})\text{S}+6\text{Aq}$.

Sp. 9. *Bonsdorfite.*

I give this name to a mineral described and analyzed by

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* From *πλινθος, a brick.*

Bonsdorf.* It occurs in a red granite at Biskopsokern, near Obo, in Finland. It is accompanied by a black grey dichroite, and a greenish coloured mineral, which Bonsdorf considers as a soda spodumene.

Colour greenish brown, or dark olive green. When viewed by transmitted light, thin lamellæ may be perceived of a light greenish colour.

Occurs crystallized in regular six-sided prisms. In general the lateral edges of the prism are replaced by so many planes that the prism assumes nearly the appearance of a cylinder.

Texture foliated; folia perpendicular to the axis of the prism; cross fracture conchoidal.

Lustre of the faces like that of talc, of the cross fracture waxy.

Translucent when in thin plates; when in thick pieces opaque.

Hardness 3·5; specific gravity not given.

Its constituents, as determined by Bonsdorf's analysis, are,

			Atoms.
Silica,	45·05	22·52	19·24
Alumina,	30·05	13·35	11·41
Magnesia with trace of oxide of manganese,	9·00	3·6	3·07
Protoxide of iron,	5·30	1·16	1
Water,	10·60	9·42	8·05
	100·		

These atomic numbers correspond with

11½ atoms silicate of alumina,
3 atoms bisilicate of magnesia,
1 atom bisilicate of iron,
8 atoms water;

Or, considering the bisilicates of magnesia and iron as previously combined, the constitution will be

3 atoms silicate of alumina,
1 atom bisilicate of magnesia and iron,
2 atoms water.

The formula is $3AlS+(\frac{3}{4}Mg+\frac{1}{4}f)S^2+2Aq$.

Sp. 10. *Chalilite.*

This mineral occurs in the Donegore mountains, near

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* Kong. Vet. Acad. Handl., 1827, p. 15.

Sandy Brae, in the County of Antrim, and was brought me by Mr. Doran.

Colour deep reddish brown.

Texture compact; fracture splintery and flat conchoidal; has a considerable resemblance to flint in its appearance. Hence the name.*

Lustre between vitreous and resinous.

Translucent on the edges.

Hardness 4·5; specific gravity 2·252.

Before the blowpipe becomes white, and spreads out like a cauliflower. With carbonate of soda it effervesces, and melts with some difficulty into a white bead with a pearly lustre. With borax it fuses into a colourless glass.

When heated it gives out 16·66 per cent. of water. Its constituents are

		Atoms.	
Silica,	36·56	18·28	19·76
Alumina,	26·20	11·82	12·77
Lime,	10·28	2·93	3·16
Peroxide of iron,	9·28	1·85	2
Soda,	2·72	0·68	0·75
Water,	16·66	14·81	16
	102·10		

It is obvious that the constituents are in the state of simple silicates. If we admit that the silicates of alumina and iron were previously united, as also those of lime and soda, the constitution of chalilite will be as follows:—

4 atoms silicate of alumina and iron,
1 atom silicate of lime and soda,
4 atoms water.

The formula is $4(\frac{7}{8}Al+\frac{1}{8}f)S+(\frac{4}{5}Cal\frac{1}{5}N)S+4Aq$.

Sp. 11. *Karpholite.*

This mineral has been hitherto found only at Schlaggenwald in Bohemia, in granite. It was examined and named by Werner, a very short time before his death.

Colour a high straw yellow. Hence the name, which signifies *strawstone*.†

It consists of minute crystals diverging from a point, so as to have the appearance of tufts.

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* From *χαλιξ*, a flint.

† From *καρφος*, *straw*.

Lustre silky, glistening; opaque.

Hardness 2·5; but it is not easily determined, on account of the ease with which the little crystalline threads may be separated from one another. Specific gravity, according to Breithaupt, 2·935; according to Steinmann, 2·923; according to Stromeyer, 2·9365.

It intumesces before the blowpipe, becomes white, and melts imperfectly into a coherent mass. With carbonate of soda it melts into a green enamel. Muriatic acid has scarcely any action in it.

Its constituents, as determined by Stromeyer*, are

		Atoms.
Silica, . .	36·154	18·07
Alumina, . .	28·669	11·85
Protoxide of mangan.,	19·160	4·25
Protoxide of iron,	2·290	0·50
Lime, . .	0·271	0·07
Fluoric acid, .	1·470	1·17
Water, . .	10·780	9·58
	98·794	

If we admit the fluoric acid to be combined with lime and alumina, and to be accidental, the mineral will consist of

7 atoms silicate of alumina,
3 atoms sesquisilicate of manganese and iron.
6 atoms water.

The formula will be $7AlS+3(\frac{17}{19}mn+\frac{2}{19}f)S^{1\frac{1}{2}}+6Aq$.

Sp. 12. *Antrimolite.*†

This mineral was first observed by Patrick Doran, an Irish mineral dealer, on the sea-shore at Bengane, about four miles east from the Giant's Causeway, on the north coast of the county of Antrim.

It consists of stalactitical looking masses about the length and thickness of a finger, adhering to the summit of cavities in an amygdaloidal rock. In the centre of each stalactite is a crystal of calcareous spar, or a fibrous looking round mass,

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* Untersuchungen, p. 410. Professor Steinmann had previously analyzed it with nearly the same result, except that he did not recognise the [illegible] fluoric acid. See Schweigger's Jour. xxv. 413.

† [illegible] county of Antrim in Ireland, where alone this mineral has [illegible]

pretty long, and having a foliated structure and a brown colour, and consisting of calcareous spar.

Colour chalk-white.

Texture fine silky fibrous. The fibres diverging from the centre nucleus like radii from a centre.

Opaque; dull.

Hardness 3·75; specific gravity 2·0964.

When heated it gives out water, which reddens vegetable blues and contains muriatic acid. The quantity driven off amounts to 15·42 per cent.

Before the blowpipe it does not froth, but softens into an enamel. With biphosphate of soda it dissolves very slowly into a transparent colourless glass.

Dissolves readily in muriatic acid and gelatinizes.

Its constituents, by my analysis, were as follow:

		Atoms.
Silica,	43·47	21·73
Alumina,	30·26	13·44
Lime,	7·50	2·14
Potash,	4·10	0·68
Protoxide of iron,	0·19	0·04
Chlorine,	0·098	0·02
Water,	15·32	13·61
	100·938	

As the chlorine is driven off by heat, it is probably in the mineral combined with protoxide of iron, constituting dichloride of iron. The atoms of silica being 21·73, while those of the bases amount only to 16·26; it is obvious that some of the bases must be in the state of bisilicates or tersilicates.

We may consider the constitution of antrimolite to be

20 atoms silicate of alumina,
3 atoms tersilicate of lime,
1 atom tersilicate of potash,
20 atoms water.

Or, admitting the tersilicates of lime and potash to be previously united,

5 atoms silicate of alumina,
1 atom tersilicates of lime and potash,
5 atoms water.

The formula is $5\mathrm{AlS}+(\frac{3}{4}\mathrm{Cal}+\frac{1}{4}\mathrm{K})\mathrm{S}^3+5\mathrm{Aq}$.

Sp. 13. *Glottallite.*[*]

I received the mineral to which I gave this name, from a dealer in minerals at Old Kilpatrick, about eight miles from Glasgow, on the banks of the Clyde. He found it, I have reason to believe, in the hills behind Port Glasgow; though of this I am not quite certain, as I have never been able to procure a second specimen. It coats one side of a fragment of greenstone.

Colour white.

Composed of crystals so mixed together, that only a small portion of each can be seen. They seem to be regular octahedrons; at least four-sided pyramids, the faces of which appeared to be equilateral triangles, are visible. Others of the crystals seem to be cubic.

Lustre vitreous; strongly translucent; brittle.

Hardness 3·5; specific gravity 2·181.

Before the blowpipe swells up and melts into a white enamel. With carbonate of soda it fuses into an opaque white bead. With borax into a translucent glass.

When heated in a glass tube it gives out 21¼ per cent. of pure water.

Its constituents, by my analysis, are

		Atoms.	
Silica,	37·014	18·51	2·71
Lime,	23·927	6·83	1
Alumina,	16·308	7·27	1·06
Peroxide of iron,	0·500	0·10	0·01
Water,	21·250	18·88	2·76
	98·999		

These atomic numbers approach pretty nearly

1 atom silicate of lime,
1 atom sesquisilicate of alumina,
2¾ atoms water.

The formula is $CalS+AlS^{1\frac{1}{2}}+2\frac{3}{4}Aq$.

Sp. 14. *Harringtonite.*

The mineral to which I have given this name, was brought me by Mr. Doran from the north of Ireland. It constitutes a vein about 0·6 inch thick in an amygdaloidal rock.

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[*] From *Glotta*, the river Clyde.

Colour snow-white; texture compact and earthy; lustre like that of the almond; opaque; very tough.

Hardness 5·25; specific gravity 2·217.

It was subjected to two successive analyses. The results were as follow:

			Atoms.
Silica,	44·960	44·840	22·42
Alumina,	26·848	28·484	12·66
Lime,	11·008	10·684	3·05
Protoxide of iron,	0·880	trace	—
Soda,	5·560	5·560	1·39
Water, with trace of mur. acid,	10·280	10·280	9·13
	99·540	99·848	

Of these analyses the second is the most accurate, being made upon a specimen selected with much care.

The atomic numbers agree very nearly with the following constitution:

3 atoms sesquisilicate of alumina,
1 atom silicate of lime and soda,
2 atoms water.

The formula is $3AlS^{1\frac{1}{2}}+(\frac{2}{3}Cal+\frac{1}{3}N)S+2Aq$.

Sp. 15. *Soapstone.*

Steatite in part.

The term *steatite* has been applied so loosely by mineralogists, that it includes minerals composed of very different ingredients and belonging in reality to different species. I confine the term *soapstone* to the mineral which occurs in the peninsula of the Lizard, partly in a vein in serpentine at the Lizard Point, and partly near the Mullyan churchtown.

Colour greenish white, sometimes with a tinge of yellow, and mottled with green and red; the white portion often traverses the red in a kind of irregular vein. When first extracted from the vein it may be kneaded like dough, but when left exposed to the air, it loses part of its moisture, becomes translucent on the edge, but still continues soft enough to be scratched by the nail.

Texture fine earthy.

Feel unctuous; lustre soapy; sectile.

Specific gravity of the reddish variety 2·411; of the white variety 2·396.

Not fusible per se before the blowpipe.

Employed in the manufacture of porcelain at Swansea.

Klaproth informs us that it was used for the same purpose at Worcester.

Breaks into a fine powder, which does not feel gritty between the teeth.

Its constituents are as follow:

Silica,	45	42·320	43·884
Magnesia,	24·75	25·680	24·144
Alumina,	9·25	9·384	9·872
Lime,	—	4·680	—
Protox. of iron,	1	1·083	—
Potash,	0·75	—	—
Water,	18·00	16·960	21·228
	98·75[*]	100·107[†]	99·128

These analyses approach each other pretty nearly. It is clear that the lime, protoxide of iron, and potash, are accidental ingredients. The mean of the three gives us

		Atoms.	
Silica,	43·734	21·86	5·18
Magnesia,	24·858	9·94	2·35
Alumina,	9·502	4·22	1
Water,	18·729	16·64	3·94

It is obvious that the bases are in the state of sesquisilicates. The atomic numbers approach very nearly

2⅓ atoms sesquisilicate of magnesia,
1 atom sesquisilicate of alumina,
4 atoms water.

The formula is $2\frac{1}{3}MgS^{1\frac{1}{2}}+AlS^{1\frac{1}{2}}4Aq$.

Sp. 16. *Killinite.*

This mineral was discovered by Dr. Taylor in coarse granite veins which traverse a fine grained granite at Killiney, Dublin bay. The veins contain also a good deal of spodumene. It was described, and an imperfect analysis of it was published by Dr. Taylor and Dr. Barker.

Colour brownish yellow, sometimes with a tinge of green. Sometimes the colour is green, but this is comparatively rare. Some specimens when heated to redness become snow-white, while others assume a reddish tinge, indicating a difference in purity.

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[*] Klaproth, Beitrage, v. 22.

[†] By my analysis. The first specimen was mottled red and white; the second was pure white. Both had been in my cabinet for at least 15 years.

Texture foliated. Sometimes in crystals. The shape is a four-sided prism, apparently rectangular; but no specimen that I have seen admits of measurement. I have a crystal of it four inches long, 1·3 inch broad, and 0·9 inch thick.

Lustre waxy; dull, except from occasional admixture of foreign matter, which may give it a glimmering lustre.

Opaque, or only slightly translucent on the edges; streak yellowish white.

Hardness 3·5; specific gravity, 2·711.

Before the blowpipe becomes white and friable, and fuses slowly into a white opaque bead, but not nearly so easily as spodumene. With carbonate of soda fuses into a transparent glass. With borax and with biphosphate of soda it fuses into a colourless glass, leaving a silica skeleton.

Two analyses of it were made in my laboratory, the first by Captain Lehunt, the second by Mr. Blythe. The result is as follows:

	*	†
Silica, . .	49·08	47·925
Alumina, . .	30·60	31·041
Potash, . .	6·72	6·063
Protoxide of iron, .	2·27	2·328
Lime, . .	0·68	0·724
Magnesia with manganese,	1·08	0·459
Protoxide of manganese, .	—	1·255
Water, . .	10·00	10·000
	100·43	99·975

These analyses approach each other very closely. The mean is as follows:

		Atoms.	
Silica, .	48·50	24·25	23·31
Alumina, .	30·82	13·70	13·17
Potash, .	6·39	1·06	1·01
Protoxide of iron,	2·30	0·51	0·5
Water, .	10·00	8·88	8·5

These atomic numbers give us the constitution of killinite as follows:

13 atoms sesquisilicate of alumina,
1 atom bisilicate of potash,
$\frac{1}{2}$ atom bisilicate of iron,
$8\frac{1}{2}$ atoms water;

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* By Captain Lehunt. † By Mr. Blythe.

Or, admitting the bisilicates of potash and iron to be previously combined,

9 atoms sesquisilicate of alumina,
1 atom bisilicate of potash and iron,
4 atoms water.

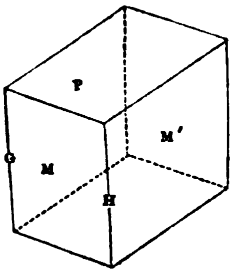
The formula is $9AlS^{1\frac{1}{2}}+(\frac{1}{3}K+\frac{2}{3}f)S^{2}+4Aq$.

Sp. 17. *Lomonite.**

Efflorescing zeolite.

This mineral was discovered in 1785, by M. Gillet Laumont, in the mine of Huelgoët, in Brittany. It is found also in the amygdaloidal rocks in the Kilpatrick hills, near Glasgow.

Colour white, usually with a shade of red, yellow, or green; streak white.



Occurs most commonly in crystals. The primary form is an oblique rhombic prism.

P on M or M′ 113° 30′
M on M′ 86° 15′

The edge H (and sometimes also the edge G) is frequently replaced by a tangent plane. The base P is commonly replaced by two low faces.

Lustre vitreous, inclining to pearly upon the more distinct faces of cleavage; translucent.

Hardness 3·5, but when the mineral is exposed to the air it loses its water, and falls into powder.

Specific gravity, as determined by Hauy, 2·3.

Before the blowpipe it fuses into a white spumous mass. It gelatinizes in acids, and acquires negative electricity by friction, if insulated.

We have two analyses of this mineral, one by M. L. Gmelin, and another by M. Vogel. The following table exhibits the results which they obtained :*

			Mean.	Atoms.
Silica,	48·3	49	48·65	24·32
Alumina,	22·7	22	22·35	9·93
Lime,	12·1	9	10·55	3·01
Water,	16·0	17·5	16·75	14·88
Carbonic acid,	—	2·5		
	99·1	100		

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* Named from the discoverer.

† Mohs' Mineralogy, ii. 235.

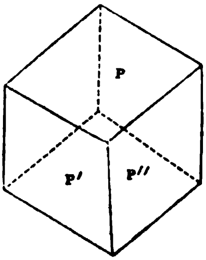
Its constitution is obviously

3 atoms bisilicate of alumina,
1 atom bisilicate of lime,
5 atoms water.

The formula is $3AlS^2+CalS^2+5Aq$.

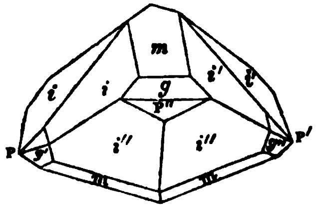
Sp. 18. *Chabazite.*[*]

This mineral was first named and described by Box d'Antic in a memoir read to the Natural History Society of Paris, about the year 1780. It occurs pretty commonly in trap rocks. Thus it is abundant at Talisker, in the Isle of Skye, and at Kilmalcolm, in Renfrewshire. It is to be found also at the Giants' Causeway, and in many other places. The first crystallized specimens were observed at Oberstein, in Germany.



Colour white; streak white.

Always crystallized. Primary form an obtuse rhomboid, P on P′ 94° 46′. This is the common form which it has in the neighbourhood of Glasgow. But at Oberstein, in Saxony, and in the north of Ireland it occurs in the form figured in the margin.[†]



P on *g*′, P″ on *g* or P″ on *g*′, 120° 5′
P on *i*, P′ on *i*′, P″ on *i*″ } . . 175° 30′
i on *i*, *i*′ on *i*″, *i*″ on *i*″ } . . 173° 32′
g on *m* . . 143° 59′

Cleaves pretty easily, and yields the primary crystal, often with brilliant faces.

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[*] The name chabazite was taken by Box d'Antic, from the Greek word χαβαζιος. This word occurs in the poem περι λιθων, ascribed to Orpheus. In this poem 20 species of stones are celebrated for their virtues and uses, but without the least attempt to describe them. Hence it is impossible to discover the minerals to which the Greek names were applied. The last of the twenty is χαβαζιος. The praises of this stone occupy 17 lines of the poem. Its cooling virtues, and its power of curing the bite or sting of the scorpion are celebrated.

[†] According to Sir David Brewster the primary form of this mineral is not a rhomboid, but a prism.

Fracture uneven; brittle.

Lustre vitreous.

Transparent to translucent.

Hardness 3·75; specific gravity of transparent rhomboids from Kilmalcolm 2·088; Haidinger states it at 2·100. Captain Lehunt found that of an Irish specimen analyzed by him (containing much soda) 2·472. Hauy makes the specific gravity 2·7176.

Before the blowpipe melts into a white spumous mass.

Easily soluble in muriatic acid.

The following table exhibits the constituents of transparent rhomboidal chabasites:

	*	†	‡	Mean.	Atoms.
Silica, .	48·756	50·65	48·30	49·202	24·6
Alumina, .	17·440	17·00	19·28	17·91	7·96
Lime, .	10·468	9·73	8·72	9·639	2·75
Potash, .	1·548	1·70	2·50	1·916	0·32
Water, .	21·720	19·50	20·00	20·41	18·14
	99·932	98·58	98·78		

The constitution seems to be

3 atoms bisilicate of alumina,
1 atom tersilicate of lime,
6 atoms water.

The formula is $3\text{AlS}^2+\text{CalS}^3+6\text{Aq}$.

But there is another variety of chabasite in which soda replaces a considerable portion of the lime. It is remarkable that this chabasite is always crystallized in the peculiar form figured in page 333. The following table exhibits the constituents of two specimens of this kind analyzed by Captain Lehunt, in my laboratory, and another by Berzelius:

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* By my analysis. The specimen was from Kilmalcolm, Renfrewshire, in transparent colourless crystals.

† Berzelius, Afhandlingar, vi. 190. The specimen was from Gustafsberg, in crystals, and selected with great care.

‡ Arfvedson, Kong. Vet. Acad. Handl., 1824, p. 356. The specimen was from the Faroe Isles. The specimen was given to Berzelius by Hauy as an example of pure chabasite.

	*	†	‡
Silica,	48·988	49·17	46·184
Alumina,	19·774	18·90	18·423
Soda,	6·066	12·19	5·967
Lime,	4·068	—	7·029
Protoxide of iron,	0·404	—	0·397
Water,	20·700	19·73	22
	100	99·99	100

The specimen analyzed by Berzelius containing no lime, but only soda and alumina, ought to constitute a new species, but unfortunately we have no description of it.

Its constituents were

		Atoms
Silica,	24·58	8·06
Alumina,	8·40	2·75
Soda,	3·05	1
Water,	17·53	5·74

This corresponds nearly with

3 atoms bisilicate of alumina,
1 atom tersilicate of soda,
6 atoms water.

There is a slight deficiency of bisilicate of alumina.

The specimens analyzed by Captain Lehunt were mixtures or combinations of the common calcareous-chabasite and the soda-chabasite of Berzelius.

Sp. 19. *Levyine.*

This mineral was first noticed by Mr. Heuland, in the cavities of an amygdaloidal rock from Dalsnypen, in Faroe, where it is accompanied by chabasite, analcime, and a new variety of heulandite. He sent specimens of it to Dr. Brewster, who determined its optical properties, and distinguished it by the name of levyite.

Colour white; streak white.

It occurs only crystallized. The primary form, according

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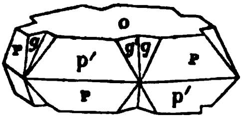
[*] Captain Lehunt. The specimen was from the North of Ireland. Colour yellow.

[†] Berzelius. He says that the specimen was from Scotland. Kong. Vet. Acad. Handl., 1825, p. 358.

[‡] Captain Lehunt. The specimen was white, and also from the County of Antrim.

[§] Named in honour of Mr. Levy.

to Haidinger, is an obtuse rhomboid. But the shape of the only crystalline form hitherto observed, is that in the margin, obviously consisting of two crystals penetrating each other.



O on *g* 136° 1′
O on P 117° 24′

Fracture imperfect conchoidal; brittle.

Lustre vitreous; semitransparent.

Hardness 4; specific gravity by my trial, 2·161.

Insoluble in acids, and does not gelatinize with them.

Before the blowpipe intumesces and whitens. With biphosphate of soda it yields a transparent globule, which contains a skeleton of silica, and becomes opaque on cooling.

The following table exhibits the constituents of this mineral according to the analyses hitherto made:

	*	†
Silica,	48	44·75
Alumina,	20	20·333
Lime,	8·35	8·833
Magnesia,	0·40	0·770
Potash,	0·41	—
Soda,	2·75	3·333
Water,	19·80	20
	99·21	98·019

It has been supposed by Dr. Brewster and Mr. G. Rose, that Berzelius had analyzed a chabasite instead of a levyine, but my result (except in the silica) approaches so near his, as to render that supposition unlikely. The mean of the two analyses is

		Atoms.	
Silica,	46·37	23·18	8·64
Alumina,	20·16	8·96	3·34
Lime,	8·59	2·45	1
Magnesia,	0·58	0·23	
Soda,	3·17	0·79	0·29
Water,	19·65	17·46	6·5

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* Berzelius, Kong. Vet. Acad. Handl., 1824, p. 356. The specimen was sent by Dr. Brewster for analysis. It came from Mr. Heuland, who had it from the Faroe Islands.

† By my analysis. I had the specimen from Mr. Doran, an Irish mineral dealer. The soda contained a trace of potash.

If we admit the soda to be accidental, the bases are in the state of bisilicates, and the constitution is

$3\frac{1}{3}$ atoms bisilicate of alumina,
1 atom bisilicate of lime and magnesia,
$6\frac{1}{2}$ atoms water.

Thus it contains less silica and more water than chabasite. The formula will be

$$3\frac{1}{3}AlS^2+(\frac{10}{11}Cal+\frac{1}{11}Mg)S^2+6\frac{1}{2}Aq.$$

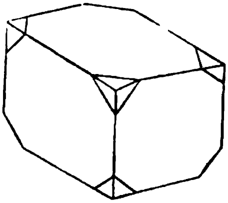
This difference in the constitution of levyine and chabasite, though not great, yet, if it be constant, will be sufficient to constitute a specific difference between the two minerals.

Sp. 20. *Analcime.**

Cubizite, sarcolite.

This mineral seems to have been first particularly noticed by Dolomieu, but Hauy constituted it a peculiar species. It occurs usually in cavities in amygdaloid and basalt, and is abundant in the Kilpatrick hills, near Glasgow. It is said also to have been found in small veins in some of the older rocks.

Colour white passing into grey; often reddish-white or flesh-red; streak white.



It occurs in nodules in aggregated crystals, in the form of minute diverging fibres, or in cubic crystals, either complete or having their solid angles replaced each by three planes, as represented in the margin. When these planes increase so much as to conceal the primary faces, a twenty-four-sided crystal is formed, of which a figure is given in page 286. It is known by the name of the leucite crystal, and consists of twenty-four equal and similar trapezoidal faces. This is by far the most usual crystal in the analcime of the Kilpatrick hills.

Fracture imperfect conchoidal.

Lustre vitreous; brittle.

Sometimes nearly transparent. This is the case with the analcime crystals which occur at the Giant's Causeway. Most commonly it is only translucent. Sometimes it puts on

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* From α privative, and *αλκες, strength*; named from its very weak electric virtue.

the appearance of an enamel, and is only very slightly translucent. The lustre then is waxy.

Hardness 6·25; specific gravity of a transparent specimen from the Giant's Causeway 2·278; Haidinger states the specific gravity at 2·068.

On charcoal it melts without intumescence or ebullition, into a clear glassy globule; gelatinizes in muriatic acid.

Its constituents are as follow:

	[*]	[†]	Mean.	Atoms.	
Silica, . .	55·12	55·60	55·36	27·68	7·8
Alumina, .	22·99	23·00	22·999	10·22	2·88
Soda, . .	13·53	14·65	14·19	3·65	1
Water, . ,	8·27	7·90	8·08	7·18	2·02
	99·91	101·15			

These two analyses almost coincide. They give us the constitution of analcime as follows:

3 atoms bisilicate of alumina,
1 atom bisilicate of soda,
2 atoms water.

The formula is $3AlS^2+NS^2+2Aq$.

Sp. 21. *Lehuntite.*[‡]

Compact zeolite.

I give this name to a species of zeolite which occurs at Glen Arm, a precipice on the east coast of the County of Antrim, in an amygdaloidal rock.

Colour flesh-red.

Appears to the naked eye like a lump of sugar. Under the microscope it appears to be composed of minute scales.

The mass, when broken in two, exhibits the appearance of five distinct layers, three of them flesh-red, and two of them white lines separating the flesh-red portion into three portions. Or it may be described as a flesh-red mass, with two parallel white lines near the centre.

Translucent on the edges.

Hardness 3·75; specific gravity 1·958.

Before the blowpipe fuses into a white enamel. With car-

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[*] M. H. Rose, Poggendorf's Annalen, xii. 181.

[†] By my analysis. The specimen was from the Giant's Causeway.

[‡] In honour of Captain Lebunt.

bonate of soda it melts easily into a white enamel. With borax or biphosphate of soda it forms a transparent bead with a silica skeleton, which becomes opaque on cooling.

Its constituents, by the analysis of my nephew, Dr. R. D. Thomson, are:

			Atoms.
Silica,	47·33	23·66	6·34
Alumina,	24·00	10·66	2·85
Soda,	13·20	3·3	1
Lime,	1·524	0·43	
Water,	13·60	12·08	3·23
	99·654		

If we allow for a small deficiency of silica, the constitution of Lehuntite is

3 atoms bisilicate of alumina,
1 atom bisilicate of soda and lime,
3 atoms water.

The formula is $3AlS^2+(\frac{8}{9}N+\frac{1}{9}Cal)S^2+3Aq$.

Sp. 22. *Cluthalite.*[*]

This mineral is found in the western part of the Kilpatrick hills, near Dumbarton, and is named from the valley of the Clyde, which the locality borders on. It forms large nodules in amygdaloid.

Colour flesh-red.

Constitutes a congeries of imperfect crystals, with rough surfaces. To the eye they seem to be right rectangular prisms.

Opaque, or only translucent on the edges.

Lustre vitreous; brittle; easily frangible.

Hardness 3·5; specific gravity 2·166.

Its constituents, by my analysis, are:

			Atoms.
Silica,	51·266	25·63	9·35
Alumina,	23·560	10·47	3·82
Peroxide of iron,	7·306	1·46	1
Soda,	5·130	1·28	
Magnesia,	1·233	0·50	0·18
Water,	10·553	9·38	3·42
	99·048		

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[*] From *Clutha*, a name by which the valley of the Clyde has been sometimes distinguished.

If we allow for a slight deficiency of silica, the bases are in the state of bisilicates. If the bisilicates of iron and soda were previously combined, and those of alumina and magnesia, the constitution of cluthalite will be

4 atoms bisilicate of alumina and magnesia,
1 atom bisilicate of iron and soda,
3 atoms water.

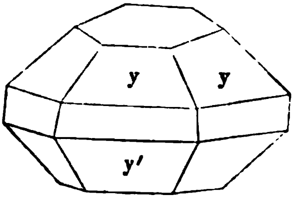
The formula is $4(\frac{19}{20}Al+\frac{1}{20}Mg)S^2+(\frac{1}{2}N+\frac{1}{2}f)S^2+3Aq$.

Sp. 23. *Hydrolite.*[*]

Gmelenite, sarcolite of Vauquelin.

This mineral was first observed by Leman, in the Vicentine, in cavities of amygdaloidal rocks. More lately it was observed by the late Mr. Thomas Allan, of Edinburgh, in the little deer park of Glen Arm, County of Antrim, Ireland. It has been since found in amygdaloidal rocks, in Antrim, by Mr. Doran, an Irish mineral dealer, from whom most of the Irish specimens of hydrolite have been obtained.

Colour snow-white; always crystallized. The only crystal which I have seen is that figured on the margin, a double six-sided pyramid with the apices truncated. Between the pyramids is interposed a short six-sided prism. The faces of the pyramids are all streaked parallel to the base y on y′ according to Dr. Brewster's measurement 83° 36′. It seems, from the observations of Haidinger, to be closely related to the crystalline form of the chabasite.



Translucent; very frangible.

Hardness 4; specific gravity 2·054.

Before the blowpipe increases in bulk, and assumes the appearance of an enamel, but does not melt into a glass.

When ignited it gives out pure water, and loses 29·866 per cent. of its weight.

Its constituents, determined by my analysis, are as follow:

---

[*] From ὕδωρ, *water*, and λίθος, *a stone*. Because it contains so great a proportion of water.

			Atoms.
Silica, .	39·896	19·94	13·3
Alumina, .	12·968	5·76	3·82
Peroxide of iron,	8·270	1·65	1·1
Potash, .	9·000	1·50	1
Water, .	29·866	26·54	17·7
	100·000*		

These numbers approach very nearly

4 atoms tersilicate of alumina,
1 atom silicate of iron,
1 atom silicate of potash,
18 atoms water.

Or, if we suppose the silicates of potash and iron previously combined,

2 atoms tersilicate of alumina,
1 atom silicate of iron and potash,
9 atoms water.

The formula is $3AlS^3+(^1f+\frac{1}{2}K)S+9Aq$.

Sp. 24. *Erinite.*†

This mineral occurs in an amygdaloidal rock in the county of Antrim, about four miles east from the Giant's Causeway. It was found by Mr. Doran, from whom I obtained the specimen which I subjected to analysis.

Colour yellowish-red.

Compact; very fine grained.

Fracture small conchoidal.

Opaque; lustre resinous; feel soapy.

Hardness 1·75; specific gravity 2·04.

When heated gives out about the fourth of its weight of water.

Before the blowpipe whitens, but does not fuse; with carbonate of soda fuses with effervescence into a blebby glass; with borax it fuses into a transparent colourless glass; with biphosphate of soda into an opaque white frit.

Its constituents were found to be

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* The analysis was made on 5·3 grains. The loss sustained was 1·987 per cent. But I had every reason to believe that this loss was wholly potash. I have therefore added it to the amount of potash in the table. I actually obtained only 7·013 per cent. of potash.

† From *Erin*, the name by which Ireland is known in the native language of the country.

			Atoms.
Silica,	47·036	23·52	16·68
Alumina,	18·464	8·2	5·8
Lime,	1·000	0·28	0·2
Protoxide of iron,	6·360	1·41	1
Magnesia,	trace	—	—
Water,	25·280	22·47	15·9
Common salt,	0·900		
	99·04		

The common salt was doubtless derived from the sea, to the spray of which the rock containing the erinite was exposed.

If we unite the lime to the alumina, the atoms of this last will be just six times as many as those of iron. The constitution of the mineral (admitting a slight excess of silica) is

6 atoms bisilicate of alumina,
1 atom quatersilicate of iron,
16 atoms water.

The formula is $6AlS^2 + fS^4 + 16Aq$.

Sp. 25. *Pyrophyllite.*[*]

This mineral comes from the Uralian mountains, and was distinguished by the name of *fibrous talc*. But its behaviour under the blowpipe is quite different from that of talc. When heated per se it spreads out in a fan-like shape, and increases to twenty times its former bulk. The matter thus swollen is infusible. With carbonate of soda it fuses into a clear yellow glass; with biphosphate of soda it fuses into a colourless glass, leaving a silica skeleton. When heated with nitrate of cobalt it assumes a fine blue colour.

Colour white; lustre pearly.

Amorphous; texture radiated, with an indistinct rectangular cleavage.

Its constituents, as determined by M. Hermann, of Moscow,[†] are

		Atoms.
Silica,	59·79	29·89
Alumina,	29·46	13
Magnesia,	4·00	1·6
Peroxide of iron,	1·80	0·36
Water,	5·62	5
	100·67	

---

[*] From πυρ, *fire*, and φυλλον, *a leaf*.

[†] Poggendorf's Annalen, xv. 592.

These numbers correspond with

8 atoms bisilicate of alumina,
1 atom bisilicate of magnesia,
0·2 atom bisilicate of iron,
3 atoms water.

If we admit the bisilicate of iron to be accidental, the formula will be $8AlS^2+MgS^2+3Aq$.

Sp. 26. *Agalmatolite.*

Bildstein, figurestone, koreite, lardite, pagodite.

This mineral is brought from China in the form of pagodas, or chimney-piece ornaments. It is found also at Nagyag, in Transylvania, as was first observed by Klaproth.

Colour white, with a shade of grey, green, yellow, red, or brown.

Massive, and sometimes imperfectly slaty.

Fracture coarse splintery; lustre waxy, and nearly dull; acquires some lustre in the streak.

Translucent, in most cases only on the edges; sectile.

Hardness 2; specific gravity, as determined by Klaproth, 2·815. I found it 2·895.

Infusible before the blowpipe, but becomes white.

Partly soluble in sulphuric acid, leaving a residue of silica.

Klaproth, in his first analysis, did not discover potash in the Chinese variety, but it was found by Vauquelin. This induced Klaproth, who had detected potash in the Nagyag variety, to repeat his analysis of the Chinese, when he found potash in it also.

The following table exhibits the constituents of this mineral, according to the best analyses hitherto made:

	*	†	†	‡	‡	§
Silica, . . .	56	54·5	55	55	51·5	49·816
Alumina, . . .	29	34	33	30	32·5	29·596
Lime, . . .	2	—	—	1·75	3·9	6·000
Protoxide of iron, .	1	0·75	0·5	1	1·75	1·500
Protoxide of manganese,	—	—	—	trace	1·2	—
Potash, . . .	7	6·25	7	6·25	6·0	6·800
Water, . . .	5	4	3	5·5	5·13	5·5
	100	99·5	98·5	99·5	101·08	99·212

* Vauquelin, Ann. de Chim. xlix. 83.

† Klaproth, Beitrage, v. 19. The first specimen was from Nagyag, the second from China.

‡ John, Annals of Philosophy, iv. 214. Both specimens were from China; the first was yellow, the second red.

§ By my analysis. The specimen was from China.

The lime, protoxides of iron and manganese vary so much in the different analyses, that we must consider them as accidental. The mean of the analyses gives the other constituents

		Atoms.
Silica,	54·3	27·15
Alumina,	31·35	13·93
Potash,	6·55	1·09
Water,	4·71	4·18

This corresponds with

13 atoms bisilicate of alumina,
1 atom silicate of potash,
4 atoms water.

The formula is $13AlS^2+KS+4Aq$.

Sp. 27. *Stilbite.**

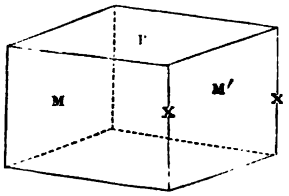
Foliated zeolite of Werner, in part. Desmine.

This mineral occurs abundantly in the amygdaloidal rocks of the Kilpatrick hills, near Glasgow. It abounds also at Talisker, Isle of Skye, and in many other places.

Colour white, most commonly with a shade of yellow, red, or brown. Beautiful specimens of it of a flesh-red colour are common in the Kilpatrick hills, especially near Dumbarton, and at Carberry, in the Stockymuir. Streak white.

It is most commonly crystallized in slender prisms, which are fasciculated in a sheaf-like form. The primary form is generally considered to be a right prism, with rectangular bases; but as there is no cleavage parallel to the lateral planes of such a prism, but in some crystals indications of a cleavage parallel to the planes of a rhombic prism, Mr. Brooke has been led to consider the primary form as a right rhombic prism, in which

M on M′ 101° 36′



The edges x are often replaced by planes, and the prism most commonly terminates in a four-sided pyramid, sometimes complete, but most commonly truncated, leaving a small face parallel to the face P of the primary form.

Lustre vitreous, that of the lateral faces of the prism pearly; brittle.

Semitransparent to translucent.

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* From στιλβω, *to shine*, on account of its great lustre.

Hardness 3·5; specific gravity, by my trials, from 2·133 to 2·143. Haidinger states it at 2·161; Dumenil at 2·14.

Does not gelatinize with acids.

Before the blowpipe yields an opaque vesicular bead.

The constituents of this mineral are as follow:

	*	†	‡	§	||
Silica, .	58	52·25	55·615	52·50	54·805
Alumina, .	16·1	18·75	16·681	17·318	18·205
Lime, .	9·2	7·36	8·170	11·520	9·830
Soda, .	—	2·39	1·536	—	—
Water, .	16·4	18·75	19·300	18·450	19·000
	99·7	99·50	101·302	99·788	101·84

The mean of all these analyses, reckoning the soda, where it occurs along with the lime, is as follows:

		Atoms.		Omitting the soda.
Silica, .	54·67 .	27·33 .	9·7 .	10·5
Alumina,	17·41 .	7·73 .	2·74 .	3
Lime, .	9·91 .	2·82 .	1 .	1
Water, .	18·4 .	16·35 .	5·8 .	6·28

These numbers approach pretty nearly to

3 atoms tersilicate of alumina,
1 atom tersilicate of lime,
6 atoms water.

If we leave out the soda as accidental, the atoms of alumina are almost exactly thrice as many as those of lime. But there is a deficiency of silica; it should be 12 atoms, while it is only 10½. However, in Hisinger's analysis, it amounts to 11·15 atoms, so that the deficiency in that case is less than an atom.¶

The formula is $3AlS^3+CalS^3+6Aq$.

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* Hisinger, Afhandlingar, iv. 357.

† Dumenil, Schweigger's Jahrbuch, vi. 163.

‡ Gehlen, Schweigger's Jour. viii. 355.

§ By my analysis. A red stilbite from the neighbourhood of Dumbarton.

|| By my analysis. A white stilbite.

¶ Stilbite frequently occurs in states not easily recognised by its external characters. My friend, Mr. Andrews, of Belfast, whose knowledge of practical chemistry enables him to analyze minerals with great precision, met with a large mass of matter at the Cave hill, near Belfast. It was in a greenstone quarry, and seemed to constitute a bed or vein about a foot thick.

Colour light red; fracture uneven; texture crystalline; streak white;

Sp. 28. *Heulandite.*

Foliated zeolite of Werner; stilbite anamorphique of Hauy; stilbite of Breithaupt and Rose.

This mineral, already constituted a sub-species by Werner, under the name of *foliated zeolite*, was shown by Mr. Brooke, in 1822, to differ essentially from the preceding species, with which it had been confounded by Hauy, and to constitute a peculiar species. He gave it the name of *heulandite*, from Mr. Heuland, of London, who has contributed so much to the advancement of mineralogy.*

Heulandite occurs in the same kind of rock with stilbite. Most beautiful specimens are brought from the Faroe Islands. It occurs also rather abundantly in the Kilpatrick hills, and other similar rocks in the neighbourhood of Glasgow.

Colour usually snow-white; that of the heulandite from the Kilpatrick hills is flesh-red. It is found also brown and grey. Streak white.

Sometimes massive, or in round balls, but more commonly

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soft. Before the blowpipe melted into a brown glass. It contained numerous cavities, partially filled by a white stalactitical zeolite, evidently formed by the percollation of water through the mass. Before the blowpipe it melted into a snow-white glass.

Mr. Andrews subjected these two zeolites to analysis. The red portion was composed of

Silica, . .	50·37
Alumina, . .	10·65
Protoxide of iron, .	9·19
Lime, . .	6·10
Water, . .	22·41
	98·72

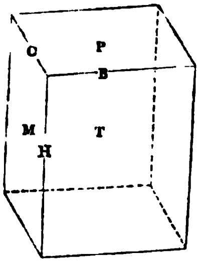
This agrees with $3AlS^3+CalS^3+\underline{f}S+10Aq$. It differs from stilbite by containing $\underline{f}S$, and 4 additional atoms of water.

The constituents of the white stalactitical zeolite were

Silica, . .	57·14
Alumina, . .	16·09
Lime, . .	7·77
Water, . .	18·60
	99·60

This is $8AlS^3+CalS^3+6Aq$, which is the formula for stilbite.

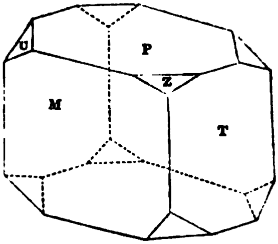
* As Mr. Brooke's name has come into general use in Great Britain, I have allowed it to remain; but as the name *stilbite* (from στιλβω, *to shine*,) was given to the mineral from its uncommon splendour, it would have been better to have applied it to the one of the two species which has the greatest lustre, and that is undoubtedly the *foliated zeolite*, or heulandite of Brooke.



crystallized The primary form is a right oblique prism, in which M on T is 130° 30′. The edges C, H, B, are to each other nearly as the numbers 160, 161, 162.

Most commonly the solid angles of the prism are replaced by triangular faces u, z.

P on Z 112° 15′.



Lustre of the lateral faces of the prism vitreous, but the base P has a very high degree of pearly lustre.

Sometimes nearly transparent, commonly only translucent; brittle.

Hardness 3·5; specific gravity of a very fine crystal from the Faroe Islands 2·195. Haidinger states it 2·200.

Before the blowpipe it behaves nearly as stilbite.

Its constituents are as follow :—

	*	†	Mean.	Atoms.	
Silica, . .	59·95	59·145	59·547	29·77	14·04
Alumina, . .	16·87	17·920	17·395	7·73	3·64
Lime, . .	7·19	7·652	7·421	2·12	1
Water, . .	15·10	15·400	15·25	13·55	6·39
	99·11	100·117			

Heulandite agrees with stilbite in consisting of tersilicate of alumina and tersilicate of lime. But it contains 0·64 atom more of tersilicate of alumina. Probably the constitution will be found,

4 atoms tersilicate of alumina,
1 atom tersilicate of lime,
6 atoms water.

The formula is $4AlS^3+CalS^3+6Aq$.

It differs from stilbite by containing an additional atom of tersilicate of alumina.

Sp. 29. *Brewsterite.*‡

This mineral has hitherto been observed only at Strontian

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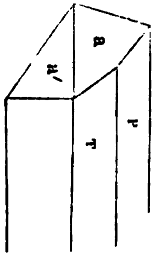
* Walmstedt, Edinburgh Jour., vii. 11.

† By my analysis. A fine snow-white crystal from the Faroe Islands.

‡ Named in honour of Sir David Brewster.

in the vein containing the galena, and is always in crystals. It was considered as an apophyllite till it was examined by Mr. Brooke, and shown by him to be a peculiar species.

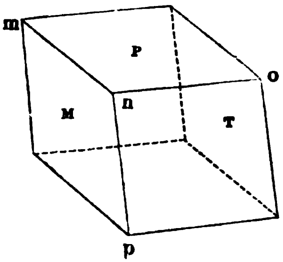


Colour white, inclining to yellow or grey.

The usual crystal is a six-sided prism terminated by two oblique and very low faces.

a on a' 172°
P on T 90°
P on a 93° 30'

Mr. Brooke considers the primary form as a right oblique prism.



M on T 93° 40'

n m, n o, and n p, are respectively to each other as the numbers 16, 10, and 35.

The prism cleaves only parallel to the face P.

Lustre vitreous, except of the face P, which is pearly.

Hardness 4·25; specific gravity 2·432.

Before the blowpipe it loses its water, and becomes opaque; then it froths and swells up, but is difficultly fusible. It leaves a silica skeleton when fused with biphosphate of soda.

This mineral was first accurately analyzed by Mr. Arthur Connell of Edinburgh, who discovered strontian and barytes in it. This induced me to repeat the analysis. The results are as follow:—

	*	†	Atoms.	
Silica, ...	52·400	53·045	26·52	13·19
Alumina, . .	15·918	16·540	7·35	3·65
Barytes, . . .	5·827	6·050	0·63	1
Strontian, . .	7·709	9·005	1·38	
Lime, ...	1·007	0·800	0·23	0·12
Peroxide of iron, .	0·208	—	—	—
Water, ...	12·584	14·735	13·09	6·52
	95·653	100·175		

I calculate from my own analysis, because I conceive that

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* By Mr. Connell's analysis. The specimen was an amorphous and crystallized mass mixed.

† By my analysis. The specimen consisted of fine crystals picked out with great care.

my specimen was rather purer than Mr. Connell's. If we admit a little bisilicate of lime to be accidental, brewsterite consists of tersilicates. The constitution seems to be

3 atoms tersilicate alumina,
1 atom tersilicate of barytes and strontian,
$6\frac{1}{2}$ atoms water.

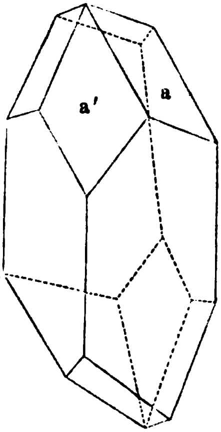
The formula is $3AlS^3+(\frac{1}{3}Br+\frac{2}{3}Str)S^3+6\frac{1}{2}Aq$.

It differs from heulandite in having tersilicate of barytes and strontian in place of tersilicate of lime. It would seem also to contain half an atom more water.

Sp. 30. *Harmotome*.*

Andreolite, andreasbergolite, ercinite, cross-stone, hyacinth blanche cruciform.

This mineral was early distinguished in consequence of the remarkable appearance of its crystals. Its localities are both metalliferous veins and the cavities of amygdaloidal rocks. Andreasberg in the Hartz, and Strontian in Argyleshire, have been long known as noted localities. It occurs also, though sparingly, in the Kilpatrick hills, and in many other places.

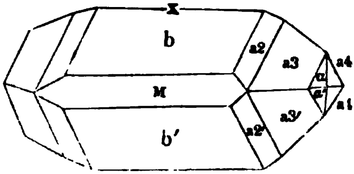


Colour white, passing occasionally into grey, yellow, red, and brown.

It is almost always crystallized, and the primary form is a right rectangular prism. One of the most common forms of the crystal is that represented on the margin, in which the base of the prism is replaced by four faces placed in the solid angles of the primary form. This is the shape of the harmotome which occurs at Strontian and in the Kilpatrick hills. The shape at Andreasberg is the same, but the crystals cross each other through the centre.

Very small transparent crystals occur pretty frequently at Strontian, having the form represented below.

b on b	69° 34′
b on adjacent plane over edge x	110° 26′
b on a^2	151° 35′
b on a^3	149° 32′
a^4 on a^4	178° 28′



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* From ἁρμος, *a joint*, and τεμνω, *I cut*. Because it admits of cleavage at the joints.

Fracture imperfect conchoidal, or uneven; lustre vitreous. Sometimes transparent, but most commonly only translucent; brittle.

Hardness 4·25; specific gravity of a translucent crystal from Strontian 2·400; of a transparent crystal 2·448.

Before the blowpipe on charcoal melts without intumescence into a clear bead.

The following tables exhibit the constituents of harmotome. according to the best analyses hitherto made :—

1. Barytes harmotome.

	*	†	‡	Mean.	Atoms.	
Silica, . .	56·30	47·04	48·753	50·694	25·34	13·77
Alumina, .	14·50	15·24	15·100	14·95	6·64	3·6
Barytes, . .	17·52	20·85	14·275	17·55	1·84	1
Lime, . .	1·00	0·10	3·180	1·43	0·4	0·2
Potash, . .	—	0·88	2·550	1·71	0·28	·29
Soda, . .	1·25	0·84	—	1·04	0·26	
Peroxide of iron,	—	0·24	—	0·24	0·05	—
Water, . .	11·69	14·92	14·000	13·54	12·03	6·5
	102·26	100·11	97·858			

2. Lime Harmotome.

	§	‖	‖	Mean.	Atoms.	
Silica, . .	53·07	48·51	48·02	49·86	24·93	13·47
Alumina, . .	21·31	21·76	22·60	21·89	9·72	5·25
Barytes, . .	0·39	—	—	0·39	0·03	—
Lime, . .	6·67	6·26	6·56	6·50	1·85	1
Potash, . .	—	6·33	7·50	6·91	1·15	0·61
Protoxide of iron,	0·56	0·29	0·18	0·34	0·07	—
Water, . .	17·09	17·23	16·75	17·02	15·12	8·17
	99·09	100·38	100·61			

3. Transparent harmotome from Strontian.¶ The crystal figured in page 699.

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* By Gmelin and Hepel. Ann. des Mines, x. 257. The specimen was from Andreasberg, which had been originally analyzed by Klaproth, (Beitrage, ii. 83), who discovered barytes in it.

† By Mr. Connell. The specimen was from Strontian.

‡ By my analysis. The specimen was from Strontian.

§ Wernekinch, Gilbert's Annalen, lxxvi. 175. The specimen was from Annerode.

‖ Gmelin and Hepel. Ann. des Mines, x. 255. The specimens were from Morbourg.

¶ By my analysis.

		Atoms.	
Silica, . .	64·755	32·27	27·43
Alumina, . .	13·425	5·96	5·05
Lime, . .	4·160	1·18	1
Protoxide of iron,	2·595	0·57	0·48
Water, . .	14·470	12·86	10·89
	99·405		

The slightest inspection is sufficient to show that these three minerals, hitherto confounded together under the name of harmotome, are essentially different in their constitution, and that they in reality constitute three distinct species.

The first, to which the name *harmotome* ought to be confined, is composed of

4 atoms tersilicate of alumina,
1 atom tersilicate of barytes,
6 atoms water.

If we unite the lime, potash, and soda, with the alumina, the atoms will be just four times as numerous as those of barytes. In that case there will be a deficiency of silica. But if we consider the lime and the alkalies as accidental, then there will be a deficiency of tersilicate of alumina.

The second, which has been distinguished by the name of *lime harmotome*, is composed of

4 atoms bisilicate of alumina,
1 atom bisilicate of lime and potash,
6 atoms water.

There is a slight excess of the potash. It is to this second species that the name *phillipsite* has been given by Mr. Levy. He observed small crystals of it in specimens brought by Sir John Herschell from Aci Reale, in Sicily. They consisted of four-sided prisms terminated by four-sided pyramids, similar to the crystal of harmotome, figured in p. 349. He was not able to measure the inclinations of the faces of the pyramids *a*, *a'*, with accuracy; but he considered them as decidedly different from those of the corresponding faces in harmotome, the most obtuse being 123° 30', and the least obtuse 117° 30'. Mr. Levy observed also, that phillipsite is much softer than harmotome.*

The constitution of the third species, to which I have given the name of *morvenite*, is

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* Annals of Philosophy (2d series), x. 362.

5 atoms quatersilicate of alumina,
1 atom quatersilicate of lime,
11 atoms water.

It differs from harmotome by being transparent, while the white harmotome crystals with which it is intermixed are white and translucent. The shape of the only crystals observed at Strontian, is that figured in page 349. I drew the attention of Mr. William Phillips to it in the year 1827, who was good enough to measure several of them. The result of these measurements is stated in page 349. They agree with the crystals of harmotome, as may be seen by comparing these measurements with those given by Mr. Phillips in his Mineralogy, p. 57. Yet it will be admitted, that the appearance of the crystal is quite different from that of any other crystal of harmotome hitherto observed. If to this we add its transparency, its greater specific gravity, and the very great difference in its composition, there will, I think, be no hesitation in considering it as entitled to rank as a distinct species.

The formulas for the constituents of these three species, are as follow:

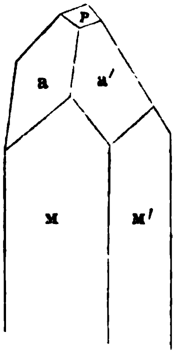
1 Phillipsite, $4AlS^2+(\frac{2}{3}Cal+\frac{1}{3}K)S^2+6Aq.$
2 Harmotome, $4AlS^3+BS^3+6Aq.$
3 Morvenite, $5AlS^4+CalS^4+11Aq.$

Sp. 31. *Apophyllite.*

Albin, fisheystone, ichthyopthalmite, tesselite.

This mineral was first observed at Uton in Sweden. It has been found since in other parts of Sweden, at Arendal, in Faroe, Greenland, the Tyrol, &c., and likewise in North America.

Colour white, usually with a shade of grey, green, yellow, or red; streak white.



Usually crystallized in right square prisms. Sometimes the prism terminates in a four-sided pyramid, sometimes complete and sometimes wanting the apex, formed by the decrement on the angles of the square base of the prism.

P on M or M,	90°
M on M', .	90°
P on a or a', .	120°
M on a or M' on a',	128° 20'
a on a' . .	104° 18'

Structure foliated, and when heated it splits into thin plates. It cleaves in the direction of all the faces of the primary prisms, but most easily in the direction of P.

Cross fracture uneven.

Lustre of P pearly; of the other faces vitreous.

Semi-transparent to translucent; brittle.

Hardness 6·25; specific gravity 2·359, by my trials. Haidinger states that of a variety from Iceland, 2·335.

Exfoliates before the blowpipe, and ultimately fuses into a white blebby glass.

In nitric acid it separates into flakes, and becomes gelatinous and semi-transparent.

The following table exhibits the constituents of this mineral, according to the best analyses hitherto made:

	*	†	†	‡	‡	§	§	‖
Silica,	52	51·8643	51·8564	52·50	52·900	51·76	51·18	51·008
Lime,	24·5	25·1992	25·2236	24·61	25·207	22·73	21·71	26·236
Potash,	8	5·1369	5·3067	5·08	5·266	5·31	5·27	5·888
Fluosil. of lime,	—	—	—	—	—	3·53	4·82	—
Water,	15	16·0438	16·9054	16·06	16·000	16·20	16·20	16·500
	99·5	98·2442	99·2920	98·25	99·373	99·53	99·18	99·632

All these analyses agree closely with each other, indicating considerable purity in the specimens examined. The mean of the whole gives us

		Atoms.	
Silica,	51·633	25·82	27·46
Lime,	24·426	6·98	7·42
Potash,	5·656	0·94	1
Water,	16·114	14·32	15·23

If we allow for a small surplus of tersilicate of lime and of silica, the constitution of the mineral will be

7 atoms tersilicate of lime,
1 atom tersilicate of potash,
15 atoms water.

The formula is $7\text{CalS}^3+\text{KS}^3+15\text{Aq}$.

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* Rose; Gehlen's Jour. v. 37.

† Stromeyer; Untersuchungen, p. 286. The first specimen from Fassa in the Tyrol; the second from Diskoe on the coast of Greenland.

‡ Berzelius, Afhandlingar, vi. 181. The first specimen from Fassa, the second from Uto.

§ Berzelius, Ann. des Mines, xii. 270. The first specimen from Faroe, called tesselite by Brewster, the second from Uto.

‖ By my analysis. The specimen was from Uto.

Sp. 32. *Rhodalite.*

I give this name to a mineral from Ireland, which I got in the autumn of 1834 from Mr. Doran. It occurs seemingly in an amygdaloidal rock, and seems to have been partially acted upon by the rain and weather.

Colour between rose red and flesh red.

Texture earthy; but seems to consist of a congeries of small rectangular prisms with square bases. It is mixed with earthy carbonate of lime and with small shining crystals, having a glassy lustre and the shape of chabasite.

Hardness about 2; easily scratched by the nail. Specific gravity 2·000. But it was found impossible to free the specimen completely from air.

Before the blowpipe per se not altered. With carbonate of soda it fuses into a greenish blue transparent bead in the exterior flame, becoming yellow in the interior flame. With borax it melts into a transparent colourless bead. With biphosphate of soda does not fuse.

Freed as much as possible from carbonate of lime and from chabasite by picking, it was analyzed in my laboratory by Mr. Richardson, who found its constituents

		Atoms.
Silica,	55·9	27·95
Alumina,	8·3	3·68
Peroxide of iron,	11·4	2·28
Oxide of manganese,	trace	
Lime,	1·1	0·31
Magnesia,	0·6	0·24
Water,	22·0	19·55
	99·3	

These numbers correspond nearly with

3 atoms quatersilicate of alumina,
2 atoms quatersilicate of iron,
$\frac{1}{2}$ atom quatersilicate of ($\frac{31}{55}$ lime, $\frac{24}{55}$ magnesia),
16 atoms water.

If we were to admit the quatersilicate of lime and magnesia to be accidental, the mineral would be

$$3\text{Al}S^4+\underline{f}S^4+16Aq.$$

But the specimen analyzed was probably not quite free from impurities.

Sp. 33. *Neurolite.*[*]

The mineral to which I have given this name was sent me

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[*] From *νευρον, a tendon,* or *string.* Named from its fibrous texture.

from Stamstead in Lower Canada, by Dr. Holmes of Montreal.

Colour greenish yellow.

Texture imperfectly foliated, being composed of thin fibres of some breadth; but rather obscure. The specimen had the appearance of having come from a vein about 2 inches wide. Not the least appearance of crystallization; brittle.

Fracture uneven; opaque, or only translucent on the edges.

Hardness 4·25; specific gravity 2·476.

Before the blowpipe gives out water and becomes snow-white and friable, but does not melt. With carbonate of soda fuses slowly into a transparent glass, slightly yellow, which cracks in various directions on cooling. In borax it does not seem to dissolve, but a snow-white opaque matter remains in the centre of the colourless globule. With biphosphate of soda the phenomena are the same.

The constituents of this mineral, determined by a careful analysis, were found as follow:

		Atoms.	
Silica,	73·00	36·5	24·01
Alumina,	17·35	7·71	5·07
Lime,	3·25	0·92	1
Magnesia,	1·50	0·60	
Peroxide of iron,	0·40	0·088	
Water,	4·30	3·82	2·51
	99·8		

If we leave out the peroxide of iron as accidental, and unite the lime and magnesia, it is obvious that the constitution of neurolite is

5 atoms quatersilicate of alumina,
1 atom quatersilicate of lime and magnesia,
2½ atoms water.

The formula is $5\mathrm{AlS}^4+(\frac{2}{3}\mathrm{Cal}+\frac{1}{3}\mathrm{Mg})\mathrm{S}^4+2\frac{1}{2}\mathrm{Aq}$.

Sp. 34. *Comptonite.*

This mineral was first found lining the cavities of an amygdaloidal rock from Vesuvius, and brought into this country by Earl Compton. It was named in honour of this nobleman by Dr. Brewster, who first recognised its difference from apophyllite, with which it had been confounded.

Hitherto it has been observed only in crystals. The colour is white, and the streak white.

The primary form is a right rectangular prism, the two adjacent sides of whose base are to each other as 5·6 to 5·5.* Frequently the edges of the prism are replaced by planes converting the prism into eight-sided. The base often is replaced by two very low planes meeting at an angle of 177° 35′.

Lustre vitreous; transparent to semitransparent.

Hardness 5; specific gravity by my trials 2·427.

It has two axes of double refraction, one of which is parallel and the other perpendicular to the axis of the prism.†

Before the blowpipe it first gives off water, intumesces a little, and becomes opaque, then it melts imperfectly into a vesicular glass. The globule obtained with borax is transparent, but vesicular; that with biphosphate of soda contains a skeleton of silica, and becomes opaque on cooling. With a little carbonate of soda it melts imperfectly, but with a larger quantity it becomes infusible.‡

It dissolves and gelatinizes in muriatic acid. If it has been previously ignited so as to deprive it of its water, the mineral is still decomposed by digestion in muriatic acid, but the silica separates in powder, and does not assume the form of a jelly.

I analyzed it, but being able to employ only 7·25 grains of it in the anhydrous state, the analysis is necessarily imperfect. The result was

		Atoms.	
Silica,	36·80	18·4	13·2
Alumina,	24·52	10·9	7·8
Lime,	10·89	3·11	2·2
Peroxide of iron,	3·66	0·73	0·52
Soda,	5·58	1·39	1
Water,	13·69	12·16	8·74
	95·14		

These numbers approach nearest to

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* Brooke, Edin. Jour. vi. 112.

† Brewster, Edin. Jour. iv. 132.

‡ Haidinger, Mohs' Mineralogy, iii. 90.

8 atoms silicate of alumina,
2 atoms bisilicate of lime,
1 atom silicate of soda,
9 atoms water.

The formula representing this constitution, is

$$8\text{AlS}+2\text{CS}^2+\text{NS}+9\text{Aq}.$$

The deficiency in the analysis was owing to the accidental loss of 0·35 grain of sediment, which was washed off a watch glass before I had examined it. I suspect it to have been chiefly lime, for it was found along with the soda in the residual liquid from which all the other constituents had been separated.

Sp. 35. *Hexagonal Talc.*

This mineral was considered by Werner as the crystalline form of common Venetian talc; but its chemical constitution is inconsistent with that supposition, and as it exists in a crystalline form and is regular in its constituents, it is entitled to rank as a peculiar species. The great quantity of water which it contains, would seem to claim for it a place among the minerals described in the present section, but its other properties separate it altogether from that beautiful tribe of minerals.

Colour bluish grey.

Texture obscurely foliated.

Lustre waxy.

Opaque; feels greasy.

Hardness 1·75; specific gravity 2·772.

Occurs crystallized in very short six-sided prisms, not susceptible of accurate measurement, but apparently regular.

The specimen above described, was from Ala in Piedmont. Its constituents, by my analysis, are

		Atoms.		
Silica, .	29·364	14·68	11·6	10·17
Alumina, .	17·808	7·91	6·25	5·26
Magnesia, .	12·144	5·06	4	4·11
Lime, .	3·092	0·88	0·69	
Protoxide of iron,	26·016	5·78	4·56	4
Water, .	11·200	9·95	7·86	6·9
	99·624			

The atoms of bases exceeding those of the silica, it is obvious that part of the bases are in the state of disilicates.

The constitution seems to be

5 atoms silicate of alumina,
4 atoms disilicate of lime and magnesia,
4 atoms disilicate of iron,
7 atoms water.

The formula is $5AlS+4(\frac{5}{6}Mg+\frac{1}{6}Cal)^2S+4f^2S+7Aq$.

Sp. 36. *Chlorite.*[*]

Common chlorite.

The mineral to which this name has been given from its green colour, occurs disseminated and in veins in primary rocks. Thus it is found in quartz veins in the islands of Bute and Arran, and in other localities both in England and Scotland.

Colour dark green.

Composed of small plates or scales cohering together without any visible cement.

Opaque.

Hardness 1·5; easily scratched by the nail.

Lustre silky, approaching resinous.

Sectile; easily frangible.

Specific gravity 2·823, by my trial.

Before the blowpipe fuses into a black opaque glass.

Its constituents, by the best analyses hitherto made, are as follow:

	†	‡	Atoms.
Silica,	26·8	27·624	13·812
Protox. of iron,	23·5	27·544	6·12
Alumina,	19·6	23·708	10·53
Magnesia,	14·3	10·960	4·38
Potash,	2·7	—	—
Water,	11·4	9·160	8·14
	98·3	98·996	

These analyses differ too much from each other, to deduce from both a formula indicating the constitution of chlorite. I shall therefore employ my own analysis, because I knew the purity of the specimen and the locality.

The atoms of bases are to those of silica as 1½ to 1, and if

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[*] From χλωρος, *green*.

[†] Berthier; Ann. des Mines, vi. 457.

[‡] By my analysis. The specimen was from Bute, and pure.

we reckon the oxide of iron and magnesia together, the constitution is

1 atom subsesquisilicate of alumina,
1 atom subsesquisilicate of iron and magnesia,
1 atom water.

The formula is $Al^{1\frac{1}{2}}S+(\frac{5}{12}Mg+\frac{7}{12}f)^{1\frac{1}{2}}S+1Aq$.

Sect. 7. *Triple Aluminous Salts.*

These salts are almost all anhydrous. But in other respects they differ much from each other. They amount to seventeen species.

Sp. 1. *Mica.*

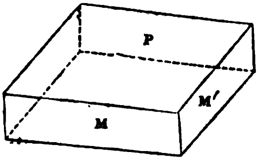
Muscovy glass, glacies mariæ, chlorite earth.

This mineral constituting an essential constituent of granite, gneiss, and mica slate, and appearing also pretty frequently in more recent formations, is obviously one of the most abundant of the mineral species. It is pretty evident that more than one species is at present confounded together under the name of mica, though we have not yet data sufficiently accurate to separate them with accuracy from each other.

Colour various shades of grey, passing into green, brown, or black. The lithia mica has usually a peach blossom red colour, and is distinguished by the name of *lepidolite*.

Texture always foliated, and it occurs frequently crystallized. The primary form is an oblique rhomboidal prism.

P on M 98° 40′
P on M′ 81° 20′
M on M′ 60



The acute edges of the prism are often replaced by tangent planes, which converts the crystal into a six-sided prism.

Mica occurs also crystallized in right rectangular prisms, which probably constitutes a peculiar species. But I have never had an opportunity of analyzing these rectangular crystals.

The folia may be obtained exceedingly thin and perfectly transparent. They are elastic and very tough.

Lustre pearly, often inclining to metallic upon P; that of the other faces when smooth, vitreous.

Hardness 2·5; specific gravity of fine rhomboidal prisms from Orange County, New-York, 2·824, by my trials. Haidinger states the specific gravity of a greenish black variety at

2·949. Dr. Turner found that of a dark brown, nearly opaque variety, from Cornwall, 3·08.

It appears from the experiments of Klaproth and Berzelius, that different varieties of mica behave differently before the blowpipe.

I consider the mica which crystallizes in rhomboidal prisms as the common mica. Its constituents are

	*	†	†	†	‡
Silica, . . .	47·19	46·10	46·358	47·5	49·380
Alumina, . .	33·80	31·16	36·800	37·2	23·668
Peroxide of iron, .	4·47	8·65	4·533	3·2	7·312
Oxide of manganese,	2·58	1·40	0·020	0·9	—
Lime, . . .	0·13	—	—	—	6·134
Fluoric acid, . .	0·29	1·12	0·760	0·56	—
Potash, . . .	8·35	8·34	9·220	9·60	15·292
Lithia, . . .	—	—	—	—	0·060
Water, . . .	4·07	0·87	1·040	1·39	—
	100·88	98·13	98·713	100·35	101·846

The mean of Rose's analyses is as follows:

		Atoms.	
Silica, .	46·787 .	23·39 .	45
Alumina, .	34·74 .	15·44 .	29·69
Peroxide of iron,	5·213 .	1·04 .	2
Potash, .	8·88 .	1·48 .	2·84

These atomic numbers give us

15 atoms silicate of alumina,
1½ atom tersilicate of potash,
1 atom tersilicate of iron.

The formula is $15\text{AlS}+1\frac{1}{2}\text{KS}^3+\text{fS}^3$.

My own analysis deviates too far from those of Rose, to warrant our employing it in calculating the constitution of common mica.

The constituents of the black mica of Siberia, according to the best analyses that we have, are as follow:

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[*] H. Rose, Poggendorf's Annalen, i. 77. The specimen was from Ochotzk in Siberia. It resembles Brodbo mica.

[†] H. Rose, Gilbert's Annalen, lxix. 164. The first specimen from Brodbo, the second from Kimita in Finland, the third from an iron foundery near Utön.

[‡] By my analysis. The specimen was from Orange County, New-York, in fine rhomboidal prisms.

	*	†	‡
Silica,	42·5	40·00	42·01
Alumina,	11·5	12·67	16·05
Peroxide of iron,	22·0	19·03	4·93
Oxide of mangan.,	2·0	0·63	trace
Magnesia,	9·0	15·70	25·97
Potash,	10·0	5·61	7·55
Fluoric acid,	—	2·10	0·68
Moisture ?	1	—	—
	98	95·74	97·10

These analyses differ so much from each other, that we are unable to deduce from them any formula for the constitution of black mica. It differs from common mica by containing magnesia. The atomic constituents of the two species analyzed by Rose, if we overlook the remarkable deficiency observable in both, may be considered as

	Atoms. 1st.	Atoms. 2d.
Silica,	20	21
Alumina,	5·63	7·13
Peroxide of iron,	3·8	0·99
Magnesia,	6·3	10·04
Potash,	0·93	1·26

The constitution of the first is nearly

6 atoms silicate of alumina,
6 atoms silicate of magnesia,
4 atoms bisilicate of iron,
1 atom silicate of potash.

The formula is $6AlS+6MgS+4fS^2+KS$.

But the constitution of the second variety is

7 atoms silicate of alumina,
10 atoms silicate of magnesia,
1 atom bisilicate of iron,
1 atom bisilicate of potash.

The formula is $7AlS+10MgS+fS^2+KS^2$.

It is clear from this, either that the specimens examined were impure, or that more than one species of black mica exists.

The peach blossom coloured micas (including the *lepidolites*,

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* Klaproth, Beitrage, v. 75.

† H. Rose, Poggendorf's Annalen, i. 80.

‡ H. Rose, Gilbert's Annalen. lxxi. 13. It was a mica with one axis of polarization.

which are mere varieties of mica), contain lithia, which, however, I discovered in minute quantity in the common mica. The following table exhibits the constituents of these micas, according to the best analyses hitherto made:

	*	*	†	‡	§
Silica,	52·254	46·233	49·06	47·995	49·64
Alumina,	28·345	14·141	33·61	23·755	24·56
Perox. of iron,	—	17·973	—	—	—
Prot. of mangan.,	3·663	4·573	1·40	7·065	3·60
Magnesia,	—	—	0·41	0·415	—
Potash,	6·903	4·900	4·18	14·635	16·32
Lithia,	4·792	4·206	3·60	3·166	1·20
Fluoric acid,	5·069	8·530	3·45	—	—
Water,	—	0·831	4·18	3·500	1·07
	101·026	101·387	99·89	100·475	96·36

These results differ a good deal, but they indicate the constitution of lithia mica to be a compound of simple silicates. Peroxide of iron in one case, seems to replace alumina. It seems to be

6 atoms silicate of alumina,
2 atoms silicate of lithia,
1 atom silicate of potash.

The formula is $6AlS+LS+KS$.

There is a brown scaly powder, which occurs occasionally among primary rocks, and which hitherto has been referred to chlorite, but it is undoubtedly a variety of mica. Its specific gravity is 2·801, and its constituents

		Atoms.	
Silica,	48·166	24·08	22·09
Alumina,	16·851	7·5	6·88
Peroxide of iron,	19·100	3·82	3·5
Potash,	6·558	1·09	1
Magnesia,	2·916	1·16	1·06
Lime,	2·675	0·76	0·7
Water,	2·350	2·06	1·89
	98·616		

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[*] H. Rose, Poggendorf's Annalen, iii. 45.

[†] Wenz, as quoted in Mohs' Mineralogy, ii. 203.

[‡] By my analysis. The specimen was from the United States.

[§] The same specimen, analyzed by Mr. Fairie in my laboratory.

These atomic numbers give us the constitution of the brown mica scales (omitting the silicate of lime as accidental)

7 atoms bisilicate of alumina,
3½ atoms silicate of iron,
1 atom bisilicate of potash,
1 atom bisilicate of magnesia,
2 atoms water.

The formula is $7\mathrm{AlS}^2+3\frac{1}{2}\mathrm{fS}+\mathrm{KS}^2+\mathrm{MgS}^2+2\mathrm{Aq}$.

Sp. 2. *Elaeolite.*[*]

Fettstein, lythrodes, sodaite.

This mineral occurs in Norway, near Laurvig, Stavern, and Frederiksvärm, imbedded in syenite. I have seen also specimens from the United States of America.

Colour duck blue, passing into blue and green; or brick red, passing into grey and brown.

Occurs massive, but has natural joints, parallel to all the planes, and to both diameters, of a right rhombic prism, with angles of 112° and 68°.

Fracture conchoidal.

Lustre resinous.

Translucent. Several varieties, when cut, became opalescent.

Hardness 6; specific gravity, according to Hoffmann, from 2·546 to 2·618.

Before the blowpipe melts into a white enamel.

When in powder it gelatinizes in acids.

Its constituents, according to the best analyses, are

	†	‡	Atoms.
Silica,	44	44·190	22·09
Alumina,	34	34·424	15·3
Soda,	16·5	16·874	4·22
Potash,	—	4·733	0·79
Lime,	0·12	0·519	0·14
Magnesia,	—	0·687	0·27
Peroxide of iron,	4	0·652	0·13
Water,	—	0·600	
	98·62	102·879	

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[*] From ελαιον, *olive oil.* Named from its fatty lustre.

[†] Vanquelin, Tableau compara, p. 228. The soda contained some potash.

[‡] C. G. Gmelin, Schweigger's Jahrbuch, vi. 82. The magnesia contained a little oxide of manganese.

If we calculate from Gmelin's analysis, and admit a slight excess of silica, and that the silicates of lime, magnesia, and iron, are accidental, the constitution of the mineral will be

3 atoms silicate of alumina,
1 atom silicate of soda and potash.

The formula is $3AlS+(\frac{1}{6}K+\frac{5}{6}N)S$.

Sp. 3. *Epidote.*[*]

Pistacite, acanticone, arendalite, delphinite, illuderite, scorza, thallite.

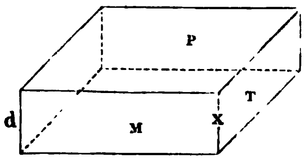
This mineral, which had been previously classed along with pyroxene, was first distinguished as a peculiar species by Hauy.

Colour green, of various shades; most commonly pistacio green. In general the green tints have a certain mixture of yellow.

Massive, but most frequently crystallized. The primary form of the crystal is a right oblique prism

M on T 115° 40′

In general the prism is elongated, and the faces are streaked. Frequently the edge x is replaced by a plane, making with M an angle of 150° 15′, and with T an angle of 145° 24′. Sometimes the edge d is replaced by one or even two planes. Thus the prism is six, eight, or ten-sided. The base P is often partly or wholly concealed by a four-sided pyramid, the faces of which rise from the lateral faces of the prism.[†]



Fracture uneven.

Translucent; said to occur transparent, but I have never seen a specimen.

Lustre vitreous, inclining to pearly upon perfect faces of cleavage.

Brittle; hardness 6.

Specific gravity, as determined by Haidinger, 3·425; by

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[*] From ἐπιδίδωμι, *I increase*. Named because the base of the primary form undergoes an increase in some of the secondary forms.

[†] For an interesting account of the crystals of epidote the reader is referred to a paper by Haidinger, Edinburgh Jour. x. 305. He deduces the forms from a different primary form. Indeed the connexion between the secondary forms and the primary forms of Hauy, which I have adopted, is far from intimate.

Descotils 3·46; by my trials 3·436 to 3·4408. I found the specific gravity of the variety called scorza 3·289.

Fuses with difficulty, and only on the thinnest edges before the blowpipe into a transparent glass. With borax it intumesces, and then yields a clear globule.

The constituents of this mineral, as determined by analysis, are as follow:—

	*	†	‡	§	§	‖	¶
Silica, . .	37	37	37	37·2	38·24	38·60	38·05
Alumina, . .	27	21	26·6	23·825	18·828	26·15	21·25
Lime, . .	14	15	20	23·075	24·080	23·84	20·20
Magnesia, . .	—	—	—	—	0·48	—	—
Protoxide of iron,	17	24	13	13·041	17·44	10·50	17·30
Protox. of manganese,	1·5	1·5	0·6	—	—	—	1·00
Moisture, . .	—	—	1·8	2·000	0·80	1·30	2·45
	96·5	98·5	99	99·141	100·588	100·35	100·25

In these analyses the proportion of silica does not differ much. But the other constituents vary a good deal in that respect. The following table exhibits the number of atoms of each constituent, deduced from the respective analyses:—

	1	2	3	4	5	6	7
Silica, . .	18·5	18·5	18·5	18·6	19·12	19·3	19·02
Alumina, .	12	9·33	11·82	10·58	8·36	11·62	9·48
Lime, . .	4	4·28	5·71	6·59	7·08	6·81	5·77
Magnesia, .	—	—	—	—	0·2	—	—
Protox. of iron,	3·77	5·33	2·9	2·9	3·87	2·33	3·84
Protox. of mangan.	0·33	0·33	0·13	—	—	—	0·22

The following table exhibits the ratios between the atoms of silica and bases in each analysis:—

Silica, .	18·5	18·5	18·5	18·6	19·12	19·3	19·02
Bases, .	20·1	19·27	20·26	20·07	19·51	20·76	19·31

In all of these the atoms of bases exceed those of silica. But in the fifth and seventh analyses this excess is very small;

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* Descotils, Jour. des Mines, v. 415.

† Vauquelin, Hauy, iii. 104.

‡ Laugier, Ann de Chim., lxix. 320.

§ By my analysis. The first specimen was in crystals, had a fine bottle green colour, and had the appearance of being very pure. The second was a superb crystallized specimen from America.

‖ By Mr. Byrkmire in my laboratory. The specimen belonged to the variety called *scorza*.

¶ The specimen was from Ireland, interspersed in a greenstone rock; had a specific gravity of 3·333. The analysis was made by Mr. Richardson, with great care, in my laboratory.

and if we exclude the magnesia (which occurring in none of the specimens except the fifth must have been accidental) almost vanishes. Now the sixth specimen analyzed was by far the finest I have ever seen. Hence it was probably purer than any of the other specimens subjected to analysis. From this I think we may conclude that epidote is composed of simple silicates.

Unless the specimen subjected to analysis contained foreign minerals mixed with the epidote, (which is very probable,) we have no other alternative but to admit that the alumina, lime, and protoxide of iron are capable of replacing each other. On that view epidote will be

$$\left.\begin{matrix}Al\\ C\\ f\end{matrix}\right\}S$$

If we calculate the ratios of the bases in the fifth analysis, we obtain

Alumina, . .	2·16
Lime, . . .	1·83
Protoxide of iron, .	1

Hence I think it likely that pure epidote is a compound of

2 atoms silicate of alumina,
1·5 atoms silicate of lime,
1 atom silicate of iron.

The formula will be $2AlS+1\frac{1}{2}CalS+fS$.*

There is a mineral which occurs at St. Marcet, in Piedmont, in gneiss. It has been long known to mineralogists under the name of *manganesian epidote.* It has a reddish brown colour, and has the form of small flat prismatic crystals, which are generally associated in groups. Before the blowpipe it fuses easily into a black glass, and with borax into a transparent glass. These crystals were analyzed by Mr. Victor Hartwall, and found composed as follow :—

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* If we calculate the constituents of the seventh analysis, which was an olive green radiated mass found in greenstone, we obtain almost exactly (omitting the manganese)

2½ atoms silicate of alumina,
1½ atoms silicate of lime,
1 atom silicate of iron.

This differs from the fifth specimen analyzed, simply in containing an additional half atom of silicate of alumina. If this last be considered as the purest specimen, the formula will be

$5AlS+3CalS+2fS$, while the fifth gives $4AlS+3CalS+2fS$.

		Atoms.
Silica,	38·47	19·23
Alumina,	17·65	7·84
Lime,	21·65	6·1
Sesquiox. of mangan.,	14·08	2·82
Peroxide of iron,	6·60	1·32
Magnesia,	1·82	0·73
	100·27[*]	

These numbers approach pretty nearly to the fifth of the preceding analyses, with this difference, that oxide of manganese is in a great measure substituted for oxide of iron. There is rather less alumina and lime, and rather more oxides of manganese and iron than in the fifth analysis. It would appear from this mineral, that oxide of manganese in epidote may replace oxide of iron.

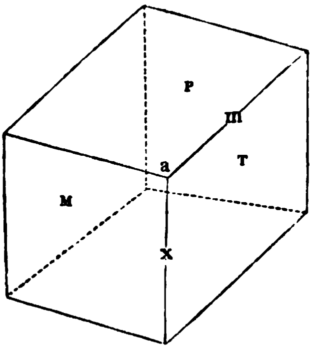
Sp. 4. *Axinite.*[†]

Thumerstone, thumite, yanolite.

This mineral was first described by Schreber, who found it near Balme d'Aaris, in Dauphiné, and gave it the name of *schorl violé.* It was afterwards found near Thum, in Saxony, in consequence of which Werner gave it the name of *thumerstein.* It seems to have been first called *axinite* by Karsten, from the resemblance of its crystals to the shape of an axe or hatchet.

Colour clove brown of various shades, sometimes inclining to plum blue, sometimes to pearl grey; streak white.

It occurs massive, but most frequently in crystals. The fundamental form of the crystal is assumed to be a doubly oblique prism, having the following angles, according to the admeasurement of Mr. W. Phillips:
P on M 134° 40′
P on T 115° 17′
M on T 135° 10′, so that the opposite edge is only 44° 50′
The solid angle a is often replaced by a plane, and the edge X is often replaced by 1, 2, or even more planes, making the



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[*] Kong. Vet. Acad. Handl., 1828, p. 171.

[†] From the resemblance of its crystals to an *axe* or *hatchet.*

prism six, eight, or ten-sided. The edge m is also sometimes replaced by a plane. Sometimes the base P is partly or wholly concealed by two oblique faces, or by an imperfect six-sided pyramid.

Fracture conchoidal, uneven; no cleavage perceptible.

Lustre vitreous, commonly splendent.

Transparent; often only translucent, sometimes only on the edges; very easily frangible.

Hardness 7; specific gravity of the Cornish specimen, as determined by Haidinger, 3·271.

Some varieties become electric when heated.

Before the blowpipe melts easily and with intumescence into a dark green glass, which becomes black in the oxidizing flame.

Its constituents are as follow:—

	*	†	‡
Silica,	44	50·5	45
Alumina,	18	16	19
Lime,	19	17	12·5
Magnesia,	—	—	0·25
Protoxide of iron,	14	9·5	12·25
Protoxide of manganese,	4	5·25	9
Potash,	—	0·25	—
Boracic acid,	—	—	2
	99	98·5	100

These analyses differ a good deal from each other. If we calculate from Wiegman's, which being the latest, has the greatest chance of being most correct, we obtain the following atomic numbers:

	Atoms.
Silica,	22·5
Alumina,	8·44
Lime,	3·57
Magnesia,	0·1
Protoxide of iron,	2·72
Protoxide of manganese,	2·00
Boracic acid,	0·66

The atoms of silica and boracic acid are 23·16, while those

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[*] Vauquelin, Jour. des Mines, No. xxiii. 1.

[†] Klaproth, Beitrage, v. 25.

[‡] Wiegman; Schweigger's Jour. xxxii. 462.

of the bases are only 16·83. Hence some of the bases must be in the state of bisilicates. The alumina very nearly equals all the other bases in the number of its atoms. Hence, supposing the boracic acid to be in combination with lime and magnesia, axinite seems to be a compound of

1 atom silicate of alumina,
1 atom bisilicates of lime, iron, and manganese.

The formula is $AlS+(\frac{39}{100}Cal+\frac{35}{100}f+\frac{26}{100}mn)S^2$.

But it is not probable that all the boracic acid was obtained by Wiegman.

Axinite occurs in beds and veins in primary countries. The most remarkable localities are Dauphiné, Thum, Kongsberg, in Norway, and Botallack, in Cornwall. It used to be abundant, but of late years it has become scarce.

Sp. 5. *Tourmalin.*

Aphrizite, apyrite, cockle, indicolite, daurite, picolite, rubellite, schorl, siberite.

The word *tourmalin* is said to be a corruption of the Ceylon name for this mineral, which was originally brought to Europe from that island. There is reason to believe, as Sir William Watson has shown, that the stone was known to the ancients, and distinguished among them by the name of *lyncurium* (λυγκουριον).* The term *schorl*, which, for many years, was applied indiscriminately to the tourmalin and various other minerals, is said to be derived from the village of Schorlaw, in Saxony, where the mineral to which that name was originally applied was first observed.

Tourmalin occurs frequently in primary rocks, especially granite and quartz. It is found also in dolomite, talc slate, and probably in other rocks. It occurs likewise not unfrequently in veins. Its localities are so numerous that it would be vain to attempt to enumerate them.

Colours brown, green, blue, red, white, frequently black. Generally dark, and scarcely ever bright. When a crystal is viewed in the direction of the axis it is usually opaque and black, but when viewed perpendicularly to the axis it is translucent, and shows the usual colour of the variety.

It occurs commonly crystallized in prisms of three, six, eight, ten, or twelve sides, and terminated by very irregular

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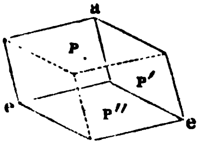
* Phil. Trans. 1759, p. 394.

summits. The primary form is an obtuse rhomboid, P on P 133° 20′. The angle at the summit *a* is usually replaced by a triangular plane; and the lateral angles e, e, being also replaced by planes, produce the ordinary six-sided prism of this mineral. By additional replacements of the edges, the prism becomes eight, ten, twelve-sided.



Fracture imperfect conchoidal, uneven.

Lustre vitreous; transparent to translucent. The black tourmalins are opaque.

Hardness 8; Æpinus first determined the specific gravity of this mineral, and found it between 3 and 3·06; Haidinger states it at 3·076.

Before the blowpipe the black tourmalin of Bovey intumesces and becomes a black scoriaceous mass. The green and red kinds intumesce, but do not fuse. With borax it fuses into a transparent glass.

The transparent varieties, when heated, become electric; the termination of the prism which presents the greater number of planes becoming positive, according to Hauy, while the other end becomes negative.*

The analysis of the tourmalin has been attended with uncommon difficulties. Lampadius in 1818 announced boracic acid as one of its constituents.† This discovery was confirmed by Gruner in 1819, who likewise detected lithia in a Greenland tourmalin.‡ The boracic acid detected amounted to 9 per cent. and the lithia to 5. The presence of lithia in tourmalin had been already discovered by Arfvedson.§ Dr. C. G. Gmelin of Tubingen soon after analyzed several tourmalins, and found in them both boracic acid and lithia.‖ Since that time several additional analyses have been published.

The following table exhibits the constituents of black tourmalin.

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* For recent experiments on the electric properties of the tourmalin, see Köhler, Poggendorf's Annalen, xvii. 146; and Becquerel, Ann. de Chim. et de Phys. xxxvii. 363.

† Gilbert's Annalen, lviii. 444.

‡ Ibid. lxv. 209.

§ Afhandlingar, vi. 166.

‖ Schweigger's Jahrbuch, viii. 514.

	*	†	‡
Silica,	33·048	44·10	35·20
Alumina,	38·235	26·36	35·50
Protoxide of iron,	23·857	11·96	17·86
Magnesia,	—	6·96	1·13 with mangan.
Lime,	0·857	0·50	0·55
Potash,	—	2·32	—
Soda,	3·175	—	2·09
Boracic acid,	1·890	5·72	—
Moisture,	—	0·60	—
	101·062	98·46	96·44

The following table exhibits the most recent and exact analyses of the green and red tourmalins, that have hitherto been made:

	§	‖	¶	**
Silica,	40·30	42·127	39·37	39·16
Alumina,	40·50	36·430	44·00	40·00
Protoxide of iron,	4·85	—	—	5·96
Protoxide of manganese,	1·50	6·320	5·02	2·14
Lime,	—	1·200	—	—
Potash,	—	2·405	1·29	—
Lithia,	4·30	2·043	2·52	3·59
Boracic acid,	1·10	5·744	4·18	4·59
Moisture,	3·60	1·313	1·58	1·58
	96·15	97·582	97·96	97·02

The following table exhibits the analyses of C. G. Gmelin

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* Gmelin, Schweigger's Jahrbuch, viii. 514. It was a black tourmalin from Eibenstock, which had already been analyzed by Klaproth, Beitrage, v. 148. The soda contained a little potash.

† Leplay, Ann. de Chim. et de Phys. xlii. 270. The specimen was from Mont Rose, and had a specific gravity of 3·14.

‡ Gmelin, Ann. des Mines (second series), iii. 219. The specimen was from Bovey, in Devonshire, and had a specific gravity of 3·246.

§ Arfvedson, Afhandlingar, vi. 166. It was a green crystallized tourmalin, from Utōn, usually called crystallized *lepidolite.*

‖ Gmelin, Schweigger's Jahrbuch, viii. 514. It was a rubellite from Rozenu. It had been analyzed by Klaproth, Beitrage, v. 86.

¶ Gmelin, Ann. des Mines (second series), iii. 218. The specimen was from Perm, in Siberia. Its colour was red, and its specific gravity 3·059.

** Gmelin, ibid. It was a green tourmalin from Brazil, of the specific gravity 3·079.

of those tourmalins that contain a notable quantity of magnesia :*

Silica,	37·65	35·48	38·79	37·81
Alumina,	33·46	34·75	37·19	31·61
Protoxide of iron,	9·38	17·44	5·81	7·77
Protoxide of manganese,	—	1·89	trace	1·11
Magnesia,	10·98	4·68	5·86	5·99
Lime,	0·25	trace	—	0·98
Potash,	2·55	0·48	0·22	1·20
Soda,		1·75	3·13	—
Boracic acid,	3·83	4·02	3·63	4·18
Loss by ignition,	—	—	1·86	0·24
	98·11	100·49	96·48	90·89

A bare inspection of these analyses shows that it would be useless at present to attempt to calculate the constitution of this mineral. The methods of analysis adopted are still too imperfect to render it probable that the results obtained hitherto, are sufficiently exact for our purpose. Boracic acid is obviously a constant ingredient, but the quantity is doubtless considerably greater than has hitherto been obtained. Some tourmalins contain lithia, others contain magnesia, and others potash, or soda, or both. But the great variation in the ratios of all these bodies, renders it impossible to draw any conclusion relative to them as essential constituents of tourmalin.

Sp. 6. *Bytownite*.†

I received the mineral to which I have given this name from Dr. Holmes, of Montreal, who informed me that it came from the neighbourhood of Bytown, in Upper Canada.

Colour light greenish-blue.

An amorphous mass, texture granular.

Fracture splintery, with some foliated portions like little crystals.

Translucent.

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* Gmelin, Ann. des Mines (second series), iii. 218. The first specimen was a black tourmalin from Käringbricka, in Westmanland, having a specific gravity of 3·044. The second, a black tourmalin from Rabenstein, in Bavaria, specific gravity 3·113. The third, a black tourmalin from Greenland, specific gravity 3·062. The fourth, a deep brown tourmalin from St. Gothard. The loss of 9 per cent. in the analysis of this tourmalin is remarkable. Bucholz had analyzed it before, and had met with a still greater loss.

† Named from Bytown, in Upper Canada, where it has been found

Lustre vitreous, shining.

Hardness 6; specific gravity 2·801.

Before the blowpipe becomes friable and white, but does not fuse. With carbonate of soda effervesces, but dissolves very slowly into an opaque white globule. With borax fuses into a transparent colourless glass, leaving a silica skeleton.

It was subjected to two separate analyses, which gave the following results:—

			Mean.	Atoms.
Silica, . .	47·735	47·400	47·567	23·78
Alumina, . .	29·695	29·60	29·647	13·17
Lime, .	8·800	9·32	9·060	2·58
Peroxide of iron, .	3·750	3·4	3·575	0·715
Magnesia, . .	trace	0·4	0·400	0·16
Soda, . . .	7·600	7·6	7·6	1·9
Moisture, . .	2·000	1·96	1·98	1·76
	99·58	99·68		

These atomic quantities approach very nearly

15 atoms silicate of alumina,
3 atoms bisilicate of lime and magnesia,
2 atoms bisilicate of soda,
1 atom bisilicate of iron.

Or, admitting the bisilicates of soda and iron to have been previously united,

5 atoms silicate of alumina,
1 atom bisilicate of lime and magnesia,
1 atom bisilicate of soda and iron.

The formula is $5AlS+(\frac{11}{12}Cal+\frac{1}{12}Mg)S^2+(\frac{2}{3}N+\frac{1}{3}f)S^2$.

Sp. 7. *Vermiculite.*[*]

This mineral also was sent me by Dr. Holmes, to whom I am indebted for so many new and interesting species. The locality is Vermont, one of the divisions of the United States.

It is composed of micaceous looking plates cemented together by a whitish matter.

Lustre soapy; feel greasy; sectile.

Hardness 1; specific gravity 2·5252.

When heated nearly to redness it projects out with a vermicular motion as if it were a mass of small worms. Hence the name. By ignition becomes of a silvery aspect with a shade of red or yellow.

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[*] So named from *vermis, a worm,* because it twists itself up like a worm when heated to redness.

Infusible per se before the blowpipe. With carbonate of soda in the reducing flame gives a greenish, in the oxidizing flame an amethyst coloured glass.

I found its constituents to be

		Atoms.
Silica,	49·08	24·54
Magnesia,	16·964	6·78
Peroxide of iron,	16·12	3·22
Alumina,	7·28	3·23
Water,	10·276	9·13
Manganese,	trace	
	99·720	

These numbers approach

2 atoms bisilicate of magnesia,
1 atom bisilicate of iron,
1 atom bisilicate of alumina,
3 atoms water.

The formula is $2MgS^2+AlS^2+fS^2+3Aq$.

Sp. 8. *Lithomarge*.

The term *lithomarge*, as applied by the older mineralogists, is so indefinite that it is difficult to fix a precise idea to the name. I shall therefore restrict my description to a specimen brought me from the banks of the Tweed, near Melrose.

Colour yellowish white; streak unaltered.

Texture fine earthy; opaque; dull.

Hardness 2·5; specific gravity 2·457.

With carbonate of soda fuses before the blowpipe in the outer flame into an opaque brown bead, becoming colourless on cooling. In the inner flame the colour became fixed. With borax it did not fuse. With biphosphate of soda in the outer flame fuses into a transparent colourless bead. In the inner flame became milky.

Its constituents were

		Atoms.
Silica,	55·50	27·75
Alumina,	24·30	10·80
Peroxide of iron,	2·50	0·50
Lime,	1·55	0·42
Magnesia,	0·95	0·38
Potash,	9·25	1·54
Water,	5·80	5·15
	99·85	

The atoms of silica amount to 27·75, and those of the bases to 13·64. It consists therefore of bisilicates. The constituents seem to be

7 atoms bisilicate of alumina,
1 atom bisilicate of potash,
1 atom bisilicate of iron, lime, magnesia,
$3\frac{1}{3}$ atoms water.

Were we to admit the small quantity of bisilicates of iron, lime, and magnesia, to be accidental, the mineral would be a compound of

7 atoms bisilicate of alumina,
1 atom bisilicate of potash,
3 atoms water.

I analyzed also a specimen of what mineralogists call indurated lithomarge.

The colours were red, green, white, yellow, and brown, mixed together unequally in the same specimen.

Texture earthy; lustre dull, except in one place which was shining, and had the aspect of being polished.

Hardness about 2; specific gravity 2·2727.

Before the blowpipe per se no alteration.

With carbonate of soda it fuses into an opaque white bead. With borax into a colourless transparent glass. And with biphosphate of soda into a semitransparent bead of a dirty white colour. Its constituents were

		Atoms.
Silica, .	46·30 .	23·15
Alumina, .	25·10 .	11·15
Peroxide of iron,	9·40 .	1·88
Magnesia, .	1·15 .	0·46
Water, .	18·50 .	16·44
	100·45	

Were the magnesia combined with oxide of iron, and only accidental, we might consider the mineral as composed of

1 atom silicate of iron,
8 atoms bisilicate of alumina,
12 atoms water.

It agrees only with the mineral first described in containing bisilicate of alumina. In every other respect it is different.

Sp. 9. *Latrobite.*

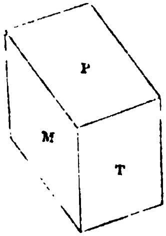
This mineral was first named and described by Mr.

Brooke.* It was given him by the reverend C. J. Latrobe, and came from Amitoke island, near the coast of Labrador. It is accompanied by mica and carbonate of lime, and is imbedded in a greyish coloured substance which Mr. Brooke also considers as new.

Its colour is pink, like that of some of the deep coloured varieties of lepidolite.

Its specific gravity is about 2·8

It scratches glass and is scratched by felspar.



It cleaves in three directions, parallel to the planes of a doubly oblique prism.

P on M 98° 30′
P on T 91°
M on T 93° 30′

The plane parallel to P is very dull, and the measurement obtained from it not to be confidently relied on. Those parallel to M and T afford good reflection, but one of them is brighter than the other.

Its constituents, determined by the analysis of Dr. C. G. Gmelin,† are as follow:

		Atoms.
Silica,	44·653	22·33
Alumina,	38·814	17·25
Lime,	8·291	2·37
Oxide of mangan.,	3·160	0·70
Potash,	6·575	1·096
	101·493	

If we leave out the manganese, the constituents are

15 atoms silicate of alumina,
2 atoms silicate of lime,
1 atom silicate of potash.

The formula is $15AlS+2CalS+KS$.

Or, admitting the silicates of lime and potash to have been previously combined, $5AlS+(\frac{2}{3}Cal+\frac{1}{3}K)S$.

Sp. 10. *Withamite.*

This mineral was discovered by Mr. Witham in Glencoe, incrusting the surface of a reddish trap rock. It was named and described by Dr. Brewster.

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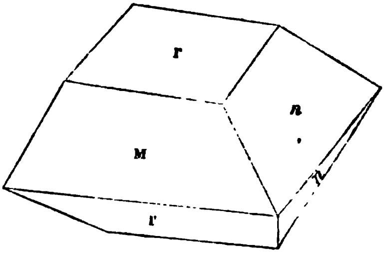
* Annals of Philosophy (2d series), v. 383.

† Ibid. x. 235.

Colour carmine red and pale straw yellow, in two different directions perpendicular to each other; streak white.



Minute crystals have been observed, similar to the figure in the margin.

r on T′ 128° 20′
M on T 16° 40′

By Dr. Brewster's measurement.

Hardness 6; specific gravity, as determined by Dr. Turner, 3·137; I found it only 2·857; but the specimen was not quite free from the trap rock which it incrusted.

Before the blowpipe it intumesces and fuses with difficulty into a dark greenish grey scoria. With biphosphate of soda it dissolves with effervescence into a globule, which contains a skeleton of silica, and becomes opaque on cooling. It behaves very nearly as the epidote from Arendal, with which it agrees in many of its properties.

Its constituents, as determined by Dr. Coverdale in my laboratory, are as follow. But he had only six grains of the mineral, and they were not quite free from the rock upon which the withamite was incrusted.

			Atoms.
Silica,	55·28	27·64	12·01
Alumina,	16·74	7·4	3·21
Peroxide of iron,	21·13	4·22	1·84
Lime,	8·13	2·3	1
Water,	3·25	2·88	1·2
	104·53		

These numbers approach to

3 atoms bisilicate of alumina,
2 atoms bisilicate of iron,
1 atom bisilicate of lime,
1 atom water.

The formula is $3AlS^2+2fS^2+CalS^2+1Aq$.

Sp. 10. *Isopyre.*[*]

This mineral has been hitherto found only in Cornwall. It

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[*] Poggendorf's Annalen, xii. 332. Named from ισος, *equal;* and πυρ, *fire;* because the effect produced on it by the blowpipe is the same as that produced on several other minerals.

was obtained from a mineral dealer at St. Just, and from Mr. Joseph Carne of Penzance, by the late Mr. Allan of Edinburgh. It was first described by Mr. Haidinger.

Colour greyish black or velvet black, with red spots like heliotrope.

Has not been observed in crystals, but is found imbedded in granite in small amorphous pieces.

Fracture conchoidal.

Lustre vitreous.

Opaque or slightly translucent on the edges.

Streak light greenish grey.

Has a great resemblance to obsidian and opal.

Its constituents, as determined by the analysis of Dr. Turner, are as follow :

		Atoms.
Silica,	47·09	23·54
Alumina,	13·91	6·17
Peroxide of iron,	20·07	4·01
Lime,	15·43	4·41
Oxide of copper,	1·94	0·39
	98·44	

This (leaving out the oxide of copper as accidental) approaches

3 atoms bisilicate of alumina,
2 atoms bisilicate of iron,
2 atoms silicate of lime.

This supposes a slight deficiency of silica and a small excess of lime.

The formula is $3AlS^2+2fS^2+2CalS$.

Sp. 12. *Kirwanite.*[*]

The mineral to which I have given this name, occurs on the north-east coast of Ireland, filling up cavities in a kind of basaltic rock. The specimens were brought me by Mr. Doran.

Colour dark olive green.

Texture fibrous, fibres diverging from a centre and forming brushes.

Opaque.

Hardness 2; specific gravity 2·941.

---

[*] Named in honour of Mr. Kirwan.

Before the blowpipe per se becomes black and partially fuses. With soda, borax, or biphosphate of soda, it fuses and forms a dark brown glass.

Its constituents, by the analysis of Dr. R. D. Thomson, are

		Atoms.
Silica,	40·5	20·25
Protoxide of iron,	23·91	5·31
Lime,	19·78	5·65
Alumina,	11·41	5·08
Water,	4·35	3·86
	99·95	

These numbers approach

1 atom silicate of iron,
1 atom silicate of lime,
1 atom bisilicate of alumina,
1 atom water.

The formula is $fS+CalS+AlS^2+1Aq$.

Sp. 13. *Scorilite.*[*]

I received the mineral, which, from its scoria-like appearance, I distinguish by this name, from Mexico, about ten years ago. It was labelled " Arcilla quenrada des Juan del Rio Casa del Calvaxio."

External colour reddish brown, internally dark brown; streak white.

Feels harsh, and has the aspect of a scoria. Full of small cavities like a cinder.

Opaque.

Hardness 2; specific gravity 1·708.

Before the blowpipe becomes whiter, but does not fuse. With carbonate of soda fuses readily into a yellow or bottle green transparent glass, according to the kind of flame to which it is exposed. With borax fuses into a blebby transparent yellow glass. Its constituents, by my analysis, are,

		Atoms.	
Silica,	58·02	29·01	11·8
Alumina,	16·78	7·45	3·02
Protoxide of iron,	13·328	2·96	1·2
Lime,	8·62	2·46	1
Water,	2·00	1·77	
	98·748		

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[*] Named from its great resemblance to scoria.

This corresponds very nearly with

3 atoms bisilicate of alumina,
1 atom bisilicate of lime,
1 atom tersilicate of iron.

Admitting a slight excess of this last salt, the formula is

$$3AlS^2+CalS^2+fS^3.$$

Sp. 14. *Sordawalite.*[*]

This mineral occurs at Sordawala, in Finland, and resembles pit coal in appearance. It constitutes a layer about an inch thick on common trap.

Colour pitch black, with sometimes, though rarely, a dark grey or greenish shade.

Massive; nor can any traces of cleavage be detected.

Fracture conchoidal.

About the hardness of crown glass.

Opaque; brittle.

Lustre vitreous and semimetallic.

Specific gravity 2·580.

Becomes reddish by long exposure to the atmosphere.

Before the blowpipe melts with difficulty into a black globule. With a small quantity of soda it fuses into a blackish green glass, with a larger quantity a slag is produced. With borax it fuses into a green glass. With biphosphate of soda it leaves a silica skeleton.

Its constituents, as determined by the analysis of Nordenskiöld, are as follow:—

		Atoms.	
Silica,	49·40	24·7	12·26
Alumina,	13·80	6·13	3·04
Protoxide of iron,	18·17	4·03	2
Magnesia,	10·67	4·25	2·19
Phosphoric acid,	2·68	0·59	0·29
Water,	4·38	3·88	1·92
	99·10		

There is some difficulty in discovering the base with which the phosphoric acid is united. If we pass by this as not determinable, the constitution of the mineral will be

3 atoms bisilicate of alumina,
2 atoms bisilicate of iron,
2 atoms silicate of magnesia,
2 atoms water.

The formula is $3AlS^2+2fS^2+2MgS+2Aq$.

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[*] Nordenskiöld's Bidrag, p. 86.

Sp. 15. *Cauzeranite.*[*]

This mineral was first noticed by Charpentier in the transition limestone of the Pyrenees. It was afterwards described and analyzed by M. Dufresnoy.

Colour black; sometimes deep indigo blue; rarely light grey.

Always in isolated crystals. The shape is an oblique rhomboidal prism, the faces of which are inclined to each other at angles of about 84° and 96°. The inclination of the base 92° or 93°. The crystals are rarely terminated. The obtuse edge of the prism is frequently replaced. Faces striated longitudinally.

Lustre vitreous and resinous; shining. Opaque.

Scratches glass; but not quartz.

Specific gravity 2·69

Before the blowpipe fuses into a white enamel, pretty much like felspar. With biphosphate of soda it fuses into a milky bead.

Its constituents, as determined by the analysis of M. Dufresnoy, are as follow:—

		Atoms.	
Silica,	52·37	26·18	28·45
Alumina,	24·02	10·67	11·6
Lime,	11·85	3·38	3·67
Magnesia,	1·40	0·56	0·6
Potash,	5·52	0·92	1
Soda,	3·96	0·99	1·07
	99·12		

These numbers correspond with

$11\frac{1}{2}$ atoms bisilicate of alumina,
$3\frac{2}{3}$ atoms silicate of lime,
1 atom silicate of potash,
1 atom silicate of soda.

Perhaps the true formula may be

$$6\mathrm{AlS}^2+2\mathrm{CalS}+(\tfrac{1}{2}\mathrm{k}+\tfrac{1}{2}\mathrm{N})\mathrm{S}.$$

Sect. 8. *Quadruple Aluminous Salts.*

These complicated minerals are probably either mixtures or combinations of two or more simpler minerals. If we were in possession of exact analyses, and knew the simple minerals

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[*] Ann. de Chim. et de Phys., xxxviii. 280. Named from Cauzeran, by which the part of the Pyrenees where it occurs was distinguished.

of which they are composed, we might point out the proportion of each. But this cannot at present be done. It is essential for the farther progress of this important branch of mineralogy, to describe the properties and determine the constituents of these compound minerals with as much accuracy as possible. They constitute twelve species.

Sp. 1. *Gieseckite.*

This mineral was brought by Sir Charles Giesecké from Akulliarasiarsuk, in Greenland, where it occurs along with felspar. It was named by Mr. Sowerby in honour of the discoverer.

Colour externally brownish; internally, it is olive green.

Crystallized in regular six-sided prisms. Texture merely granular, so that the crystals are probably pseudomorphous.

Fracture uneven, splintery.

Lustre resinous, almost dull.

Opaque or feebly translucent on the edges.

Hardness 3·5; specific gravity, as determined by Haidinger, 2·832.

Its constituents, as determined by Stromeyer,* are

		Atoms.
Silica,	46·0798	23·04
Alumina,	33·8280	15·03
Magnesia,	1·2031	0·5
Protoxide of iron,	3·3587	0·74
Protoxide of manganese,	1·1556	0·25
Potash,	6·2007	1·33
Volatile matter,	4·8860	4·34
	96·7119	

These numbers correspond best with the following constitution:

10 atoms silicate of alumina,
$1\frac{1}{3}$ atoms quatersilicate of potash,
1 atom bisilicate of iron, manganese, and magnesia,
3 atoms water.

The formula is $10AlS+1\frac{1}{3}KS^4+(\frac{1}{6}mn+\frac{2}{6}Mg+\frac{3}{6}f)S^2+3Aq$.

Sp. 2. *Nutallite.*

This mineral was found at Bolton, in Massachusetts. The first specimens brought to this country were by Mr. Nutall.

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* Gilbert's Annalen, lxiii. 272.

This induced Mr. Brooke to give it the name of that distinguished naturalist.

It occurs in crystals in a rock consisting partly of limestone and partly of a green-coloured mineral, having the aspect of amphibole. Small brown-coloured crystals (probably of sphene) are interspersed in my specimens.

The crystals are eight-sided prisms, which cleave in the direction of a right square prism, which consequently is the primary form.

Colour white, in some parts of the crystal yellowish, in others bluish or greenish. The yellowish white parts are transparent, the bluish nearly opaque, showing evidently the presence of some foreign matter; streak white.

Lustre vitreous.

Hardness 7; specific gravity from 2·748 to 2·758.

Its constituents, determined by the analysis of Dr. Thomas Muir, in my laboratory, are as follow:

		Atoms.
Silica,	37·808	18·4
Alumina,	25·104	11·11
Lime,	18·336	5·23
Peroxide of iron,	7·892	1·38
Potash,	7·305	1·21
Water,	1·500	
	97·945	

These numbers coincide nearly with

3 atoms silicate of alumina,
2 atoms silicates of lime, iron, and potash.

The formula is $3AlS+2(\frac{4}{6}Cal+\frac{1}{6}f+\frac{1}{6}K)S$.

Sp. 3. *Phyllite.*[*]

I give this name to a mineral which I received from Mr. Nutall. The locality is Sterling, Massachusetts. It is found in mica slate, and by the American mineralogists was considered as a variety of amphibole.

Colour brownish-black.

Composed of thin plates, without any perceptible regularity of shape.

Lustre semimetallic, splendent.

Opaque; sectile.

Hardness 5·75; specific gravity 2·889.

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[*] From φυλλον, *a leaf.*

Its constituents, by my analysis, are

		Atoms.	
Silica,	38·40	19·2	16·99
Alumina,	23·68	10·52	9·3
Peroxide of iron,	17·52	3·50	3·09
Magnesia,	8·96	3·6	3·18
Potash,	6·80	1·13	1
Water,	4·80	4·26	3·77
	100·16		

These numbers approach very nearly to

9 atoms silicate of alumina,
3 atoms silicate of iron,
3 atoms silicate of magnesia,
1 atom silicate of potash,
$3\frac{3}{4}$ atoms water.

The formula is $9\mathrm{AlS}+3\mathrm{fS}+3\mathrm{MgS}+\mathrm{KS}+3\frac{3}{4}\mathrm{Aq}$.

Sp. 4. *Huronite.*

I received the mineral to which I have given the name of huronite from Dr. Holmes, of Montreal. Its locality was from the neighbourhood of lake Huron. It exists in boulder stones, nearly spherical, in a black matter like hornblende. In this black matter the huronite is imbedded, in nearly spherical masses, attached to the surrounding black matter very firmly, without any visible cement.

Colour light yellowish green; of the powder greyish white.

Structure partly in imperfect folia, partly granular.

Lustre waxy, inclining to pearly on the foliated surfaces.

Translucent on the edges.

Hardness 3·25; specific gravity 2·8625.

When ignited becomes greyish-white, and loses 4·169 of its weight.

Infusible per se by the blowpipe. When mixed with the usual fluxes it melts into a greenish glass. Not acted on by acids.

Its constituents, by my analysis, are

		Atoms.	
Silica,	45·80	22·9	33·68
Alumina,	33·92	15·07	22·1
Protoxide of iron,	4·32	0·96	1·4
Lime,	8·04	2·30	3·38
Magnesia,	1·72	0·68	1
Water,	4·16	3·69	5·4
	97·96		

These numbers approach very nearly
22 atoms silicate of alumina,
3½ atoms bisilicate of lime,
1½ atoms bisilicate of iron,
1 atom bisilicate of magnesia,
5½ atoms water.

The formula is $22AlS+3\frac{1}{2}CalS^2+1\frac{1}{2}fS^2+MgS^2+5\frac{1}{2}Aq$.

Sp. 5. *Erlanite.*[*]

This mineral was first observed by Breithaupt, in 1818, at the Erla iron forges in the Saxon Erzegebirge. It forms a part of the oldest gneiss formation, and is always mixed with more or less mica. Between Gros-Pohle and Erla there exists a bed of it, at least 100 fathoms in thickness. Breithaupt has given to this mixture of erlanite and mica the name of *erlan-rock*. It has been used for 200 years as a flux by the iron smelters, and had been always considered as limestone till the mistake was rectified by Breithaupt.

Colour light greenish-grey; streak white. Sometimes compact, sometimes in small and fine granular distinct concretions.

Fracture sometimes foliated, sometimes splintery and uneven. Structure decidedly crystalline, though no regular cleavages have been observed; lustre fatty, from shining to dull.

Transparency not specified, but it is probably opaque, or only translucent on the edges, as it had been mistaken for limestone.

Hardness from 6·25 to 7; specific gravity from 3·0 to 3·1.

Before the blowpipe it melts easily into a slightly coloured transparent compact bead. With borax it fuses into a clear greenish glass. With biphosphate of soda it is decomposed, leaving a silica skeleton. Carbonate of soda easily fuses with a small, but not with a considerable proportion, of erlanite.

Its constituents, determined by the analysis of Dr. C. G. Gmelin, are

		Atoms.	
Silica,	53·160	26·58	12·24
Alumina,	14·034	6·23	2·87
Lime,	14·397	4·11	1·89
Soda,	2·611	0·65	0·3
Magnesia,	5·420	2·17	1
Peroxide of iron,	7·138	1·43	0·65
Oxide of manganese,	0·639	0·13	
Volatile matter,	0·606		
	98·005		

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[*] Schweigger's Jahrbuch, vii. 76.

These numbers approach

3 atoms bisilicate of alumina,
2 atoms bisilicate of lime,
1 atom bisilicate of magnesia,
1 atom silicates of soda and iron.

The formula is $3\mathrm{AlS}^2+2\mathrm{CalS}^2+\mathrm{MgS}^2+(\frac{1}{3}\mathrm{N}+\frac{2}{3}\mathrm{f})\mathrm{S}$.

Sp. 6. *Pinite.*

Micarell.

This mineral was first observed in the mine called Pini, at Schneeberg, in Saxony. It has been since met with in granite in many other places, Salzburg, Auvergne, Cornwall, North America, &c. It is always in crystals, but does not appear in general to possess any regular structure; indeed there can be little doubt that different substances have been confounded together under the same name.

Colour blackish-green, or greenish grey, but it is usually covered externally with a coating of ochre, which gives it a yellowish tinge.

Crystals regular six-sided prisms, whole lateral and terminal edges are frequently replaced by tangent planes.

Lustre resinous, glimmering.

Faintly translucent on the edges, or opaque.

Fracture uneven; sectile.

Hardness 2·25; specific gravity of the variety from St. Pardoux, as determined by C. G. Gmelin, 2·7575.* Haidinger found that of the crystallized variety from France, 2·782.†

The pinite of St. Pardoux fuses before the blowpipe into a glass full of blisters, when thin splinters are presented to the flame, though it does not melt into a globule. With borax it fuses with extreme difficulty into a transparent glass, faintly tinged by iron. Biphosphate of soda has no visible action on pinite in mass, but it gradually decomposes it in powder, leaving a residue of silica. The glass becomes opaline on cooling. With carbonate of soda it dissolves slowly into an opaque glass, slightly tinged by iron, and of difficult fusion.

The pinite of St. Pardoux, by Gmelin's analysis, is composed of

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* Edinburgh Jour. xi. 88.

† Mohs' Mineralogy, iii. 139.

			Atoms.
Silica,	55·964	27·98	21·35
Alumina,	25·480	11·32	8·64
Potash,	7·894	1·31	1
Soda,	0·386	0·09	0·06
Peroxide of iron,	5·512	1·10	0·84
Magnesia, with manganese,	3·760	1·50	1·14
Water, with animal matter,	1·410	1·25	1
	100·406		

These numbers approach very nearly to

8½ atoms bisilicate of alumina,
1 atom bisilicate of potash,
2 atoms silicates of iron and magnesia,
1 atom water.

The formula is $8\frac{1}{2}\text{AlS}^2+\text{KS}^2+2(\frac{9}{20}\text{f}+\frac{11}{20}\text{Mg})\text{S}+\text{Aq}$.

Sp. 7. *Glauconite.*[*]

Green earth—chlorite baldagée—talc chlorite zographique.

This mineral is a very common constituent of amygdaloid, the cavities of which are frequently filled with small concretions of this substance. It constitutes also the characteristic constituent of the green sand, to which that formation is indebted for its name. It is employed as a colour by painters, and is the mountain green used in water painting. It probably varies in its nature, yet there is a considerable resemblance between the analyses of this substance by Klaproth and Berthier.

Colour celandine green, of different degrees of intensity.

It occurs in globular and almond shaped pieces, which are sometimes hollow.

Structure earthy; fracture small grained, uneven.

Dull; streak feebly glistening.

Very soft and sectile.

Feels greasy; adheres slightly to the tongue.

Specific gravity from 2·598 to 2·632.

Not acted upon by muriatic acid, but attacked easily by aqua regia at a boiling temperature.

The following table shows its constituents, as determined by Klaproth and Berthier:—

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[*] From *γλαυκος, sea-green.*

	*	†	‡	§	‖
Silica, . .	51·5	53	51	46·1	57·8
Protoxide of iron, .	20·5	28	17	19·6	7·5
Alumina, . .	—	—	12	5·5	6·5
Magnesia, . .	1·5	2	3·5	3·8	19·5
Lime, . . .	—	—	2·5	—	—
Potash, . .	18	10	—	5·3	4·0
Soda, . . .	—	—	4	—	—
Water, . .	8	6	9	8·9	4·7
Grains of quartz, .	—	—	—	11·5	—
	99·5	99	99·5	100·7	100

Though the constituents in these specimens be not identical, yet the ratio between the atoms of acid and bases in each is nearly the same. In the first specimen analyzed by Berthier the atoms are

	Atoms.	
Silica, . .	23·0 .	26
Protoxide of iron, .	4·35 .	4·94
Alumina, . .	2·44 .	2·77
Magnesia, . .	1·12 .	1·27
Potash, . .	0·88 .	1
Water, . .	7·9	9

Very nearly $3fS^{2\frac{1}{2}}+2(\frac{7}{11}Al+\frac{4}{11}K)S^{2\frac{1}{2}}+MgS^{2\frac{1}{2}}+5Aq$.

Sp. 8. *Glaucolite.*[¶]

This name has been given by M. Bergmann to a mineral found by Menge near lake Baikal, in Siberia, imbedded in compact felspar, and granular limestone.

Colour lavender blue, occasionally passing into green.

Massive, presenting traces of cleavage parallel to the faces of a rhombic prism of 143° 30′, according to Brooke.

Fracture splintery; translucent on the edges; lustre vitreous.

Hardness 5; specific gravity 2·72 to 2·9.

Constituents:—

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[*] Klaproth, Beitrage, iv. 242. The specimen was from Cyprus.

[†] Klaproth, ibid., p. 241. The specimen was from the Veronese.

[‡] Klaproth, ibid., p. 244. The specimen was from East Prussia.

[§] Berthier, Memoirs, i. 157. The specimen was from Germany.

[‖] Berthier, ibid., p. 158. The specimen was from the Vosges.

[¶] Edin. New Jour. iii. 385.

		Atoms.
Silica,	54·58	27·29
Alumina,	29·77	13·23
Lime,	11·08	3·16
Potash,	4·57	0·76
	100·00	

This is nearly

1 atom sesquisilicate of potash,
4 atoms sesquisilicate of lime,
16 atoms sesquisilicate of alumina.

Sp. 9. *Mountain Leather*.

This term has probably been applied to different mineral species. I confine it here to a mineral which occurs at Strontian, and which I subjected to analysis.

Colour light buff.

Composed of fine threads felted like a hat.

Feels soft, quite flexible, but tough, and like leather in appearance. Imbibes water like a spunge, and then puts on very much the appearance of wet leather.

Opaque; specific gravity 1·334.

Before the blowpipe curls up, and then fuses easily into an opaque bead. Melts with carbonate of soda into a transparent yellow bead. With borax fuses into a colourless transparent glass.

Its constituents are

		Atoms.	
Silica,	51·650	25·82	31·11
Alumina,	9·505	4·22	5·08
Lime,	10·005	2·85	3·43
Magnesia,	2·065	0·83	1
Protox. of iron, with a little mangan.,	5·805	1·28	1·54
Water,	21·700	19·28	23·2
	100·730		

These numbers approach

10 atoms tersilicate of alumina,
7 atoms tersilicate of lime,
3 atoms tersilicate of iron,
2 atoms bisilicate of magnesia,
40 atoms water.

The formula is $10AlS^3+7CalS^3+3fS^3+2MgS^2+40Aq$.

Whether the whole water is chemically combined or not is a question. But as the mineral feels quite dry, and may be exposed to the air without losing weight, the probability is that the greatest portion at least is in combination with the mineral.

Sp. 10. *Pearlstone.*

This mineral occurs in great beds in clay porphyry, and in secondary trap rocks. It is found in Hungary, and at Cap de Gate, in Spain, where it is associated with obsidian. It is said also to have been observed in Iceland, and at Sandy Brae, in Ireland.

Common colour grey; but it is said also to occur of a black and red colour.

It consists of roundish balls from one to two inches diameter, which are composed of very thin concentral lamellæ. Sometimes it is vesicular.

Lustre strongly pearly and shining.

Translucent on the edges.

Very easily frangible.

Hardness 6; specific gravity 2·342. The specimen tried was from Spain.

Intumesces before the blowpipe, and is converted into a white frothy-like glass.

Its constituents, by my analysis, are

		Atoms.	
Silica,	70·4	35·2	40·93
Alumina,	11·6	5·15	6
Peroxide of iron,	4·384	0·88	1·02
Lime,	3·000	0·85	0·98
Potash,	5·200	0·86	1
Water,	4·280	3·80	4·42
	98·864		

These numbers approach very nearly

6 atoms quintosilicate of alumina,
1 atom quatersilicate of iron,
1 atom quatersilicate of lime,
1 atom quatersilicate of potash,
4 atoms water.

The formula is $6AlS^5+Sf^4+CalS^4+KS^4+4Aq$.

Sp. 11. *Saussurite.*

Iade, felspath tenace.

This name was given by Saussure Junior to a mineral which Saussure Senior had described under the name of *iade.*

It occurs usually along with diallage, constituting a beautiful rock, to which the name of *diallage rock* has been given. In this way it is found in the peninsula of the Lizard, in Cornwall. It exists in the same way in Corsica, constituting the well-known rock called Verde di Corsica. Its other localities are very numerous.

Colour various shades of grey; that from the Lizard is commonly reddish grey. Sometimes it is bluish, and sometimes greenish grey.

Texture granular.

Fracture splintery; very tough.

Translucent on the edges.

Hardness 7; specific gravity 2·801. The specimen examined was from the Lizard.

Before the blowpipe the thin edges softened, but it did not melt into a globule.

The constituents of the Lizard Saussurite, by my analysis, are as follow:—

			Atoms.
Silica,	82·168	41·08	128
Alumina,	5·072	2·25	7
Protox. of iron, with some manganese,	2·880	0·64	2
Lime,	5·520	1·57	4·9
Magnesia,	4·520	1·80	5·62
Potash, a trace			
	100·16		

These numbers (admitting a slight excess of magnesia) approach very closely to

7 atoms septisilicate of alumina,
2 atoms septisilicate of iron,
5 atoms septisilicate of lime,
5 atoms sexsilicate of magnesia.

The formula is

$$7\mathrm{AlS}^7\,5\mathrm{CalS}^7+2\mathrm{fS}^7+5\mathrm{MgS}^6.$$

Sp. 12. *Pitchstone.*

This mineral has been observed only hitherto in veins. It occurs in veins traversing sandstone in the Island of Arran, and constitutes that remarkable vein called the Skuir of Egg, in the Hebrides. It is found in many other situations, both in Scotland and on the Continent.

Usual colour dark green; but it passes on the one side into black, grey, and blue; and on the other into green, brown, yellow, and red.

It has never been observed in crystals. Structure compact, without any appearance of folia.

Fracture conchoidal, sometimes nearly even.

Lustre resinous, shining.

Feebly translucent on the edges.

Easily frangible.

Hardness 6·5; specific gravity, by my trials, from 2·338 to 2·3604.

Before the blowpipe per se it may be fused into a globule.

The constituents of the Arran pitchstone, by my analysis, are as follow:—

		Atoms.	
Silica,	63·500	31·75	37·56
Alumina,	12·736	5·66	6·73
Lime,	4·460	1·27	1·5
Protoxide of iron,	3·796	0·84	1
Soda,	6·220	1·55	1·84
Volatile matter,	8·000		
	98·712		

These numbers approach

13½ atoms tersilicate of alumina,
4 atoms quatersilicate of soda,
3 atoms quatersilicate of lime,
2 atoms quatersilicate of iron.

The formula $13\frac{1}{2}AlS^3+4NS^4+3CalS^4+2fS^4$.

The nature of the volatile matter was not determined. If it were water, as is most likely, the water will amount to 8½ atoms.

I analyzed a specimen of dark green pitchstone from Saxony, the specific gravity of which was 2·3604. Its constituents were

		Atoms.
Silica,	73·100	36·55
Alumina,	13·560	6·02
Protoxide of iron,	0·864	0·19
Lime,	1·484	0·42
Soda,	6·320	1·58
Water,	4·724	4·2
	100·042	

These constituents do not agree with those in the Arran pitchstone, showing that the constitution of the mineral is not always the same. The Saxon pitchstone is composed of

3 atoms quatersilicates of alumina,
1 atom sexsilicates of iron, lime, and soda,
2 atoms water.

The formula is $3AlS^4+(\tfrac{1}{11}f+\tfrac{2}{11}C+\tfrac{8}{11}N)S^6+2Aq$.

Sp. 13. *Obsidian.*

This mineral was named, as Pliny informs us, from a Roman called Obsidius, who first brought it from Ethiopia. I have a specimen which Mr. Salt brought from Abyssinia, doubtless the same locality from which Obsidius got it. It abounds in Iceland, and from Sir George Mackenzie's observations, seems to constitute part of a stream of lava from a volcano. It is found in Hungary and the Grecian Islands. I have specimens from Mexico, and many other localities are well known.

Colour velvet black, but when in very thin layers it has a brownish cast.

Never crystallized; has exactly the appearance of a mass of opaque glass.

Fracture conchoidal.

Lustre vitreous, splendent.

Breaks into very sharp edged fragments.

Translucent on the edges.

Easily frangible; streak grey.

Hardness 6·5; specific gravity of a specimen from Iceland, by my trials, 2·363; of a specimen from Mexico 2·372.

Before the blowpipe per se it melts into a vesicular glass, usually very bulky. The colour is white or grey.

I analyzed two specimens, the first from Iceland, the second from Mexico. The constituents were,

			Mean.	Atoms.	
Silica,	84·000	82·776	83·388	41·69	34·4
Protoxide of iron,	5·012	5·916	5·464	1·21	1
Alumina,	4·640	2·948	3·794	1·69	1·4
Soda,	3·552	5·510	4·531	1·13	0·93
Lime,	2·392	2·444	2·418	0·68	0·56
Water,	—	0·300	0·150		
	99·596	99·894			

These results do not absolutely agree, yet they show an approach to a chemical constitution. They correspond with

3 atoms novisilicate of alumina,
2 atoms novisilicate of soda,
2 atoms novisilicate of iron,
1 atom novisilicate of lime.

The formula is $3AlS^9+2NS^9+2fS^9+CalS^9$.

But the specimen of obsidian from Pasco, in Columbia, analyzed by Berthier, differs exceedingly from my results. He obtained*

			Atoms.	
Silica,	69·46	34·73	29·18	29
Potash,	7·12	1·19	1	1
Soda,	5·08	1·27	1·06	1
Lime,	7·54	2·15	1·8	2
Magnesia,	2·60	1·04	0·87	1
Alumina,	2·60	1·15	1	1
Peroxide of iron,	2·60	0·52		
Volatile matter,	0·30			
	97·30			

This approaches nearest to

2 atoms quintosilicate of lime,
1 atom quintosilicate of potash,
1 atom quintosilicate of soda,
1 atom quintosilicate of magnesia,
1 atom quintosilicate of alumina.

It is obvious from this that obsidian is not a true chemical compound.

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* Ann. des Mines (third series), v. 543.

How far the *sphærulite* of Breithaupt agrees with obsidian has not been determined by analysis, but there is a considerable resemblance in the characters of the two. It occurs at Glashütte, near Schemnitz, in Hungary, imbedded in pearlstone, and at Spechtshausen, near Tharand, in Saxony, imbedded in pitchstone.

Colour various shades of brown and grey.

Imbedded in spheroidal masses. Surface of some of them smooth, of others rough.

Fracture conchoidal.

Translucent on the edges; opaque.

Brittle.

Hardness 7·25. Specific gravity 2·416 to 2·452.

Before the blowpipe it is almost infusible, on the edges becomes covered with a sort of enamel.[*]

We have now finished the description of those minerals which contain alumina as an essential constituent, and in which the other essential constituents are those bases which have been already described, with the exception of oxide of iron, which is a substance so generally distributed through nature that but few minerals are found which contain no trace of it. The aluminous minerals which we have described amount to no fewer than 143 species, while the species belonging to ammonia, potassium, sodium, lithium, barium, strontium, calcium, and magnesium, taken together, amount only to 86. Those belonging to glucinum, yttrium, cerium, zirconium, and thorium, are much less numerous. Thus the species of minerals belonging to the genus aluminum, considerably exceed the species belonging to the thirteen kindred bases. We shall find iron ranking next after aluminum in the number of its species, as it is also next it of all the bases in the universality of its distribution.

GENUS X.—GLUCINUM.

The remarks made upon aluminum at the beginning of the last genus, apply equally to glucinum. It has never been met with in the metallic state, but only in the state of the white oxide, or earth, known by the name of glucina. The number of species belonging to this genus being only four, no subdivision of them is necessary. They are all (except

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[*] See Breithaupt's *Volständige Charakteristik des Mineral-Systems*, p. 179.

the first) double salts; the second and third consist of two bases united each to alumina, which acts in it the part of an acid.

Sp. 1. *Phenakite.*

This mineral has been lately discovered by Nordenskiöld, in specimens from the Uralian mountains, mixed with emerald. It oocurs imbedded in mica slate. From its external characters it was considered as rhomboidal quartz, but its behaviour before the blowpipe proved it to be something else. It was not fusible per se, did not form a transparent glass with carbonate of soda, and was difficultly fusible in borax and biphosphate of soda.

It occurs in flat colourless rhomboids, similar to the flat crystals of calcareous spar near Freiberg.

The primary form is a rhomboid, the faces of which are inclined to each other at angles of 115° 25′, and 64° 35′, the edges and angles of which are generally replaced by tangent planes.

Texture foliated in the direction of the large diagonal of the faces; cross fracture similar to that of quartz.

Somewhat harder than quartz, and not attacked by acids.

Lustre vitreous.

Specific gravity 2·969.

Unaltered per se before the blowpipe; fuses with borax into a transparent glass; with biphosphate of soda it dissolves with difficulty, leaving a silica skeleton; with carbonate of soda it gives only a white enamel.

Its constituents, determined by the analysis of Hartwall, were:

		Atoms.	
Silica, . .	55·14	. 27·57 .	2·01
Glucina, . .	44·47	. 13·68 .	1
Magnesia and alumina,	trace		
	99·61		

It is therefore a bisilicate of glucina.

Nordenskiöld named it from φεναξ, *a deceiver*, because it had been mistaken for quartz.*

Sp. 2. *Euclase.*†

This mineral was first brought from Peru, by Dombey,

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* Poggendorf's Annalen, xxxi. 57.

† From ευ and κλαω, *to break*, because it is easily broken.

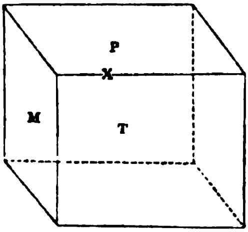
about the end of the eighteenth century. It was found afterwards in the mining district of Villa Rica, in Brazil. It occurs there in a chlorite slate resting on sandstone, and is associated with topaz.

Colour mountain-green, passing into blue and white; always pale; streak white.

Always in crystals; the primary form is a right oblique angled prism.

M on T 130° 52′

It cleaves easily parallel to the plane P, the edges X are usually replaced by three different planes. The other terminal edges of the prism, and also the lateral edges are frequently replaced also, so that its common form is that of a fourteen-sided prism, terminated by thirty-two facets, disposed in four ranges.



Fracture perfect conchoidal, and very easily obtained, for the mineral is very easily frangible. Hence the name euclase, imposed by Hauy, which signifies *easily broken*.

Lustre vitreous, splendent.

Transparent or semitransparent.

Hardness 7·5; specific gravity, as determined by Haidinger, 3·098. Mr. Wilson Lowry found it 2·907. Hauy gives the specific gravity, on the authority of the School of Mines, 3·0625.

Before the blowpipe it fuses into a white enamel, but requires a strong heat. In borax it dissolves slowly and with effervescence, into a colourless glass. In biphosphate of soda it is decomposed with strong effervescences, leaving a silica skeleton, which is whiter than common. With a small quantity of carbonate of soda it fuses into a white bead; with a greater quantity it gives a transparent glass, which becomes opaque on cooling.

Vauquelin analyzed it, and detected in it silica, alumina, glucina and oxide of iron. But he sustained a loss of 28 per cent., and his specimen was too small to permit a repetition of the analysis.* It was afterwards analyzed with much care by Berzelius, who published the result of his experiments in 1819. It is as follows:†

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* Jour. des Mines, x., lv. 509.

† Kong. Vet. Acad. Handl., 1819, p. 136.

			Atoms.
Silica,	43·22	21·61	3·22
Alumina,	30·56	13·58	2·02
Glucina,	21·78	6·70	1
Peroxide of iron,	2·22	0·44	0·06
Peroxide of tin,	0·70	0·07	
	98·48		

It is obviously a compound of

2 atoms silicate of alumina,
1 atom silicate of glucina,

with a little silicates of iron and tin.

The formula is $2AlS+GS$.

Sp. 3. *Emerald.*

Beryl, aquamarine, agustite.

The finest specimens of the emerald come from Peru. The present mine is situated in the valley of Tanca, in Santa Fe, between the mountains of New Granada and Popayan. Emeralds occur there, according to Humboldt, in veins traversing hornblende slate, clay slate, and granite. The ancients procured their emeralds from Egypt, but of late years they have been discovered in Mount Zalora, in Upper Egypt, where they occur in granite and mica slate. In Siberia, the mineral occurs in the granite district of Nertschinsk, and in the Uralian and Altai mountains. It has been found in Cornwall by Mr. A. R. Barclay, crystallized in a dark grey quartz wall of a vein traversing the granite and slate of St. Michael's Mount.* They have been found also in Scotland, at Kinloch Raimoch and Cairngorm, and it is said also in Rubislaw quarry, near Aberdeen. They occur in the beautiful crystallized granite of the Morne mountains in Ireland. Fine specimens are met with in the county of Wicklow, and in the mountains above Dundrum. There are various localities in Germany, Sweden and North America, not to mention Brazil, where it is found in the sand of rivers.

Colour emerald green, passing into blue, yellow and white. The bright green variety is called *emerald*, while all the pale varieties are denominated *beryl.* Streak white.

Sometimes it occurs massive, but most commonly crystallized. The primary form is the regular six-sided prism, the terminal edges and angles of which are usually replaced by

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* Annals of Philosophy (second series), x. 383.

tangent planes. The crystals are frequently very large, even a foot in length.

Fracture conchoidal uneven.

Lustre vitreous. Hardness 7·5 to 8.

Specific gravity of an emerald variety determined by Haidinger, 2·732; of an apple green variety, 2·678. I found that of some small emeralds from Brazil 2·580.

Before the blowpipe the edges are rounded, and a shapeless vesicular scoria is produced. It fuses with borax.

The following table exhibits the constituents of this mineral, according to the best analysis hitherto made :

	*	*	†	†	‡	§
Silica, . . .	64.5	68	68·5	66·45	68·35	66·858
Alumina, . . .	16	15	15·75	16·75	17·60	18·406
Glucina, . . .	13	14	12·5	15·50	13·13	12·536
Oxide of chromium, .	3·25	—	0·3	—	—	—
Peroxide of iron, .	—	1	1	0·60	0·72	2·002
Oxide of columbium, .	—	—	—	—	0·27	—
Lime, . . .	1·6	2	0·25	—	—	—
Water, . . .	2	—	—	—	—	—
	100·35	100	98·3	99·3	100·07	99·802

These results approach each other so closely as to leave no doubt about the chemical constitution, and the purity of the specimens examined by the different experimenters. My analysis gives the following atomic numbers:

		Atoms.
Silica, .	33·43 .	8·68
Alumina, .	8·18 .	2·12
Glucina, .	3·85 .	1

The mean of all the analyses gives

		Atoms.
Silica, .	67·11 .	33·55
Alumina,	16·58 .	7·36
Glucina, .	13·44 .	4·1

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* Vauquelin, Jour. des Mines, No. xxxviii. 98, and xliii. 563. The first specimen was an emerald from Peru, the second a beryl.

† Klaproth, Beitrage, iii. 219 and 226. The first specimen an emerald, the second a beryl.

‡ Berzelius, Afhandlingar, iv. 192. The specimen was from Brodbo, in Sweden.

§ By my analysis. The specimen was a Siberian beryl. The iron was scattered through the stone in small rifts, and must therefore be considered as accidental.

There is an excess of alumina, and a deficiency of silica in my analysis. But there is an excess in the others. The constitution of emerald is obviously

2 atoms tersilicate of alumina,
1 atom tersilicate of glucina.

The formula is $2AlS^3+GS^3$.

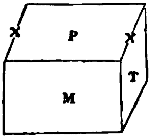
Sp. 4. *Chrysoberyl.*

Cymophane.

This mineral occurs in greatest abundance in Brazil, where it is accompanied by topazes in the alluvial soil. In Ceylon it has been observed in the sand of rivers. It is met with at Nerbschink, in Siberia, but the nature of its repository in that quarter is unknown. At Hoddam, in Connecticut, it occurs in granite.

Colour asparagus green, passing into greenish white, olive green, and yellowish grey. When viewed in a direction perpendicular to the base of the primary prism, it shows a bluish opalescence. Streak white.

It occurs in irregular grains, roundish pieces and in crystals. The primary form is a right rectangular prism. Sometimes the base P is replaced by two planes, produced by decrements on the edges X.



Sometimes the edges and the prism are replaced by one or more planes, making the prism 8 or 12-sided. In such cases the prism is terminated by a six-sided or eight-sided irregular pyramid.

Lustre vitreous.

Transparent to translucent.

Cross fracture conchoidal. Splits easily parallel to the face M.

Hardness 8·5; specific gravity, according to Haidinger, 3·754. Seybert found that of the Hoddam variety from 3·508 to 3·597. I found picked specimens of the Brazil variety to vary from 3·7112 to 3·733.

Does not melt before the blowpipe per se, nor can it be fused along with carbonate of soda. With borax and biphosphate of soda it fuses perfectly, but not without a good deal of difficulty.

Chrysoberyl was analyzed long ago by Klaproth, who obtained

Alumina, . .	71·5
Silica, . .	18
Lime, . .	6
Oxide of iron, .	1·5
	97*

Arfvedson analyzed it in 1822, and obtained

Alumina, .	81·43
Silica, . .	18·73
	100·16†

But he seems to have taken for silica the portion of matter left, when the mineral was heated with caustic potash and digested in muriatic acid. This was rather unaccountable both in him and Klaproth, as the difficulty of dissolving the mineral might have suggested the suspicion that it had not been completely decomposed. Seybert analyzed chrysoberyl in 1824, and made the important discovery that it contains glucina. The following table exhibits the result of his analyses:‡

Alumina, .	73·60 .	68·666
Glucina, .	15·80 .	16·000
Silica, . .	4·00 .	5·999
Protoxide of iron,	3·38 .	4·733
Oxide of titanium,	1·00 .	2·666
Moisture,	0·40 .	0·666
	98·18	98·730

After seeing Seybert's analyses, I made three successive analyses of the Brazilian chrysoberyl, and Dr. Thomas Muir, at that time, in my laboratory, made another. Our results almost coincided. The following table shows them:

		Atoms.
Alumina, .	76·752 .	34·11
Glucina, .	17·791 .	5·47
Protoxide of iron,	4·494 .	1
Volatile matter,	0·480 .	
	99·517	

This constitutes

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[*] Beitrage, i. 102.

[†] Kong. Vet. Acad. Handl., 1822, p. 90.

[‡] Silliman's Jour. viii. 109. The first specimen was from Hoddam, the second from Brazil.

5½ atoms sexaluminate of glucina,
1 atom aluminate of iron.

The formula is $5\frac{1}{2}GAl^6+fAl$.

I did not examine whether the volatile matter was pure water. Its quantity was so small that I conceive it could have been nothing else but hygrometrical water, mechanically lodged in the powder of the mineral.

Besides these three species, there are other three minerals which contain a notable quantity of glucina as an essential constituent. These are *gadolinite*, *pyrochlore* and *helvine*. The first two of these belong to the next genus. The last will be described under the genus *manganese*.

GENUS XI.—YTTRIUM.

Yttrium bears so close a resemblance to glucinum in many of its properties, that we need not be surprised to find it follow the same law in the manner in which it occurs in the mineral kingdom. It has never been found in any other state than that of the oxide, or earth called *yttria*. It is found in combination with phosphoric acid, with columbic acid, and with silica; so that in the mineral kingdom it always acts the part of a base.

The number of species belonging to this genus is so small that no subdivision is necessary.

Sp. 1. *Phosphate of Yttria.*

Thorina.

This mineral was discovered in the neighbourhood of Lindisnäs in Norway, by Mr. Tank, in a coarse grained granite, along with another mineral resembling *orthite*. It was at first taken for a zircon from its colour and appearance. Its nature was determined by Berzelius, to whom specimens of it had been sent.

Colour yellowish brown, very similar to that of the Frederikvörn zircons, for which on that account it was taken.

Form irregular; but it has been observed crystallized in octahedrons with a square base; the pyramids usually separated by a very short prism.*

Foliated with cleavages in more than one direction.

Cross fracture uneven, splintery.

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* Haidinger, Ann. des Mines (2d series), iii. 231.

Dull externally. Foliated fracture resinous, cross fracture fatty.

Translucent when in thin splinters.

Easily scratched by the knife. Hardness 4·25; specific gravity 4·5577.

Before the blowpipe it behaves very like phosphate of lime. Per se it is infusible, but becomes darker coloured. When heated in a tube it gives out no water. With borax it dissolves slowly into a colourless glass, which by flaming can be rendered milk-white, and which when fully saturated becomes white on cooling. With biphosphate of soda, it dissolves with great difficulty into a clear colourless glass. This constitutes the great distinction between phosphate of yttria and phosphate of lime, the latter fusing very easily with the phosphoric salt. With carbonate of soda it gives, with a strong effervescence, a light grey infusible slag. With boracic acid it dissolves with difficulty, but gives, with the addition of iron, phosphuret of iron in abundance.

In acids it is quite insoluble.

Its constituents, as determined by Berzelius,* are as follow:

			Atoms.
Phosphoric acid,† .	33·49 .	7·44 .	1
Yttria, . .	62·58 .	11·38 .	1·52
Diphosphate of iron,	3·93		
	100·00		

It is obviously a compound of 1 atom phosphoric acid and 1½ atom yttria, or a subsesquiphosphate of yttria. The formula is $Y^{1\frac{1}{2}}\underset{\cdot}{P}$.

Sp. 2. *Yttrotantalite.*

Of this mineral there are three subspecies, differing from each other in the proportion of yttria which they contain.

Subsp. 1. *Black Yttrotantalite.*

Dicolumbate of yttria.

This mineral occurs at Ytterby, in a rock composed of red felspar and mica, in pieces never exceeding the size of a

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* Kong. Vet. Acad. Handl., 1824, p. 334, and Annals of Philosophy (2d series), xii. 116.

† With a little fluoric acid.

hazel nut, but sometimes exhibiting the rudiments of a crystallized form.

Colour black; powder grey.

Structure foliated.

Lustre metallic.

Opaque.

Hardness 5·5; specific gravity 5·395.

Before the blowpipe decrepitates feebly and becomes dark brown, but does not fuse per se. When a piece is heated to redness, the colour often becomes unequal, and some portions remain quite black; showing that the constituents are unequally distributed. It dissolves with difficulty in biphosphate of potash, and the bead is either colourless or yellowish. If additional portions of the mineral be added while the heat is continued, a saffron coloured glass is obtained, which becomes at last opaque. A white matter continues, which does not dissolve in the glass. In borax it dissolves with more ease. The glass is colourless or yellowish, but becomes opaque during the cooling; or, if the portion of the mineral be small, it remains transparent, but becomes white and muddy when heated anew. With carbonate of soda it fuses with effervescence; after which the alkali is absorbed by the charcoal, and leaves a white mass, which is no farther altered.

Insoluble in acids.

It is most easily distinguished from gadolinite by its behaviour with borax. Gadolinite, when heated with borax, becomes dark green, or almost black.

Its constituents, according to the analysis of Berzelius,* are as follow:

		Atoms.	
Columbic acid,	57·00	2·21	4·17
Tungstic acid,	8·25	0·53	1
Yttria,	20·25	3·68	6·94
Lime,	6·25	1·78	3·35
Peroxide of iron,	3·50	0·70	1·32
Oxide of uranium,	0·50	0·017	0·03
	95·75		

In what way these constituents are united in the mineral, it is impossible to say. The atoms of the bases are rather more than double those of the acids, so that the constituents must

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* Afhandlingar, iv. 268.

be in the state of disalts. The numbers approach nearest to

5 atoms dicolumbate of yttria,
1 atom dicolumbate of iron,
4½ atoms tristungstate of lime.

But a more accurate analysis would be requisite before the chemical constitution of this mineral could be considered as settled.

Subsp. 2. *Yellow Yttrotantalite.*

Triscolumbate of yttria.

This mineral is met with at Ytterby, in thin irregular layers, between felspar. Sometimes also in grains, the largest of which, according to Berzelius, does not exceed a peppercorn in size.

Colour yellowish-brown, in some cases inclining somewhat to green. Generally striped with greenish stripes or flakes. Powder white.

Foliated with only one cleavage; cross fracture uneven.

Lustre of the plates resinous, of the fracture vitreous.

About the hardness of crown glass; opaque.

Specific gravity, as determined by Ekeberg, 5·882.

Before the blowpipe it does not fuse, but decrepitates feebly, and changes its colour to straw yellow. If a grain of the mineral be laid upon a pearl of biphosphate of soda, and a good reducing flame be applied, a portion is dissolved, leaving a silica skeleton, which is taken up by the glass with extreme difficulty. On cooling, the bead (before yellow) becomes colourless, and gradually cracks in different directions, showing a weak, but pure green colour. When the mineral, in powder, is laid on biphosphate of soda, and a good reducing heat applied, the whole fuses into a muddy glass, green while hot, but assuming, on cooling, a weak rose-red colour, and becoming opaque. This last phenomenon, proceeding from the presence of tungstate of iron, is not constant. In borax it fuses in the reducing flame, to a clear yellow glass, becoming still more yellow on cooling. When the bead is again gently heated, and then left to cool, it becomes milk-white. It is not attacked by carbonate of soda.

Insoluble in acids.

Its constituents, by Berzelius's* analysis, are:

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* Afhandlingar, iv. 272.

		Atoms.
Columbic acid, .	60·124 .	2·33
Yttria, . .	29·780 .	5·41
Lime, . .	0·500 .	0·14
Oxide of uranium,	6·622 .	0·24
Peroxide of iron, .	1·155 .	0·23
Tungstic acid with tin,	1·044 .	0·06
	99·225	

The atoms of bases amount nearly to three times as many as the atoms of acids. Hence the bases are in the state of trisalts.

The preceding numbers agree very nearly with
9 atoms triscolumbate of yttria,
1 atom triscolumbate of lime, uranium and iron.

Subsp. 3. *Brownish-black Yttrotantalite.*

This mineral occurs mixed with the yellow yttrotantalite in thin plates, or very rarely in grains, which show no marks of crystallization.

Colour black, with a very slight shade of brown; powder white.

Fracture fine granular.

Lustre between vitreous and resinous.

When in thin layers translucent; almost colourless by transmitted light, or only slightly yellowish.

As hard as the other two subspecies.

Specific gravity not determined, but heavy.

Does not fuse before the blowpipe, but decrepitates weakly, and becomes light yellow. With biphosphate of soda it exhibits the same phenomena as the yellow yttrotantalite, with this difference, that the colour is a weaker green, and that the red colour cannot be produced when pure pieces are employed, without the saturated glass bead becoming opaque, and slightly greenish-grey. With borax it gives a clear yellow glass, which with a greater addition becomes opaque and yellowish-brown. It does not fuse with carbonate of soda.

It is not attacked by acids.

Its constituents, as determined by Berzelius, are as follow:

		Atoms.
Columbic acid,	51·815	2·01
Yttria,	38·515	7·00
Lime,	3·260	0·93
Oxide of uranium,	1·111	0·04
Tungstic acid with tin,	2·592	0·16
Peroxide of iron,	0·555	0·11
	97·848	

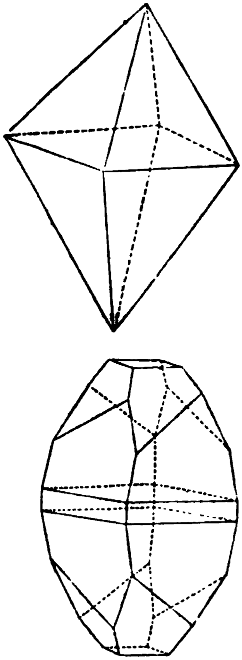
The atoms of bases are four times as numerous as those of the acids. The constitution of the mineral seems to be

7 atoms tetracolumbate of yttria,
1 atom tetracolumbate of lime, uranium, and iron,
0·16 atom tungstate of lime.

Doubtless the tungstate of lime is accidental. This remark probably applies to all the three subspecies of yttrotantalite.

Sp. 3. *Fergusonite.*[*]

This mineral was discovered by Sir Charles Giesecké at Kikertaursak, near Cape Farewell, in East Greenland, where it is found in imbedded groups and single crystals, in white quartz. It was first distinguished as a peculiar species, and described by Mr. Haidinger.[†]



Colour dark brownish-black; but in very thin scales it appears of a pale liver-brown, or yellowish-brown colour, and is translucent. In large crystals it becomes opaque; streak pale brown.

It occurs frequently crystallized, and the primary form, according to Haidinger, is an octahedron, whose faces are isosceles triangles, the terminal edges of the pyramids being 100° 28′, and their lateral edges 128° 27′. The most common crystal is that represented in the margin. There is a short prism interposed between the two pyramids, and the pyramid terminates in another more acute four or eight-sided pyramid, truncated at the summit.

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[*] Named in honour of Mr. Ferguson, of Raith.

[†] Edin. Trans. x. 274.

Brittle; hardness 5·75; specific gravity, as determined by Dr. Turner, 5·800; by Mr. Allan 5·838.

When heated in a glass tube it gives out a little water, becomes first darker, and then light yellow. It is infusible per se before the blowpipe on charcoal. In borax it dissolves with difficulty. The glass, while hot, has a yellow colour; but a white portion remains undissolved. The saturated glass, by flaming, becomes opaque, and assumes a dirty yellowish-red colour. With biphosphate of soda it dissolves slowly, the undissolved portion remaining white. The glass in the oxidizing flame becomes yellow; in the reducing flame it is colourless, or, when fully saturated with the mineral, inclining to red. With carbonate of soda it is decomposed, and fuses, leaving a reddish slag.

Its constituents, as determined by the analysis of Mr. Victor Hartwall,[*] are as follow:

		Atoms.
Columbic acid,	47·75	1·85
Yttria, . .	41·91	7·62
Protoxide of cerium,	4·68	0·72
Zirconia, .	3·02	0·80
Oxide of tin, .	1·00	0·10
Oxide of uranium,	0·95	0·03
Peroxide of iron,	0·34	0·07
	99·65	

The atoms of bases are almost five times as numerous as those of the acids (including the peroxide of tin). The constitution of the mineral agrees best with the following numbers:

4½ atoms pentacolumbate of yttria,
1 atom pentacolumbate of cerium, zirconia, uranium and iron.

But the probability is, that all these constituents are not in chemical combination.

Sp. 4. *Gadolinite.*[†]

This mineral was first observed by Captain Arhenius in the quarry at Ytterby, about three Swedish miles from Stockholm, where a white felspar was collected for the porcelain manufactory of Stockholm. A short account of it was published by Geijer, in 1788.[‡] Gadolin published a chemical

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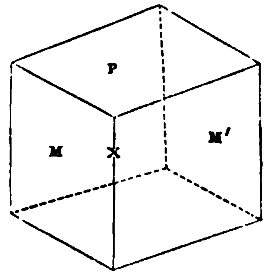
[*] Kong. Vet. Acad. Handl., 1828, p. 167.

Named in honour of Professor Gadolin, who first analyzed it.

ell's Annalen, 1788, ii. 229.

analysis of it in 1794.[*] It was examined again by Ekeberg, in 1797;[†] by Berzelius, in 1815,[‡] and by Dr. Steele and myself, in 1831.

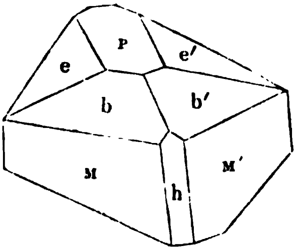


Colour greenish-black, very dark, so as to appear on a slight inspection, velvet black.

Usually massive, but it occurs also crystallized. The primary form seems to be an oblique rhombic prism, in which

M on M′ 115° by the common goniometer,

P on the edge X 98°.



The figure in the margin represents a crystal in the possession of Mr. Brooke, the measurement of which, by Mr. W. Phillips, is as follows:

P on h	98°
M on e M′ on e′	100°
M on b M′ on b′	153°
b on b′	120°
e on e′	120°
b on e b′ on e′	130°

Fracture flat conchoidal.

Lustre vitreous, inclining to resinous.

Slightly translucent on the edges, almost opaque.

Hardness 6·5. Specific gravity, by my trials, from 4·1493 to 4·1795. Geijer states it at 4·223; Rinman at 4·03; Gadolin states that of a specimen, not quite free from felspar, at 4·028. Haidinger found it 4·238, and Hauy 4·0497.

Before the blowpipe alone it intumesces, throwing out cauliflower-like ramifications, and becomes white, giving off water. When heated in a matrass it gives out no moisture, but when the matrass is beginning to fuse, it shines suddenly as if it had taken fire. With borax it fuses readily into a dark glass, strongly coloured by iron, which in the reducing flame becomes dark bottle-green. With biphosphate of soda it fuses

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[*] Kong. Vet. Acad. Handl., 1794, p. 137. [†] Ibid, 1797, p. 156.

[‡] Afhandlingar, iv. 228.

with extreme difficulty. The glass assumes an iron tint, and the fragment becomes rounded on the edges, but remains white and opaque, so that the phosphoric acid does not in this instance effect the separation of the silica. With carbonate of soda the vitreous gadolinite changes into a semifluid brownish red scoria; the splintery variety fuses into a globule, if the quantity of flux be not too great. On platinum foil neither of them gives the least indication of containing manganese.

Gadolinite was analyzed by Ekeberg, Klaproth, and Vauquelin, but neither of them detected the presence of oxide of cerium, though it seems to be an essential constituent of this mineral. This substance was discovered in it by Berzelius, who found the constituents of gadolinite

Silica, . .	24·16	. 25·80
Yttria, . .	45·93	. 45·00
Protoxide of cerium,	16·90	. 16·69
Protoxide of iron,	11·34	. 10·26
Moisture, . .	0·60	. 0·60
	98·93	98·35

The specimen analyzed in my laboratory by Dr. Steele and myself, I had purchased from a German mineralogist, who had found it in a Swedish cabinet. It weighed several ounces. During the pounding, small grains of metallic platinum were detected in it, very irregularly distributed. The whole obtained weighed 2·33 grains, from at least 200 grains of gadolinite. Dr. Steele found in this gadolinite a notable quantity of glucina, which was overlooked by Berzelius, though the presence of it had been noticed by Ekeberg. The constituents obtained by Dr. Steele and myself, are the following. I have added a second analysis made during the winter 1834–5, by Mr. Richardson.

			Atoms.
Silica, .	24·330	. 24·65	. 12·16
Yttria, .	45·330	. 45·20	. 8·06
Protoxide of cerium,	4·333	. 4·60	. 0·88
Glucina, .	11·600	. 11·05	. 3·91
Protoxide of iron,	13·590	. 14·55	. 3
Manganese, .	trace	. —	.
Moisture, .	0·986	. 0·50	
	100·179	100·55	

The excess of weight was probably owing to the yttria not having been completely deprived of carbonic acid. If we were to admit the protoxide of iron to be accidental, gadolinite would consist of

2 atoms silicate of yttria,
1 atom silicate of glucina and cerium.

But the probability is, that other principles besides the platinum grains are mechanically mixed in it.

There is a variety of gadolinite at Korarvet, in the neighbourhood of Fahlun, which differs from the mineral just described in several particulars.

Its fracture is even or fine granular, while that of common gadolinite is conchoidal and glassy. It has a dark brownish yellow colour, while common gadolinite is black. When heated to redness it becomes white, inclining to greyish blue, without changing its form; whereas common gadolinite either froths or swells up, and when heated to redness, gives the phenomena of apparent combustion. With borax it gives very slowly an iron green glass, whereas common gadolinite gives a glass so dark that it is opaque. Its powder is dark brown, while that of common gadolinite is almost white, having merely a greyish green shade.

Its constituents, as determined by Berzelius, are

Silica, . . .	29·18
Yttria, . . .	47·30
Protoxide of iron, .	8·00
Lime, . . .	3·15
Glucina, . .	2·00
Protoxide of cerium,	3·40
Protoxide of manganese,	1·30
Water, . . .	5·20
	99·53

Berzelius considers it as composed of

Common gadolinite,	83·67
Bisilicate of lime, .	7·27
Silicate of glucina, .	2·90
Silicate of cerium, .	4·33
Silicate of manganese,	1·83
	100·00*

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* Afhandlingar, iv. 388.

Sp. 5. *Orthite*.*

This mineral occurs at Finbo, constituting very thin veins in gneiss, and is very scarce. Berzelius gave it the name of *orthite*, because, though scarcely exceeding $\frac{1}{16}$th of an inch in thickness, it may be traced running more than two feet in length.

Colour black; powder grey, inclining to brown.

Massive; fracture small conchoidal.

Lustre vitreous.

Opaque, even when in very thin plates.

Hardness 7; specific gravity 3·288.

Brittle; easily frangible.

Before the blowpipe per se it froths like a zeolite, and becomes yellowish brown. In a stronger heat, it melts with effervescence into a black vesicular glass. With biphosphate of soda it fuses with difficulty, leaving a silica skeleton. The globule in the reducing flame becomes colourless, but in the oxidizing flame fine yellow, which disappears on cooling. With saltpetre it gives sometimes greater, sometimes smaller indications of manganese. With borax it dissolves easily into a clear glass, which in the reducing flame becomes greenish, but in the oxidizing flame blood-red, which last colour, in a great measure, vanishes on cooling. It is decomposed by soda, but not fused.

It dissolves when digested in acids, and gelatinizes.

Its constituents, as determined by Berzelius,† are as follow:

			Atoms.	
Silica, . . .	36·25	32·184	16·09	30·94
Lime, . . .	4·89	7·96	2·27	4·36
Alumina, . . .	14·00	14·81	6·57	12·63
Protoxide of cerium, .	17·39	20·51	3·15	6·05
Protoxide of iron, .	11·42	12·38	2·75	5·3
Yttria, . . .	3·80	2·87	0·52	1
Protoxide of manganese,	1·36	3·36	0·74	1·42
Water, . . .	8·70	5·36	4·76	9·1
	97·81	99·434		

From the great number of ingredients, and their different proportions in the two specimens, there seems little doubt that

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* From ὀρθος, *straight*.

† Afhandlingar, v. 32. The first specimen was from Finbo, the second from Gottlieb's vein.

more than one chemical compound exists mechanically mixed in orthite. The third column exhibits the atomic ratios deduced from the second analysis. The atoms of silica and of bases agree in number; hence it is clear that all the bases are in the state of simple silicates. The following constitution approaches pretty near to the numbers in the table:

12½ atoms silicate of alumina,
6 atoms silicate of cerium,
5⅓ atoms silicate of iron,
4⅓ atoms silicate of lime,
1½ atom silicate of manganese,
1 atom silicate of yttria,
9 atoms water.

The formula is

$$12\tfrac{1}{2}\text{AlS}+6\text{CrS}+5\tfrac{1}{2}\text{fS}+4\tfrac{1}{3}\text{CalS}+1\tfrac{1}{2}\text{mnS}+\text{YS}+9\text{Aq}.$$

Sp. 6. *Pyrorthite.*[*]

This mineral occurs along with gadolinite, in a granite vein at Korafsberg, a quarter of a Swedish mile west from Fahlun.

Colour pitch black; some effloresced pieces are yellowish brown.

Occurs in long needles, usually agglutinated together. They consist of four-sided prisms, longitudinally streaked, and having commonly a large streak in the centre, giving the prism the appearance of being divided into two.

Longitudinal fracture small conchoidal or splintery; cross fracture uneven.

Lustre resinous; opaque.

Hardness 2·75; specific gravity 2·19.

Before the blowpipe it catches fire, glows, and consumes without flame. When the combustion is at an end the mineral is white, with a shade of grey or red, and so light that it is difficult to prevent it from being dissipated before the blowpipe. It fuses per se with difficulty into a black enamel. With borax or biphosphate of soda it fuses into a clear glass. The addition of saltpetre shows the presence of manganese. In carbonate of soda it does not dissolve.

When digested in acids it dissolves, leaving behind a black powder.

Its constituents, as determined by Berzelius, are

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[*] From *πυρ*, *fire*, and *ὀρθος*, *straight*.

			Atoms.
Silica,	10·43	5·22	5·8
Alumina,	3·59	1·59	1·8
Lime,	1·81	0·51	0·57
Protoxide of cerium,	13·92	2·14	2·4
Protoxide of iron,	6·08	1·35	1·5
Yttria,	4·87	0·90	1
Protoxide of manganese,	1·39	0·30	0·33
Water and volatile matter,	26·30		
Charcoal,*	30·00		
	98·39†		

It is evident that the atomic numbers belonging to the constituents of this mineral (leaving out the water and charcoal), are different from those of orthite. The following constitution approaches the numbers in the table:

2½ atoms silicate of cerium,
2 atoms disilicate of alumina,
1½ atom disilicate of iron,
1 atom disilicate of yttria,
½ atom disilicate of lime,
⅓ atom disilicate of manganese,

The formula is

$$2\tfrac{1}{2}CrS + 2Al^2S + 1\tfrac{1}{2}f^2S + Y^2S + \tfrac{1}{2}Cal^2S + \tfrac{1}{3}mn^2S.$$

But this formula is too complex to represent a simple chemical compound.

GENUS XII.—CERIUM.

The resemblance between the oxides of cerium and yttria in their chemical properties, is so close that it is exceedingly difficult to separate them from each other, and nature seems to have taken a pleasure in combining them together. Like yttrium, cerium never occurs in the mineral kingdom except in the state of oxide. The number of species known is so small that no subdivision is necessary.

Sp. 1. *Carbonate of Cerium.*

I have never seen this mineral, nor even a description of it. Berzelius says that it has been found at Bastnäs, in cerite.‡

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[*] Allowing 1·61 for loss.

[†] Afhandlingar, v. 49.

[‡] Kong. Vet. Acad. Handl., 1824, p. 134.

The artificial carbonate of cerium is a silvery-white tasteless powder, insoluble in water, even when acidulated with carbonic acid.

Sp. 2. *Cerite.*

Silicate of cerium—ochroite.

This mineral has been hitherto found only at Bastnäs, near Redderhyttan, Westmanland, where it occurs in a bed of gneiss.

Colour intermediate between clove brown and cherry red, passing into grey; streak white.

Always massive; granular; fracture uneven and splintery; brittle.

Lustre adamantine.

Translucent on the edges.

Hardness 5·5; specific gravity, as determined by Haidinger, 4·912.

Infusible per se by the blowpipe; fuses with borax into a yellow bead, which becomes paler on cooling.

Its constituents, as determined by Hisinger,* are

		Atoms.
Silica,	18	9
Peroxide of cerium,	68·59	10·55
Peroxide of iron,	2·00	0·40
Lime,	1·25	0·35
Water and carbonic acid,	9·60	8·53
	99·44	

These numbers approach

1 atom silica,
1 atom peroxide of cerium,
1 atom water.

It is therefore a hydrous silicated peroxide of cerium. The formula is $CrS+Aq$.

Sp. 3. *Thulite.*

This mineral has been found at Souland, in Tellemark, in Norway, in a rock consisting chiefly of quartz.

Colour rose-red; streak greyish-white.

Texture usually granular; but Mr. Brooke informs us that he found it to yield to mechanical division an oblique

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* Afhandlingar, iii. 283.

prism, with angles of 87° 30′ and 92° 30′, but he could perceive no distinct cleavage transverse to the axis of this prism.

Lustre vitreous; translucent on the edges.

Hardness about 6, or between 5 and 6; but the grains separate so easily from each other that it is rather difficult to determine the hardness; specific gravity 3·1055.

Before the blowpipe it fuses with carbonate of soda into an opaque greenish-white bead. With borax it fuses into a colourless transparent bead, which, by the addition of saltpetre, assumes a sensibly violet colour, indicating the presence of a trace of manganese.

Its constituents, by my analysis, are as follow:—

		Atoms.
Silica, .	46·10 .	23·05
Peroxide of cerium,	25·95 .	3·7
Lime, .	12·50 .	3·57
Peroxide of iron,	5·45 .	1·1
Potash, .	8·00 .	1·33
Moisture, .	1·55 .	1·38
	99·55	

There is an excess of silica, because the thulite was mixed with numerous small globules of quartz, which it was impossible to exclude entirely. The constituents, allowing for this excess, indicate

3 atoms bisilicate of cerium,
3 atoms bisilicate of lime,
1½ atoms bisilicate of potash,
1 atom bisilicate of iron.

The formula is $3CrS^2+3ClS^2+1\frac{1}{2}KS^2+\underline{f}S^2$.

Sp. 4. *Fluate of Cerium.*

This mineral was found by Berzelius in Albite, both at Brodbo and Finbo, in the neighbourhood of Fahlun.

Colour dark tile red, or almost yellow. The colour deepens when the mineral is wetted; powder white or slightly yellowish.

Found crystallized in regular six-sided prisms, the axis of which is commonly shorter than the diameter of the base. The angles of the prism are frequently replaced by planes.

Fracture uneven or splintery.

[illegible]ttle lustre; brittle.

[illegible]ness 4; specific gravity 4·7.

Infusible per se before the blowpipe. In borax and biphosphate of soda it fuses slowly but completely. The bead in the exterior flame is blood red, but loses its colour on cooling. In the interior flame the glass is colourless at all temperatures. In carbonate of soda it does not fuse, but swells out and is decomposed.

The constituents, according to Berzelius'* analysis, are

		Atoms.
Peroxide of cerium,	82·64	11·8
Yttria,	1·12	0·2
Fluoric acid,	16·24	13
	100·00	

But he ascertained that both protoxide and peroxide of cerium exist in the mineral, and concluded from his observations, that they are in the proportion of 1 atom of protoxide to 2 atoms peroxide. We perceive that the mineral is composed of simple fluates. Therefore (neglecting the yttria) it must consist of

$$\left.\begin{array}{l}\text{1 atom fluated protoxide}\\ \text{2 atoms fluated peroxide}\end{array}\right\}\text{of cerium.}$$

Sp. 5. *Subsesquifluate of Cerium.*

This mineral was found by Berzelius at Finbo, and like the preceding it occurs very sparingly.

Colour a beautiful yellow with some red, and (when the mineral is impure) brownish yellow; powder fine yellow.

Usually massive; sometimes it exhibits the rudiments of the garnet or rhomboidal dodecahedron.

Lustre vitreous.

Opaque, or only translucent on the edges.

Hardness 5; specific gravity not determined.

Soluble in hot sulphuric acid, solution yellow; dissolves in muriatic acid with the evolution of much chlorine; a little white powder remains undissolved.

Not fusible before the blowpipe per se. But the colour becomes much darker. On cooling, the original colour is restored, though it continues redder than at first. With borax, biphosphate of soda, and carbonate of soda, it behaves like the last species.

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* Afhandlingar, v. 56.

Its constituents, according to the analysis of Berzelius,* are,

		Atoms.
Peroxide of cerium,	84·20	12·03
Fluoric acid,	10·85	8·67
Water,	4·95	4·4
	100	

These numbers approach to 1½ atom peroxide of cerium for every atom of fluoric acid. The constitution of the mineral is obviously

1½ atom peroxide of cerium,
1 atom fluoric acid,
$_2$ atom water.

It is therefore a hydrous subsesquifluated peroxide of cerium.

Sp. 6. *Yttrocerite.*

This mineral occurs very sparingly at Finbo and Brodbo, near Fahlun, imbedded in quartz.

Colour violet blue, inclining to grey and white, sometimes white. These colours generally alternate in layers in the same specimen.

Massive; but has a foliated structure, and cleaves in the direction of a right rhombic prism, measuring by the common goniometer about 97°.†

Fracture uneven.

Lustre glistening.

Opaque.

Hardness 5; specific gravity 3·447.

Before the blowpipe it loses its colour and becomes white, before it has been exposed to a red heat, but does not fuse. With the addition of gypsum it melts easily into a bead, which does not become clear to what degree soever of heat it be exposed.

When heated in a glass tube it does not phosphoresce, but gives out a little moisture and loses its colour.

When in fine powder it dissolves completely in muriatic acid with the assistance of heat. The solution has a yellow colour.

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* Afhandlingar, v. 64.

† Brooke's Familiar Introduction, p. 458.

Its constituents, according to the analysis of Berzelius,[*] are

			Mean.
Lime,	47·63 to	50·00	48·81
Yttria,	9·11	8·10	8·60
Peroxide of cerium,	18·22	16·45	17·33
Fluoric acid,	25·04	25·45	25·24
	100	100	

The quantity of fluoric acid was determined by the loss sustained in the analysis. But as the mineral contains water, it is obvious that the quantity of acid must be a little overrated.

The atomic weights are

		Atoms.
Lime,	13·9	8·9
Yttria,	1·56	1
Peroxide of cerium,	2·47	1·58
Fluoric acid,	20·19	12·9

There is an excess of fluoric acid. But this excess is probably owing to its quantity being overrated. The mineral then may be considered as composed of simple fluates. The constitution is obviously

9 atoms fluate of lime,
1½ atom fluated peroxide of cerium,
1 atom fluate of yttria.

The yttria and oxide of cerium were imperfectly separated from each other. It is possible, therefore, that its real constitution may be

7 atoms fluate of lime,
1 atom fluated peroxide of cerium,
1 atom fluate of yttria.

Sp. 7. *Allanite.*

This mineral was discovered by Sir Charles Gieseckė at Allick, near the southern extremity of East Greenland, where it is imbedded in quartz, and associated with mica and albite. It was first noticed by Mr. Allan of Edinburgh about the year 1803. I analyzed it soon after, ascertained its peculiar nature, and gave it the name *Allanite.*[†] Since that time I have seen a specimen in the Museum of the East India

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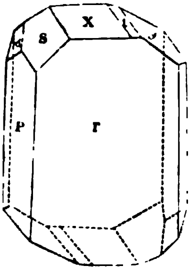
[*] Afhandlingar, iv. 151.

[†] In honour of Mr. Allan, who first noticed it.

Company, brought from Hindostan, but I could not learn the exact locality.

Colour black, verging upon green or brown; powder and streak greenish grey.



It is usually massive, but occurs also crystallized. The most complete crystal I have seen is that figured in the margin. From this figure it would appear that the primary form is a right oblique four-sided prism, M on T about 115°.

The following are the measurements of the angles taken by Mr. Haidinger, with a common goniometer:

r on M	129°	y on r	109°
r on P	116	s on x	156½
M on P	115	x on t	164½
s on r	135½	x on y	151
d on r	124½	t on y	166½

Faint traces of cleavage are observable parallel to P and r, but they are very indistinct and interrupted.

Fracture imperfect conchoidal.

External lustre dull, internal shining and resinous, inclining to metallic.

Opaque. The edges of very thin splinters are somewhat translucent, and of a dark yellowish-brown colour.

Brittle; easily frangible.

Hardness 6; specific gravity, when pure, 4·001. But it is almost always mixed with mica, and then its specific gravity varies from 3·119 to 3·797.

Before the blowpipe froths and melts imperfectly into a brown scoria.

Gelatinizes in nitric acid.

By ignition loses water, amounting to 3·98 per cent. of its weight.

Its constituents, by my analysis, were:

		Atoms.
Silica,	35·4	17·7
Lime,	9·2	2·6
Alumina,	4·1	1·8
Protoxide of iron,	22·86	5·0
Protoxide of cerium,	31·48	4·8
Volatile matter,	3·98	3·5
	107·02	

But a later and more accurate analysis has been given by Stromeyer,* who found its constituents as follows:

		Atoms.
Silica, . .	33·021 .	16·51
Alumina, . .	15·226 .	6·76
Protoxide of cerium,	21·600 .	3·32
Protoxide of iron,	15·101 .	3·35
Protoxide of manganese,	0·404 .	0·09
Lime, . .	11·080 .	3·16
Water, . .	3·000	
	99·432	

It is obvious that the mineral consists of simple silicates, in the following proportions:

2 atoms silicate of alumina,
1 atom silicate of cerium,
1 atom silicate of iron,
1 atom silicate of lime,

Sp. 8. *Pyrochlore.*†

This mineral was first discovered by Mr. Tank at Frederickvärn, in Norway, along with polymignite and phosphate of yttria. It was afterwards observed by Wöhler and Berzelius, and Alexander Brogniart, near Laurvig, in Norway, in the zirconsyenite formation, where, besides zircons, it was associated with green elaeolite, large black hornblende crystals, and green apatite. It was described and analyzed by Wöhler, in 1826.‡

Its colour is reddish-brown, not unlike brown titanite, and the fresh fracture is almost black.

In thin splinters it is translucent and appears brown; in larger pieces it is quite opaque.

It is almost always crystallized, but the crystals are so firmly attached to the rock that they can scarcely be extricated entire. The primary form, according to Dr. G. Rose, is the regular octahedron. The largest crystal which Wöhler observed did not exceed the size of a pea. They are usually immersed in felspar, and not unfrequently in elaeolite, and

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* Poggendorf's Annalen, xxxii. 292.

† From πυρ, *fire*, and χλωρος, *greenish-yellow*.

‡ Poggendorf's Annalen. vii. 417.

seem at first sight like irregular points, varying from the size of a needle point to that of a pea.

It scratches fluor spar, and is itself scratched by felspar, so that its hardness is about 5. Specific gravity, as determined by G. Rose, from 4·206 to 4·216.

Fracture conchoidal without any indication of cleavage; streak and powder light brown.

Lustre between vitreous and resinous.

When heated before the blowpipe per se it becomes brownish-yellow, assumes a shining lustre, and fuses with great difficulty into a blackish-brown slaggy mass. With borax, in the oxidizing flame, it fuses into a reddish-yellow transparent bead, which by flaming becomes opaque and yellow. When a considerable portion of the assay is added, the glass, on cooling, assumes the form of a white enamel. In the reducing flame we obtain a dark red globule as from ferruginous titanic acid, which by flaming is converted into a light greyish-blue enamel, often striped with streaks of pure blue. In biphosphate of soda it dissolves completely, with some effervescence at first. The glass in the oxidizing flame is yellow while hot, but on cooling it becomes grass-green. In the reducing flame the colour is changed into a dark red, with a shade of violet, as is the case with titanic acid when it contains some iron. In the oxidizing flame this colour disappears, and the bead, if not too long exposed, becomes of a fine grass-green colour. With carbonate of soda, on the platinum foil, it shows the green reaction from manganese.

Its constituents, according to the analysis of Wöhler, are:

Titanic acid, . .	62·75
Lime, . . .	12·85
Protoxide of uranium,	5·18
Peroxide of cerium,	6·80
Protoxide of manganese,	2·75
Peroxide of iron, .	2·16
Peroxide of tin, .	0·61
Water, . . .	4·20
	97·30

with a trace of fluoric acid and magnesia.

This mineral was found also in Siberia by Humboldt, and Wöhler has announced that he has found in that variety 5 per cent of *thorina.** Till his new analysis (which he has promised) appear, it would be needless to attempt to calculate the constitution of this complex mineral.

GENUS XIII.—ZIRCONIUM.

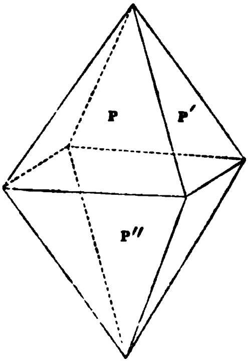
Zirconium agrees with the preceding genera in never occurring in the earth except in the state of the oxide called zirconia. For many years the genus was limited to a single species, but four other species having been successively discovered, it now consists of five species.

Sp. 1. *Zircon.*

Hyacinth, jargen, silicate of zirconia.

This mineral is found sometimes in the sands of rivers. In this way it is found at Expailly, in Auvergne, and in Ceylon. In the United States, in Carinthia, &c., it occurs in gneiss. At Frederickvärn, in Norway, it is a constituent in zirconsyenite.

Colour red, brown, yellow, grey, green, white. None of them are bright except some of the red tints; streak white.



It occurs usually crystallized. The primary form is an octahedron with a square base.

P on P′ 123° 20′
P on P″ 84° 20′

The angles at the base are often replaced by planes, which, when they become large, convert the crystal into a four-sided prism, terminated by a quadrangular pyramid with rhombic planes, similar to the most common form of harmotome. Sometimes the edges of the base are also replaced by planes, which makes the prism eight-sided.

Several cleavages may be detected, but they are all rather obscure. Fracture conchoidal.

Lustre more or less adamantine.

Transparent to translucent; sometimes only on the edges; refracts doubly very powerfully.

Brittle; rather easily frangible.

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* Poggendorf's Annalen, xxvii. 80.

Hardness 6·5. When pounded in an agate mortar, it did not occasion any diminution of its weight.

I found the specific gravity of pure crystals from Expailly, 4·681; Mr. Wilson Lowry found it 4·721; Haidinger states it at 4·505.

Before the blowpipe (if pure) it loses its colour, but retains its transparency, and does not fuse. Infusible with carbonate of soda, and with biphosphate of soda. Melts with borax into a transparent glass.

The constituents of zircon are as follow:

	[*]	[†]	Mean.	Atoms.
Silica,	33·48	33·32	33·4	16·7
Zirconia,	67·16	66·00	66·58	17·75
	100·64	99·32	99·98	

These two analyses erring in opposite ways, the mean of the two must be almost perfectly accurate. It is obviously a simple silicate of zirconia, composed of

1 atom silica,
1 atom zirconia.

The formula is ZrS.

Sp. 2. *Sillimanite*[‡].

This mineral was found at Petty Pog, in the township of Saybrook, Connecticut, and was described and analyzed by Mr. Bower.[§] For the specimen which I had an opportunity of examining, I was indebted to the kindness of Mr. Nutall.

Colour dark grey, passing into clove brown.

It is crystallized in long four-sided prisms, which are often bent, and whose faces are too rough to admit of accurate measurement. Mr. William Phillips obtained by cleavage a small prism, with angles of about 88° and 92°, but he was unable to determine the position of the base.[||] Mr. Bower says, that the base is inclined on the axis at an angle of 113°.

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[*] Berzelius, Kong. Vet. Acad. Handl., 1824, p. 306. Those crystals were selected for analysis, which became colourless on ignition.

[†] Dr. Thomas Muir, in my laboratory. The crystals were from Expailly, and carefully selected. There was also a trace of iron found in the analysis.

[‡] In honour of Professor Silliman.

[§] Jour. of the Academy of Sciences of Philadelphia, iii. 375, as quoted by Haidinger.

[||] Phil. Mag. (2d series), i. 401.

The crystals have a fibrous structure.

Lustre vitreous; brittle; easily frangible.

Translucent on the edges.

Hardness 6; specific gravity, by my trials, (on only 5·64 grains) 3·1636; but the quantity was rather too small for much accuracy. Mr. Bower states it at 3·410.

Infusible before the blowpipe per se, nor does it melt into a bead with borax.

It was analyzed by Dr. Thomas Muir, in my laboratory, who found the constituents

Silica,	38·670	19·33	12·05
Alumina,	35·106	15·60	9·75
Zirconia,	18·510	4·93	3·08
Peroxide of iron,	7·216	1·60	1
	99·502*		

If we admit the peroxide of iron to be only a mechanical mixture, the constitution of sillimanite will be

3 atoms silicate of alumina,
1 atom silicate of zirconia.

Perhaps the excess of alumina may be a combination with the protoxide of iron in the mineral.

Sp. 3. *Æschynite.*

Colour black; streak dark grey, almost black.

Lustre semimetallic.

Occurs crystallized in rhomboidal pyramids.

Hardness between 6 and 8; specific gravity 5·550.

Berzelius informs us that Menge brought it from Minsk in the Ural, and that he himself had determined its behaviour before the blowpipe.†

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* Mr. Bower the original namer and describer of this mineral, gives its constituents as follows:

		Atoms.
Alumina,	54·11	24·04
Silica,	42·67	21·33
Peroxide of iron,	2·00	
Water,	0·51	
	99·29	

This approaches a silicate of alumina. Is it not possible that Mr. Bower may have analyzed *bucholzite* instead of *sillimanite?*

† I have not succeeded in finding any such account in the English translation of Berzelius on the blowpipe. It occurs, he says, in page 216, I presume, of the German edition.

It was analyzed by Hartwall, and found composed of

			Atoms.
Titanic acid, .	56 .	10·66 .	9·8
Zirconia, . .	20 .	5·33 .	4·93
Peroxide of cerium,	15 .	2·14 .	2
Lime, . .	3·8 .	1·08 .	1
Peroxide of iron, .	2·6 .	0·52 .	0·48
Peroxide of tin, .	0·5 .	0·05	
	97·9*		

Obviously

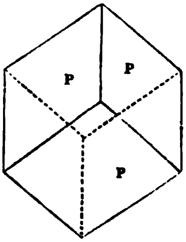
5 atoms titaniate of zirconia,
2 atoms titaniate of peroxide of cerium,
1 atom titaniate of lime,
½ atom titaniate of peroxide of iron.

Sp. 4. *Eudyalite.*

This mineral was discovered by Sir Charles Giesecké in Greenland, at Kangerluarzuc, in the same bed from which the sodalite was procured.

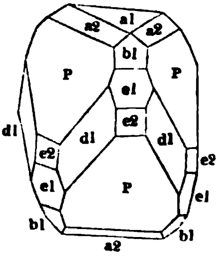
Colour sometimes rose red, sometimes hyacinth red.

Sometimes massive, sometimes crystallized. The crystals have somewhat the aspect of rhomboidal dodecahedrons with their edges truncated. Mr. Levy has given a description of a very fine crystal in possession of Mr. Brooke, the figure of which is given in the margin. He considers the primary form as an acute rhomboid, in which



P on P 73° 40′

The following are the incidences calculated by Mr. Levy,† all of which, he says, agree within ten minutes with observation.



P on P	73°	40′	P on a1	112°	33′
b1 on b1	96	15	b1 on a1	129	34
e1 on e1	63	59	e1 on a1	101	40
a2 on a2	126	44	a2 on a1	148	49
e2 on e2	120	.	e2 on a1	90	
d1 on d1	120		d1 on a1	90	

Structure foliated; fracture imperfect conchoidal or splintery.

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* Poggendorf's Annalen, xvii. 483.

† Edinburgh Journal, xii. 81.

Lustre vitreous.

Hardness 6; specific gravity, by my trials, 2·9036. Stromeyer states it at 2·90355.

Before the blowpipe it fuses into a leek green scoria.

When pulverized it gelatinizes in acids.

Its constituents, as determined by the analysis of Stromeyer,* are

		Atoms.	
Silica,	53·325	26·66	27
Zirconia,	11·102	2·96	3
Lime,	9·785	2·79	2·83
Soda,	13·822	3·45	3·49
Protoxide of iron,	6·754	1·50	1·52
Protoxide of manganese,	2·062	0·45	0·45
Muriatic acid,	1·034	0·22	0·22
Water,	1·801	1·6	
	99·685		

I repeated this analysis, and verified it so far that I got all the constituents, but not in the same proportions, because my specimen was not quite pure.† The above numbers approach

3½ atoms bisilicate of soda,
3 atoms bisilicate of lime,
3 atoms tersilicate of zirconia,
1½ atom tersilicate of iron,
½ atom silicate of manganese.

Sp. 5. *Polymignite.*‡

This mineral occurs sparingly in the zirconsyenite of Frederikvärn, in Norway. Specimens of it were sent by

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* Untersuchungen, p. 438.

† The result of my analysis was

Silica,	51·654
Zirconia,	3·248
Lime,	12·624
Soda,	17·776
Protoxide of iron,	6·092
Protoxide of manganese,	6·816
Muriatic acid,	0·952
Water,	1·750
	100·912

The specimen was in small fragments, mixed with much impurity.

‡ From πολυς, *many*, and μιγνυμι, *I mix*.

Mr. Tank to Berzelius, to whom we are indebted for its description and analysis.*

Colour black; powder brown.

Always crystallized in long slender prisms having a rectangular base, whose edges are more or less truncated. The prism has frequently two opposite faces broader than the two others. Its length varies from 1 to 4 lines. Mr. G. Rose has shown that its primary form is a rhomboidal octahedron, the three axes of which are to each other : : $\sqrt{2\cdot114} : \sqrt{4\cdot255} : 1$, and the dihedral angles are 136° 28, 116° 22, and 80° 16.†

Lustre splendent and nearly metallic.

Fracture conchoidal without any perceptible cleavage; opaque.

Scratches glass and is not itself scratched by the knife, 7? specific gravity 4·806.

Before the blowpipe it remains unaltered, and gives out no water. With borax it fuses easily, and forms a glass coloured by iron. It becomes opaque by flaming when an additional dose of borax is added. It then assumes an orange colour, and if still more borax be added it remains opaque after cooling. When fused with tin it gives a red colour, approaching yellow. Biphosphate of soda dissolves it also, but with more difficulty. In a reducing heat the glass becomes reddish, and this colour is not altered by tin. In the oxidizing flame the colour becomes lighter, and more approaching to yellow. In carbonate of soda it is decomposed without fusion, and becomes greyish red. An additional dose causes it to fuse completely. When a little borax is added, it gives some marks of reduction, but inconsiderable ones.

Its constituents, determined by Berzelius, from the analysis of 10·16 grains of it, are as follow:

			Atoms.
Titanic acid,	46·3	8·43	7·02
Zirconia,	14·4	3·84	3·2
Peroxide of iron,	12·2	2·44	2·03
Lime,	4·2	1·20	1
Sesquioxide of manganese,	2·7	0·54	0·47
Peroxide of cerium,	5·0	0·71	0·6
Yttria,	11·5	2·09	1·74
	96·3		

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[*] Kong. Vet. Acad. Handl., 1824, p. 388, or Annals of Philosophy (2d series), xii. 117.

[†] Ann. des Mines (2d series), iii. 233.

The resulting constitution from the preceding analysis, is

3 atoms titaniate of zirconia,
2 atoms titaniate of iron,
$1\frac{3}{4}$ atoms dititaniate of yttria,
1 atom dititaniate of lime,
$\frac{1}{2}$ atom dititaniate of cerium,
$\frac{1}{2}$ atom dititaniate of manganese.

But the analysis would require repetition, in order to determine which of the constituents were lost during the process.

GENUS XIV.—THORIUM.

Thorium has been known for so short a time, that it is not surprizing that very few mineral species containing it are yet discovered. Indeed, if we except Siberian pyrochlore, in which Wöhler has discovered it to the amount of 5 per cent., the only species known is the one in which *thorina* was originally discovered.

Sp. 1. *Thorite.*[*]

This mineral was discovered in syenite in the island of Löv-ön, situated near Brevig in Norway. It was discovered by the Rev. Mr. Esmark, son of Esmark the celebrated professor in the university of Christiania. Esmark sent a specimen to Professor Berzelius, who analyzed it, and detected in it a new substance, to which he gave the name of thorina.

Thorite is black.

Amorphous, without any indication of crystalline shape or cleavage. It resembles very closely the gadolinite of Ytterby. Sometimes its surface is covered with a thin coating of rust coloured matter. Streak reddish grey; powder brownish red.

Very easily frangible and full of rifts.

Lustre of the fresh fracture vitreous, of the old surfaces resinous and dull.

Easily scratched by the knife; opaque.

Specific gravity 4·63.

Before the blowpipe it loses its black colour, gives out water, and becomes pale brownish red. It does not fuse.

Calcined in a tube, it gives out slight indications of fluoric acid. With borax it fuses easily; and when the assay is added in considerable abundance, the bead becomes opaque on cooling, but by flaming recovers its transparency. The bead

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[*] Kong. Vet. Acad. Handl., 1829, p. 1.

has the usual colour imparted by iron. The addition of nitre shows the presence of manganese. With biphosphate of soda it dissolves, leaving a skeleton of silica; the glass, which is coloured by iron, becomes opaline in cooling. With carbonate of soda the mineral is decomposed without fusion, and a yellowish brown scoria remains on the charcoal. When borax is added, small metallic grains are obtained, which flatten under the pestle. When heated with carbonate of soda on platinum foil, the whole becomes green coloured.

The constituents, by Berzelius's analysis, are as follow:

		Atoms.
Thorina,	57·91	6·81
Silica,	18·98	9·49
Lime,	2·58	0·73
Peroxide of iron,	3·40	0·68
Oxide of manganese,	2·39	0·48
Magnesia,	0·36	0·14
Peroxide of uranium,	1·61	0·57
Oxide of lead,	0·80	0·05
Oxide of tin,	0·01	
Water,	9·50	8·44
Potash,	0·14	
Soda,	0·10	
Alumina,	0·06	
Powder not dissolved,	1·70	
	99·54	

If we consider the silica as the only acid, and all the other constituents as bases, the mineral will be composed of simple silicates, and its constitution is very nearly

2 atoms silicate of thorina,
1 atom silicate of lime, iron, manganese, &c.
$1\frac{1}{4}$ atom water.

But it is probable that several of the constituents are only accidentally present.

GENUS XV.—IRON.

Iron is scattered in such profusion through almost every part of the globe, that but few minerals exist which do not contain some trace of it. But we include under this genus those minerals only which consist chiefly of it, or which at least contain it as an essential and notable constituent. These minerals are so numerous that *iron*, after alumina, is the richest in species of any genus at present known. They may be divided into three sections. The first consists of those species in which iron either exists uncombined, or in combination with a simple substance. The species belonging to the second section consist of oxide of iron, united to an oxygen acid; while the third section embraces those species in which a sulphuret of iron is united with a sulphur acid.

Sect. 1. *Iron uncombined, or united to a simple substance.*

The species belonging to this section amount to about 12, and they constitute some of the most abundant and important ores of this metal.

Sp. 1. *Native Iron.*

Bolide.

It is still a question among mineralogists whether native iron really occurs. There is no doubt, however, that specimens of it have been occasionally met with. Cramer describes one found in the mine of Hackenburgh, weighing four lbs.* Charpentier, in his Mineralogical Geography of Saxony, mentions a specimen found at Kamsdorf, in Saxony. Klaproth had in his cabinet a specimen from the mine Eiserner Johanness, at Great Kamsdorf, which he subjected to chemical analysis.† Specimens of native iron were found in veins at Canaan, in Connecticut. These veins pass through a quartz rock. It is said to occur in the same place in thin beds in mica slate. Some of the specimens found weighed 8 ounces.‡

Colour bluish-white.

Fracture hackly; cleavage none.

Lustre metallic; malleable.

Hardness 4·5.

Attracted by the magnet.

The specific gravity of the specimens found in Connecticut varied from 5·95 to 6·72.

The constituents of the specimen analyzed by Klaproth were

Iron, .	92·5
Lead, .	6·0
Copper, .	1·5
	100·0

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* Phil. Mag. xiii. 32.

† Gehlen's Jour. i. 34.

‡ Ann. des Mines (second series), iii. 258.

It is not probable that these constituents could be chemically combined. The Connecticut specimens contained no foreign metal, but they were mixed with plates of plumbago, and associated with native steel.

Sp. 2. *Meteoric Iron.*

This species of iron is believed to have constituted a portion of those igneous meteors which occasionally make their appearance in our atmosphere, and after burning for some time, burst with a loud explosion. It does not therefore, strictly speaking, belong to the mineral bodies of which our globe is composed; but as it exists occasionally on the surface of the earth in large masses, which are applied to useful purposes, it would be improper to pass it over here.

The most remarkable specimens of meteoric iron are those discovered by Pallas in Siberia, and Rubin de Celis in South America. Masses of native iron have been found also in Mexico, in Peru, on the Andes, at the Cape of Good Hope, at Elbugen in Bohemia, Agram in Croatia, and in one of the islands on the north coast of America. From this last specimen, as we are informed by Captain Parry, the Esquimaux supply themselves with all the iron which they require.

Meteoric iron is silver-white, and not nearly so liable to rust as common iron. Its structure is granular, and its specific gravity 7·3.*

The following table exhibits the constituents of various specimens of native iron, according to the best analyses hitherto made:

	†	†	‡	‡	‡	‡
Iron,	96·5	98·5	91·51	91·23	91·76	90·76
Nickel,	3·5	1·5	8·59	8·21	6·36	7·87
	100	100	100·10	99·44	98·12	98·63

If these specimens be chemical compounds of iron and nickel, it is clear that the two metals combine in many various

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* This was the specific gravity of native iron found on the Eastern Cordillera of the Andes. See Edinburgh Jour. xi. 120.

† Klaproth, Gehlen's Jour. i. 13. The first specimen from Sclavonia, the second from Siberia.

‡ Mariano de Rivero, and Boussingault, Edin. Jour. xi. 120. The specimens analyzed were from the Eastern Cordillera of the Andes.

proportions. The specimen in the third column is a compound of

10 atoms iron,	35
1 atom nickel,	3·25
	38·25

Sp. 3. *Magnetic Iron Ore.*

Octahedral iron ore—oxidulous iron—ferroso ferric oxide.

This mineral occurs in beds or in single crystals imbedded in chlorite slate, serpentine, greenstone, &c. The beds often extend a great way both in length and thickness. Hence magnetic iron ore constitutes one of the most abundant and important ores of that metal.

Colour iron black; streak black.

Massive and crystallized. Primary form the regular octahedron. Frequently all the edges of the octahedron are replaced by tangent planes. When these secondary faces become so much enlarged as to efface the primary planes, the crystal assumes the form of the rhombic or garnet dodecahedron.

Cleavage sometimes perfect, parallel to the faces of the primary octahedron, sometimes not to be observed.

Fracture conchoidal, uneven.

Lustre metallic; but sometimes imperfect.

Opaque; brittle.

Hardness 5·5 to 6·5; specific gravity of a very pure specimen 5·092, by my trial.

Not altered before the blowpipe per se. With borax in the oxidizing flame it fuses into a dull-red glass, which becomes clear on cooling, and often assumes a yellow tint. In the reducing flame it becomes bottle-green. The same appearances are produced with biphosphate of soda. Does not fuse with carbonate of soda.

Berzelius first showed that magnetic iron ore is a compound of

1 atom protoxide of iron, .	4·5
2 atoms peroxide of iron, .	10·0
	14·5

His results were confirmed by the analysis of a very pure specimen in my laboratory by Messrs. Mitchell and Hilton. 25 grains of the mineral yielded them

Peroxide of iron, .	25·432
Silica, . . .	0·4
	25·832

The excess was owing to the conversion of the protoxide of iron in the specimen to peroxide. The silica was doubtless foreign matter mechanically mixed with the pure ore. It will be found on calculation, that in magnetic iron ore, 1 atom of iron is combined with 1⅓ atom oxygen, which gives the very constitution pointed out by Berzelius.

Magnetic iron ore occurs most commonly in primary formations. Hence its abundance in Scandinavia. It is from it that all the Swedish iron, so celebrated for its excellent qualities, and so fit for steel, is extracted.

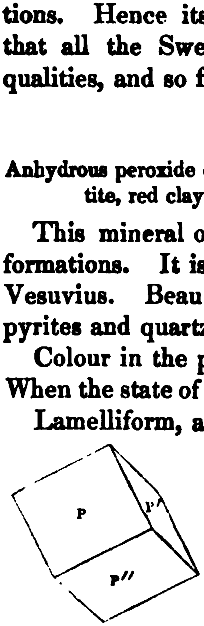
Sp. 4. *Specular Iron Ore.*

Anhydrous peroxide of iron, oligiste iron, iron froth, iron mica, red hematite, red clay ironstone, red siliceous ironstone, red ochre.

This mineral occurs usually in beds and veins in primary formations. It is found crystallized in the lava ejected from Vesuvius. Beautiful crystals occur in Elba along with iron pyrites and quartz. It is found also in many other places.

Colour in the perfect specimens steel-grey and iron-black. When the state of aggregation is lost, the mineral becomes red.

Lamelliform, and crystallized in a great variety of forms. The primary form is a slightly acute rhomboid.



P on P′ 86° 10′
P on P″ 93° 50′

Sometimes the mineral assumes the form of an octahedron, sometimes of a triangular dodecahedron, with its apices truncated either very deep or near the apex. The common shape of the crystal from Elba is rather complicated. For a description we refer to Hauy or Phillips.

Lustre metallic.

Opaque; very thin laminæ are faintly translucent. They show a deep blood-red colour.

Brittle; sometimes acts feebly on the magnet.

Hardness 5·5 to 6·5; specific gravity of a crystallized specimen from Sweden, as determined by Haidinger, 5·251.

Before the blowpipe it behaves like magnetic iron ore.

When pure it consists entirely of peroxide of iron.

The *micaceous* variety of this species occurs massive or crystallized in thin six-sided tables. It usually consists of thin plates, which held between the eye and the light appear blood-red. In other respects it is similar to the common specular iron ore. Sp. gr. 4·491 to 5·059, according to Kirwan.

Iron froth (Eisenrahm) is composed of scaly friable parts, which soil strongly; colour between cherry and brownish-red; very soft. It was analyzed by Dr. Henry, who obtained

Peroxide of iron, .	94·5
Silica? . . .	4·25
Alumina, . . .	1·25
	100

Red hematite (Rothglaskopf) is found in masses, stalactites and kidney-form balls; colour brownish red; powder red; structure fibrous; specific gravity of a specimen from Muirkirk 6·305; hardness 7; opaque; lustre semimetallic. I subjected it to analysis, and obtained

Peroxide of iron, .	96·65
Columbic acid? .	1·45
Alumina, . .	0·79
Water, . . .	1·09
	99·98

Compact red iron ore occurs massive or in pseudomorphous cubic crystals; colour brown red; fracture uneven; texture compact. Sp. gr. 4·232, as determined by Hoffmann.

The *red lenticular clay-iron stones* belong also to this species. They consist of red oxide of iron more or less mixed with foreign matter.

Red ochre and *reddle* also belong to it.

Sp. 5. *Crucite.*

The singular mineral to which I have given this name is found disseminated in purple coloured clay slate at Clonmell, in the County of Waterford, in Ireland. It was brought me by Mr. Doran, who, I presume, was the person who first found it.

It is always in crystals. The shape is a four-sided oblique prism, the faces of which meet at angles of 60° and 120°. These crystals are about an inch in length, and about one-fifth of an inch in thickness. Two of them always occur together crossing each other at angles of 60° and 120°. Hence the reason of the name by which I have distinguished it. Sometimes three crystals cross each other constituting a kind of star with six rays. Each of the angles at the centre where the crystals cross is an angle of 60°.

Internal colour black with something of the metallic lustre. Externally the colour is red, obviously from the action of the atmosphere. Does not act on the magnetic needle.

External lustre dull; opaque.

Hardness 3; specific gravity 3·579. That of another specimen was as high as 3·8095. But the quantity which could be employed for these determinations was so small that great accuracy is not likely to have been attained.

Before the blowpipe it acts precisely as oxides of iron do.

It was analyzed with great care by my nephew Dr. R. Thomson, but he found it impossible to exclude the whole of the matrix in which the crystals occur. The constituents obtained were

		Atoms.
Peroxide of iron,	81·666	16⅓
Alumina,	6·866	3
Silica and scales of mica,	6·000	3
Lime,	4·000	1·14
Magnesia,	0·532	0·21
	99·064	

It is impossible to draw any satisfactory conclusion from these numbers, because part of the constituents was certainly derived from the matrix. This matrix, examined by the magnifying glass, was so full of quartz grains that I am disposed to ascribe all the quartz to this source. If the alumina, lime, and magnesia be constituents of the mineral, which, however, is more than doubtful, it might be perhaps considered as composed of

2 atoms terferrate of alumina,
1 atom terferrate of lime.

The peroxide of iron acting the part of an acid.

The great difference between the specific gravity of crucite and of specular iron ore, makes it impossible to consider it as a variety of that mineral, even if the crystalline form were not incompatible.

I have placed it provisionally next in order after specular iron ore, till the discovery of purer crystals than we were able to pick out from the specimens of Mr. Doran, enable us to determine whether or not our present views respecting its chemical constitution be correct.

Sp. 6. *Manganesian Iron Ore.*[*]

This mineral was sent me by Mr. Nutall from Stirling, in Massachusetts.

Colour black; lustre splendent, semimetallic; streak red.

On some parts of the surface splendent facets appear, which seem to indicate an octahedron as the primary form of its crystals. Texture foliated, but cleaves only in one direction.

Surface smooth; brittle; opaque.

Hardness 7; specific gravity 5·079.

Fracture small conchoidal. This, together with the colour and lustre, gives the mineral something of the aspect of cherry coal.

Acts feebly on the magnetic needle, but has no polarity.

Its constituents, by my analysis, are

		Atoms.
Peroxide of iron, .	75·5	. 15·1
Sesquioxide of manganese,	22·65	. 4·53
Titanic acid with some iron,	1·15	
Moisture, . .	0·40	
	99·7	

This approaches

3 atoms peroxide of iron,
1 atom sesquioxide of manganese.

There is an excess of peroxide of iron which is probably united in the mineral with titanic acid.

Sp. 7. *Franklinite.*

This mineral exists in great abundance at Franklin, in Sussex county, New Jersey. It was analyzed and described by Berthier in 1819.[†]

Colour iron grey; powder dark brown.

Granular and massive. Found also in crystals. The shape is an octahedron, but all of them that I have seen have rough surfaces and cannot be measured. They are sometimes several inches in length.

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[*] I have a suspicion that this species and the following are only varieties of each other.

[†] Ann. des Mines, iv. 483.

Fracture conchoidal.

Lustre metallic.

Opaque; crystals semitransparent, and show a blood-red tint; brittle; not easily pounded.

Hardness 6 to 6·5; specific gravity of the pure crystals 5·069; pieces picked out of a mixture of franklinite and red zinc 4·257; Berthier states the specific gravity 4·87.

Acts sensibly on the magnetic needle, but does not adhere to the magnet, nor is it possessed of sensible polarity.

Its constituents are as follow:—

	*	†	Atoms.
Peroxide of iron,	66	66·10	13·22
Sesquiox. of manganese,	16	14·96	2·99
Oxide of zinc,	17	17·425	3·31
Silica,	—	0·204	
Water,	—	0·560	
	99	99·249	

These analyses very nearly coincide. Probably in neither was the oxide of zinc completely freed from all oxide of manganese. The numbers approach

4 atoms peroxide of iron,
1 atom sesquioxide of manganese,
1 atom oxide of zinc.

Were we to consider the peroxide of iron as acting the part of an acid, the constitution of the mineral might be represented thus,

1 atom biferrate of manganese,
1 atom biferrate of zinc.

Sp. 8. *Dihydrous Peroxide of Iron.*

A nodule of this mineral, about the size of a hen's egg, was found in a trap rock at Gourock, in the neighbourhood of Greenock. It occurs also in crystals at St. Just, in Cornwall, and with crystallized quartz at St. Vincent's rocks, near Bristol.

Colour reddish brown; streak lighter.

The nodule was composed of very fine needles, diverging slightly like a painter's brush. The crystals have a right rhombic prism for their primitive form.

The faces of the prism are inclined to each other at angles

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* By Berthier's analysis.

† By my analysis. The specimen was very pure, and had been sent me by Dr. Torrey expressly for analysis.

of 130° 40′ and 49° 20′. They cleave easily in the direction of the short diagonal of the base.

Lustre imperfect metallic and silky, that of the crystals adamantine.

Brittle; opaque.

Hardness 4·5; specific gravity 4·375.

The constituents, determined by my analysis, are

			Atoms.
Peroxide of iron,	91·7	18·34	1
Water,	8·5	7·55	0·41
	100·2		

The water is rather less than half an atom. Doubtless a little of it had made its escape before the nodule was subjected to analysis. In the crystals the proportion of water was very nearly half an atom.

Sp. 9. *Hydrous Peroxide of Iron.*

Stilpnosiderite, bonerz, brown fibrous hematite, brown ochre, brown clay ironstone, gothite, lepidokrokite, pyrosiderite, rubinglimmer, umber, yellow clay ironstone.

This species occurs both in beds and veins in primary as well as secondary rocks, and is very abundant.

Colour various shades of brown, as yellowish brown, hair brown, clove brown, and blackish brown; streak yellowish brown.

Massive. It is said also to occur crystallized, but I suspect that all the crystals hitherto described belong to the last species. Those of St. Just I analyzed and found to be in that predicament.

Opaque; does not act on the magnet.

Hardness 4·5 to 5; specific gravity of the crystals from St. Just 4·04. Haidinger states the specific gravity 3·922.

The *fibrous brown iron ore* or *brown hematite* constitutes the true type of the species. In the compact brown ore the structure of the species is no longer visible, though the constituents are still firmly compacted together. The *lenticular clay ironstone*, the *kidney form* or *etites*, and the *pisiform iron ore*, and *brown iron ochre* are to be considered as impure varieties.

The following table exhibits the constituents of the different varieties:—

	*	†	†	†	†	†	†	†	†
Peroxide of iron, .	80·50	79	72	84	81	78	73	76	83
Sesquiox. of mangan.,	trace	2	2	1	—	trace	1	2	trace
Water, . .	16·00	15	14	11	12	13	14	14	12
Silica, . .	2·25	3	1	2	4	6	9	5	5
Alumina, . .	—	—	trace	—	—	1	—	—	—
	98·75	99	99	98	97	99	97	97	100

The first three specimens analyzed exhibit the species in its state of greatest purity. The mean of them gives

		Atoms.
Peroxide of iron, . .	80·5 .	16·1
Sesquioxide of manganese,	1·3 .	0·26
Water, . . .	15·0 .	13·34
Silica, . . .	2·08 .	1·04

If we admit the silica to be united with peroxide of iron in the state of disilicate, or rather trisilicate, and to be accidental, it is obvious that the mineral is a hydrous peroxide of iron, composed of

1 atom water,
1 atom peroxide of iron.‡

Sp. 10. *Magnetic Pyrites.*

Sulphuret of iron.

This species occurs in beds along with other minerals containing iron. It also forms an accidental ingredient in several rocks, and crystallizes in their fissures. In this way it occurs in Cornwall, Wales, at the base of Moel Elion, in Caernar-

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* Ulmann, Hoffman's Miner., iv. 188. The specimen was stilpnosiderite.

† D'Aubuisson, Ann. de Chim., lxxv. 237. The first two specimens brown hematites. The third and fourth compact brown hematites. The fifth and seventh etites. The sixth lenticular iron ore. The eighth brown ochre.

‡ The variety called ligniform hematite, from some resemblance which it bears to wood, has a brown colour, a fibrous texture, and a specific gravity of 3·443. I analyzed a specimen and obtained

		Atoms.
Silica, . . .	1·80 .	0·9
Peroxide of iron, .	78·80 .	15·76
Alumina, . .	1·48 .	0·65
Water, . .	16·60 .	14·75
	98·68	

If we leave out the alumina as accidental, the constituents are

16 atoms perhydrate of iron,
1 atom persilicate of iron.

vonshire, and in some of the hills of Galloway. Crystals of it are found in Bodenmais, in Bavaria, and at Breitenbrun and Geyer, in Saxony.

Colour intermediate between bronze-yellow and copper-red; streak dark greyish-black.

It occurs most frequently massive, but Count Bournon informs us that it is found also crystallized in irregular six-sided prisms, variously modified. It affords, by cleavage, the regular six-sided prism, which is therefore its primary form.

Lustre metallic; opaque; brittle.

Hardness 5 to 6; Specific gravity 4·631.

Acts slightly on the magnetic needle.

Its constituents have been found as follow:

Iron,	63·5	59·85	56·37
Sulphur,	36·5	40·15	43·63
	100[†]	100[‡]	100[‡]

There are two sulphurets of iron, which have been long known to chemists; namely, the sulphuret composed of 1 atom sulphur and 1 atom iron, and the bisulphuret composed of two atoms sulphur and one atom iron.

If we consider the three analyses given in the table to be accurate, the specimens analyzed must be composed as follow:

		Atoms.
1st, of Sulphuret of iron,	99·199	180
Bisulphuret of iron,	0·801	1
	100	
The 2d, of Sulphuret of iron,	77·688	5
Bisulphuret of iron,	22·312	1
	100	
The 3d, of Sulphuret of iron,	57·175	2
Bisulphuret of iron,	42·825	1
	100	

They constitute, in fact, three distinct species, although we have no adequate means of distinguishing them by their external characters.

[†] Hatchett, Phil. Trans. 1804, p. 315.

[‡] Stromeyer, Gilbert's Annalen, xlviii. 183. The specimens were from the Hartz. The first analysis corresponded with the constitution of magnetic pyrites made artificially.

Sp. 11. *Bisulphuret of Iron.*

Iron or cubic pyrites, mundic, sulphur.

This species is almost universally diffused. It occurs in clay slate, both in isolated crystals and in beds. In greenstone and granular limestone it exists in massive nodules. It is a pretty abundant ingredient in coal beds, and often contaminates the coal; being known to colliers by the name of *sulphur*. It frequently accompanies ores of zinc, lead and copper.

Colour a characteristic bronze-yellow, varying a little in shade; streak brownish-black.

Massive and crystallized in cubes and regular octahedrons, and in figures derived from these forms, as the pentagonal dodecahedron and the icosahedron. The cube has been adopted as the primary crystal, because the mineral cleaves best parallel to its faces.

Fracture conchoidal; opaque; lustre metallic.

Hardness 6·5; specific gravity from 4·830 to 5·031.

The following table exhibits the constituents of this mineral, according to the best analyses hitherto made:

	*	*	*	†
Sulphur, .	52·15	52·5	52·7	54·26
Iron, . .	47·85	47·5	47·3	45·74
	100	100	100	100

If we calculate the constitution of the mineral from Berzelius's analysis, we have:

		Atoms.
Sulphur, .	27·13 .	2·07
Iron, . .	13·06 .	1

The mean of Hatchett's analyses gives:

		Atoms.
Sulphur, .	26·22 .	1·93
Iron, . .	13·58 .	1

The mean of the two gives us:

Sulphur 2 atoms,
Iron 1

There cannot therefore be the least doubt about the true constitution of this mineral.

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* Hatchett, Phil. Trans. 1804, p. 325. The first specimen was in pen[illegible]rons, and had a specific gravity of 4·830. The second [illegible]; the third in smooth cubes, and had a specific gravity

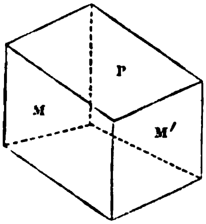
† Berzelius.

Sp. 12. *Radiated Pyrites.*

White bisulphuret of iron, cockscomb pyrites, kamkies, leberkies, zelkies.

This species is much less abundant than the preceding. It occurs most commonly in coal beds. It is found also in veins along with ores of silver, lead and copper.

Colour pale bronze yellow, sometimes inclining to green or grey; streak greyish black.



Massive and crystallized. The primary form is a right rhombic prism,

M on M′ 106°

But the most common form is a very flat crystal, having at first sight the appearance of a dodecahedron, with triangular faces, but consisting in fact of similar portions of five crystals connected together.

Lustre metallic; opaque; brittle.

Hardness 6; specific gravity from 4·678 to 4·847.

Its constituents, as determined by Hatchett and Berzelius, are as follow:

Iron,	46·40	45·66	45·07
Manganese,	—	—	0·70
Sulphur,	53·60	54·34	53·35
Silica,	—	—	0·80
	100*	100*	99·92†

The constitution is obviously the very same as that of the preceding species. This is remarkable, as the two species differ in their specific gravity, and in the shape of their crystals.

Sp. 13. *Sesquiarseniet of Iron.*

This mineral was first distinguished as a peculiar species by Mohs, under the name of *axotomous arsenical pyrites.*‡ Hitherto it has been found only in beds either along with sparry iron ore, or imbedded in serpentine. In the first way it occurs in the valley of Löling, near Huttenberg, in Carinthia; in the second way at Reichenstein, in Silesia.

Colour between silver-white and steel-grey.

It is found crystallized, and its primary form, according to Mohs, is an octahedron, whose faces are scalene triangles, and whose axes are to each other as $1 : \sqrt{0{\cdot}8747} : \sqrt{0{\cdot}4806}$

Fracture uneven; brittle; lustre metallic; opaque.

Hardness 5 to 5·5; specific gravity of the massive variety from Reichenstein, 7·228.

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* Hatchett, Phil. Trans. 1804, p. 325. † Berzelius, Mineralogie, p. 263.

‡ Mohs' Mineralogy, ii. 448.

Its constituents, as determined by the analysis of Hoffmann,[*] are:

		Atoms.	
Sulphur,	1·94	0·97	0·12
Arsenic,	65·99	13·89	1·72
Iron,	28·06	8·01	1
Serpentine,	2·17		
	98·16		

If we allow the sulphur to be united to arsenic, and to be only accidental, it is obvious that the constitution of the mineral is

1½ atom arsenic,
1 atom iron.

It is therefore a sesquiarseniet of iron.

Sect 2. *Oxygen Salts of Iron.*

These salts being numerous, for they amount to no fewer than 48 species, it will be convenient to subdivide them.

I. *Simple Oxygen Salts.*

These constitute more than half of all the oxygen salts of iron, but the simplicity of their constitution renders it easy, in a chemical point of view, to distinguish them from each other.

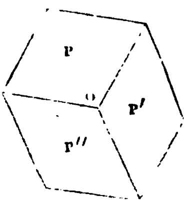
Sp. 1. *Carbonate of Iron.*

Brownspar, stahlstein, spherosiderite, spathose iron, fer spathique, clay ironstone, argillaceous iron ore.

This species occurs frequently in veins along with ores of lead and copper, and is rather abundant in the contemporaneous veins of primary rocks. Great beds of it occur in our coal formations, which supply all the ore requisite for the immense quantity of iron annually smelted in Great Britain.

Colour various shades of yellowish-grey, passing into ash, and greenish-grey, also into several shades of yellow, white, and red. The clay ironstone is sometimes black, from the carbonaceous matter which it contains; streak usually white.

Massive and crystallized in obtuse rhomboids, approaching pretty nearly to the shape of the primary crystal of calcareous spar.



P on P′ 107°
P or P′ on P″ 73°

according to the measurements of Dr. Wollaston.

Sometimes the angle o is replaced by

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[*] Poggendorf's Annalen, xxv. 489.

three planes, which, increasing in size, form a kind of elongated double three-sided prism, terminated by the half of the original rhomboid.

Not unfrequently the lateral angles of the rhomboid are replaced by tangent planes, which converts the crystal into a regular six-sided prism. Very large crystals of this shape have been found in Cornwall.

Fracture imperfect conchoidal.

Lustre vitreous, inclining to pearly.

Translucent to opaque; brittle.

Hardness 3 to 4·5; specific gravity from 3·7317 to 3·829.

Before the blowpipe it blackens, giving off carbonic acid, and leaves an oxide of iron very attractable by the magnet.

The first attempt to analyze *sparry iron ore*, as this species was called, was by Bergman, but his results were too inaccurate to induce confidence. Drappier analyzed three specimens in the year 1803, and found them composed of protoxide of iron, magnesia, and carbonic acid.* Soon after two other specimens were analyzed by Collet Descotils, with nearly the same result.†

The following table shows the constituents, according to the most recent analyses hitherto made:—

	‡	‡	§	‖
Protoxide of iron,	57·5	58	54·57	52·128
Protox. of mangan.,	3·5	4·25	1·155	—
Lime, . .	1·25	0·50	3·176	9·965
Magnesia, .	—	0·75	—	
Alumina, .	—	—	—	5·676
Moisture, .	—	—	2·630	—
Carbonic acid, .	36·0	35	35·900	32·231
	98·25	98·5	97·431	100

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* Jour. des Mines, xviii. 47.

† Ibid. p. 211.

‡ Klaproth, Beitrage, iv. 110. The first specimen was from Dankerode, in Halberstadt; the second from Bareuth.

§ By my analysis. The specimen was from Slitt lead mine, in the county of Durham. It exists in considerable quantity in the gangue of the ore, and is granular, and of a reddish-white colour, and has a specific gravity of 3·7317.

‖ Bischoff, Ann. des Mines (second series), i. 279. It was a *spherosiderite*.

It is obvious that the mineral consists essentially of carbonate of iron, composed of

1 atom carbonic acid,
1 atom protoxide of iron;

but there are generally present carbonates of lime and magnesia, in more or smaller quantity.

The important metallurgical ore called *clay ironstone*, is in reality a mixture of carbonate of iron with clay, and sometimes with carbonaceous matter. Hence the variety of colour which it exhibits.

The fracture is usually earthy; the mineral is opaque, and has a specific gravity which varies from 2·936 to 3·471. The following table exhibits the specific gravity of several varieties of clay ironstone, from the coal beds in the neighbourhood of Glasgow, as determined by Dr. H. Colquhoun.

Localities.		Specific gravity.
Crossbasket, . .		3·1793
Do.	greyish-black,	3·3801
Do.	light greyish black,	3·2699
Do.	brownish-black,	3·1175
Clyde Iron Works, .		3·1482
Do. do. . .		3·2109
Easterhouse, . .		3·3109
Airdrie, Mushet's black band,		3·0553

The following table exhibits the composition of these specimens, as determined by the analysis of Dr. Colquhoun:*

Carbonic acid, .	32·53	33·63	31·86	30·76	26·35	33·10	32·24	35·17
Protoxide of iron,	35·22	45·84	42·15	38·80	36·47	47·33	43·73	53·03
Protox. of mangan.,	—	0·20	—	0·07	0·17	0·13	—	—
Lime, . . .	8·62	1·90	4·93	5·30	1·97	2·00	2·10	2·33
Magnesia, . .	5·19	5·90	4·80	6·70	2·70	2·20	2·77	1·77
Silica, . .	9·56	7·83	9·73	10·87	19·20	6·63	9·70	1·40
Alumina, . .	5·34	2·53	3·77	6·20	8·03	4·30	5·13	0·63
Peroxide of iron,	1·16	—	0·80	0·33	0·40	0·33	0·47	0·23
Coaly matter, .	2·13	1·86	2·33	1·87	2·10	1·70	1·50	3·03
Sulphur, . .	0·62	—	—	0·16	—	0·22	0·02	—
Moisture, . .	—	0·99	—	—	—	—	—	—
	100·37	100·68	100·37	101·00	98·09	97·94	97·66	98·59

The following table exhibits the analyses of nineteen varieties of clay ironstone occurring in nodules or beds in the coal beds of France:

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* Brewster's Journal, vii. 234.

	Magescote.	Barthes.	Gabliers.	Baumer.	Fine.	Vescheres.	Morillon.	Mouillar.	Do.	Do.	Do.	Do.	St. Etienne.	Do.	Do.	Do.
Protoxide of iron,	35	51	43·9	54·2	37·3	13·5	20·3	28·5	45·0	40·0	38·0	46·7	41·8	50·8	38	41·2
Protoxide of mangan.	0·3	1·5	0·2	1·1	1·7	0·3	0·6	1·1	2·9	1·5	1·4	2·8	4·1	1·0	2·5	1·0
Magnesia, . . .	1·6	—	2·0	0·9	1·9	0·8	0·3	5·0	—	3·0	2·6	—	0·2	—	1·5	3·0
Lime, ...	—	1	—	0·3	6·0	7·4	4·2	3·0	0·3	—	—	2·4	0·2	3·5	13·0	8·0
Loss by calcination,	25·5	29·5	30·5	28·9	27·7	24·6	21·9	21·0	25·7	14·6	9·1	32·5	38·4	31·6	42·2	21·4
Silica, ...	26·5	9·0	10·2	12·8	25·0	47·1	47·4	35·7	18·9	35·7	44·4	11·4	12·3	10·3	—	18·2
Alumina, . . .	11·8	7·0	13·0	1·8	0·9	6·3	3·3	6·5	6·1	5·5	4·4	2·9	3·2	2·8	2·0	2·0
Phosphoric acid,	—	—	—	—	—	—	—	0·3	—	—	—	—	—	—	0·8	6·1
	100·7	99	99·8	100	100·5	100	98	100·9	98·9	100·3	99·9	98·7	100	100	100	100·9

These analyses and many others were made by Berthier. See his *Traité des Essais par la voie seche*, vol. ii. p. 252.

It is obvious from an inspection of these analyses, that all the specimens examined, were mixtures of

Carbonate of iron,
Carbonate of lime,
Carbonate of magnesia,
Pyrites,
Clay,
Coal,

in various proportions. Thus the first specimen consisted of

Carbonate of iron,	55·697
Carbonate of lime,	15·390
Carbonate of magnesia,	10·899
Clay, . . .	16·060
Pyrites, . .	1·125
Coaly matter, .	2·130
	101·301

The excess is owing to the deficiency of carbonic acid in the analysis. The quantity necessary to saturate the protoxide of iron, lime, and magnesia, in the specimen, is 33·605 grains, while only 32·53 grains were obtained.

Mushets black band is the specimen which contains the greatest quantity of carbonate of iron. It is composed of

Carbonate of iron, .	85·437
Carbonate of lime, .	5·946
Carbonate of magnesia, .	3·317
Clay, ...	2·260
Coaly matter, . .	3·030
	99·99

In this analysis also there is a loss of 1·4 grain of carbonic acid, provided the whole of the protoxide of iron, lime, and magnesia be saturated with that acid, as is very probably the case. None of the French specimens, analyzed by Berthier, is so pure as Mushet's black band. I analyzed a specimen of ironstone from the neighbourhood of the Monkland canal, which contained 80·2 per cent. of carbonate of iron.

Its specific gravity was 3·505. Next to Mushet's black band, it is the purest specimen of clay ironstone that I have ever met with.

Sp. 2. *Junkerite.*

This mineral has been lately discovered in the mine of Poullaouen, in a gallery of research opened in the pit Kœnig. It covers the surface of small quartz veins which traverse the grey wacke of the locality. M. Paillette, sub-director of the mine, discovered the crystals constituting this species, and gave them the name of Junkerite, in honour of the director, M. Junker, to whom the mine is indebted for its present state of activity.

Colour yellowish grey, not unlike that of some varieties of tungstate of lime.

It is in crystals, the usual form of which is a rectangular octahedron, the faces of which are curved somewhat like those of the diamond. The faces of the octahedron are dull, so that the angles cannot be measured by the reflecting goniometer. But it possesses three cleavages, which bring into view new faces of such brilliancy, that the angles admit of easy measurement. Two of these cleavages are parallel to the diagonal planes of the octahedron, and consequently meet at an angle of 108° 26′. The third cleavage is perpendicular to the axis of the octahedron. Hence the primary form is a right oblique prism, the faces of which meet at angles of 108° 26′, and 71° 34′. The two vertical cleavages always occur, but the third only occasionally.

The common carbonate of iron which constitutes the preceding species, has for its primary form an obtuse rhomboid with angles of 107°. A form quite incompatible with the present. Thus common carbonate of lime and Junkerite differ from each other precisely as calcareous spar and arragonite differ. Calcareous spar has for its primary form an obtuse rhomboid of 105° 5′, while that of arragonite is a right oblique prism, the faces of which meet at angles of 116° 10′, and 63° 50′.

Hardness 3·5; specific gravity 3·815.

Before the blowpipe with borax it fuses into a yellowish green glass, which becomes brown when the proportion of Junkerite is considerable.

The constituents of this mineral, determined by two different analyses of M. Dufresnoy, to whom we owe the only description hitherto published, are as follow:

Protoxide of iron, .	53·6 .	47·9
Carbonic acid, .	33·5 .	30·0
Silica, . .	8·1 .	16·8
Magnesia, . .	3·7 .	3·9
	98·9	98·6*

If we admit the silica to be accidental, as can hardly be

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* Ann. de Chim. et de Phys. lvi. 198.

doubted from the great difference in the two analyses, there is a slight excess of bases. The atoms of acids and bases being

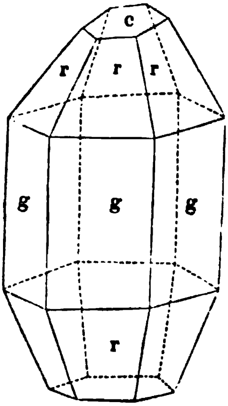
		By 1st analysis.		By 2d analysis.
Carbonic acid, . .		12·1 atoms		10·64
Protoxide of iron,	11·91	13·3	10·64	12
Magnesia, .	1·4		1·4	

But we have no evidence that the mineral was not a neutral carbonate of iron, as M. Dufresnoy did not determine the weight of the carbonic acid evolved, but deduced it simply from the quantity of protoxide obtained.

Sp. 3. *Bisulphated Peroxide of Iron.*

This mineral was brought from South America by Dr. Meyen. It is found in the province of Coquimbo, the most northerly part of the republic of Chili, not far from the boundary of the province of Bolivia, and about half a day's journey from the town of Copiapo. It constitutes a bed in a felsparry rock, which fuses before the blowpipe. This rock agrees with a fine grained granite in its properties. It is probable that the salt is derived from the decomposition of a bed of iron pyrites situated in the rock. The bed of salt rises in various places to-day, and pits almost 20 feet deep have been dug in it by the country people.

The salt is white, and partly in fine granular masses and partly in crystals. These crystals have the figure in the margin, a regular six-sided prism, terminated at both extremities by a truncated six-sided pyramid. The following are the angles calculated by M. H. Rose, from some measurements by his brother:



r on r	128° 8′
r on c	151
r on g	119
g on g	120

The crystals cleave imperfectly parallel to the faces r and g. Their fracture is conchoidal.

The salt is completely soluble in water, and when the solution is heated, a copious precipitate of peroxide of iron falls. When it is dissolved in water containing muriatic acid, a portion of silica remains undissolved.

From the analysis of Mr. H. Rose,* the constituents of this salt are

		Atoms.
Silica,	0·31	0·15
Sulphuric acid,	43·55	8·71
Peroxide of iron,	24·11	4·82
Alumina,	0·92	0·40
Lime,	0·73	0·20
Magnesia,	0·32	0·13
Water,	30·10	26·75
	100·04	

As the salt is soluble in water, it is clear that all the bases must be combined with sulphuric acid. If we admit the alumina, lime, and magnesia, to be in the state of sulphates, as is most probable they will, for saturation require 0·73 atom of sulphuric acid. There will remain 8 atoms to unite with 4·82 atoms peroxide of iron. It is pretty clear from this that the salt is in the state of a bisulphate, or a compound of

2 atoms sulphuric acid,
1 atom peroxide of iron,
5 atoms water,

These numbers must represent very nearly the constitution of the salt.

Sp. 4. *Sulphated Peroxide of Iron.*

This salt is generally found encrusting the preceding. It consists of small grains frequently covered with small thin six-sided tables, so minute that their angles cannot be determined. Easily cleavable parallel to the surface of the table.

Colour yellow; translucent; lustre pearly. It is mixed with a good deal of siliceous matter which is not easily separated. Its constituents, according to the analysis of H. Rose,† are

		Atoms.
Silica,	1·37	0·68
Sulphuric acid,	39·60	7·92
Peroxide of iron,	26·11	5·22
Alumina,	1·95	0·86
Magnesia,	2·64	1·05
Water,	29·67	26·37
	101·34	

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* Poggendorf's Annalen, xxvii. 310.

† Ibid. p. 314.

The alumina and magnesia were doubtless in combination with the sulphuric acid. They amount together to 1·91 atoms. This subtracted leaves 6·01 atoms of sulphuric acid to combine with 5·22 atoms of peroxide of iron These numbers approach so near equality, that we may consider the salt as composed of

1 atom sulphuric acid,
1 atom peroxide of iron,
5 atoms water.

Mixed with this salt there occurs a small quantity of a dirty yellowish green matter not crystallized, but forming small balls composed of short excentric rays two or three lines in length, very loosely connected together. When mixed with cold water, this salt is decomposed and deposites peroxide of iron. Its constituents, according to H. Rose,* are

		Atoms.
Silica,	1·43	0·71
Sulphuric acid,	31·73	6·33
Peroxide of iron,	28·11	5·62
Lime,	1·91	0·54
Magnesia,	0·59	0·21
Water,	36·56	32·5
	100·53	

The lime and magnesia amount together to 0·75 atom. If they were united to sulphuric acid, there will remain 5·58 atoms of that acid to combine with 5·62 atoms of peroxide of iron. These numbers are so near equality, that we cannot doubt that the salt is a neutral sulphated peroxide. The water combined with one atom of the salt is 5·78 atoms. The difference between this salt and the preceding, consists chiefly in this excess of water, which however does not amount to so much as an atom.

Sp. 5. *Mullicite.*†

This mineral was brought many years ago from the Isle of France and from Brazil, and was analyzed by Laugier and Cadet. I do not know whether the specimens from Bodenmais in Bavaria, analyzed by Fouveroy and Laugier,‡ and by

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* Poggendorf's Annalen, xxvii. 316.

† From Mullica Hill, where the mineral was found.

‡ Ann. de Mus. d'Hist. Nat. iii. 405.

Vogel,[*] belong to this species; but from the analyses, I think it is probable they do. The specimens in my possession are from the United States. They were found at Mullica Hill, Gloucester County, New Jersey. They consist of cylinders about two inches long and half an inch in diameter, encrusted with a yellowish red sand, which also occurs interspersed through the cylinders; thus giving them the appearance of having been formed in loose sand. The sand consists of grains of quartz, deeply tinged on the surface with oxide of iron.

Colour bluish black; lustre splendent and vitreous, and each cylinder consists of a congeries of small needle-form crystals radiating from the centre of the cylinder.

Opaque; sectile.

Hardness 1; specific gravity 1·787. The specimen was not free from grains of sand, and it doubtless contained small cavities between the crystals, though they could not be distinguished by the naked eye.

I found its constituents to be

		Atoms	
Phosphoric acid,	24	5·33	1
Protoxide of iron,	42·65	9·47	1·67
Water,	25·00	22·22	4·16
Grains of quartz sand,	7·90		
	99·55		

These numbers approach very nearly to

1 atom phosphoric acid,
$1\frac{2}{3}$ atom protoxide of iron,
4 atoms water.

Probably the true composition is

1 atom phosphoric acid,
2 atoms protoxide of iron,
4 atoms water.

This would make it a diphosphate of iron.

The *diphosphate of iron* from Haute Vienne, analyzed by Vauquelin, is nearly allied to this species, but it contains less water, and a little phosphate of manganese.

It has a brown colour, and is crystallized in radiating needles. Its powder has an olive colour. Fuses before the blowpipe into a black glass. Its constituents, as determined by Vauquelin, are

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[*] Gilbert's Annalen, lix. 174.

			Atoms.
Phosphoric acid,	24·8	5·51	1
Protoxide of iron,	51·0	11·33	2·05
Protoxide of manganese,	9·0	2·00	0·36
Water,	15·0	13·33	2·4
	99·8		

It is very nearly 1 atom of diphosphate of iron (neglecting the manganese), and 2½ atoms water.

According to Berthier's analysis,* the constituents are

		Atoms.
Phosphoric acid,	28·82	6·4
Protoxide of iron,	56·67	12·59
Water,	14·51	12·9
	100·00	

This obviously gives us

1 atom phosphoric acid,
2 atoms protoxide of iron,
2 atoms water.

To this mineral the name of Anglarite has been given, from Anglar, the place where it is found.

Sp. 6. *Subsesquiphosphate of Iron.*

Blue iron earth. Native Prussian blue.

This mineral occurs in nests among the strata of bog iron ore, and in mosses.

It is a powder composed of earthy particles. At first its colour is greyish-white, but when exposed to the air it gradually acquires a smalt blue colour.

Soils slightly; feels harsh.

Before the blowpipe becomes reddish brown, and melts into a black brilliant globule, attracted by the magnet.

Its constituents, according to the analyses of Klaproth† and Brandes,‡ are

	†	‡	Mean.	Atoms.
Phosphoric acid,	32	30·32	31·15	1
Protoxide of iron,	47·5	43·775	45·68	1·465
Alumina,	—	0·700	0·70	—
Silica,	—	0·025	0·02	—
Water,	20	25·000	22·5	2·88
	99·5	99·820	100·0	

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* Ann. des Mines, xii. 303.

† Beitrage, iv. 120.

‡ Schweigger's Jahrbuch, i. 77.

This is obviously

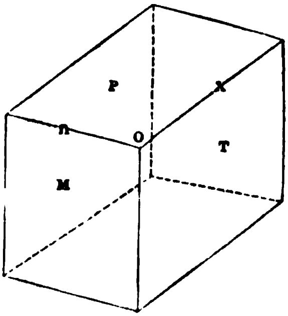
1 atom phosphoric acid,
1½ atom protoxide of iron,
3 atoms water.

It is therefore a hydrous subsesquiphosphate of iron.

Sp. 7. *Vivianite.*

This mineral occurs in beautiful crystals in Huel Kind, at St. Agnes, in Cornwall, and doubtless in other places; but it is hazardous to specify localities, because two different species have hitherto been confounded under the name of *phosphate of iron.*

Colour various shades of blue and green; at first light, but the colour deepens by exposure, and becomes at last a dirty indigo blue.



Usually crystallized. Primary form a right oblique prism,

M on T 125° 15′

The edge x is often replaced by two planes, making the crystal (which is lengthened by the enlargement of the face T), a twelve-sided prism.

P makes with the planes next it an angle of 125° 56′, while T makes with plane next it an angle of 165° 25′. The edge n is also sometimes replaced by a plane. The solid angle o is also occasionally replaced.

Lustre pearly, almost metallic on the summit of the prism; the other faces have a vitreous lustre.

At first translucent or semitransparent, but by long exposure it becomes opaque.

Sectile; thin laminæ are flexible, but not elastic.

Hardness 1·5 to 2; specific gravity 2·661.

When held in the flame of a spirit lamp it immediately loses its blue colour, and becomes white and opaque. It then exfoliates and melts into a black enamel, which, when the heat is continued, becomes magnetic. When heated in a glass tube it gives out a considerable quantity of pure water.

Its constituents, as determined by Stromeyer,* are as follow:

		Atoms.	
Phosphoric acid,	31·1825	6·93	1
Protoxide of iron,	41·2266	9·16	1·32
Water,	27·4843	24·43	3·52
	99·8934		

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[*] Untersuchungen, p. 274.

These numbers obviously correspond with

1 atom phosphoric acid,
1⅓ atom protoxide of iron,
3½ atoms water.

The analysis of the phosphates is attended with peculiar difficulties, on account of the numerous proportions in which phosphoric acid unites with bases. But if any confidence can be placed in the analyses hitherto made, there are at least four species of phosphated protoxide of iron. These are

1. Diphosphate, composed of
   1 atom phosphoric acid,
   2 atoms protoxide of iron.
2. Mullicite, composed of
   1 atom acid,
   1·66 atom base.
3. Native prussian blue,
   1 atom acid,
   1·5 atom base.
4. Vivianite, composed of
   1 atom acid,
   1⅓ atom base.

A more rigid investigation of the true constitution of these minerals is highly worth the attention of chemists.

Sp. 8. *Diarseniate of Iron.*

White iron sinter.

This mineral is found in the neighbourhood of Freiberg. It was first noticed by Freiesleben, and analyzed by Kersten.

It is a yellowish grey substance, which occurs in kidney-form pieces, soft, approaching to friable, with a coarse earthy fracture, and adhering strongly to the tongue; dull and somewhat rough to the feel.

Its constituents, as determined by Kersten,* are

			Atoms.
Arsenic acid, . .	30·25	3·9	1
Peroxide of iron, . .	40·45	8·09	2·07
Water with trace of sulphuric acid,	28·50	25·11	6·43
	99·20		

These numbers obviously correspond with

1 atom arsenic acid,
2 atoms peroxide of iron,
6 atoms water.

It is therefore a hydrous diarseniate of iron.

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* Schweigger's Jahrbuch, xxiii. 176.

Sp. 9. *Subsesquiarseniate of Iron.*

Cube ore of iron, hexahedral liricone malachite, wurfelerz, pharmacosiderite, ferarseniaté.

This mineral was noticed by Klaproth, but mistaken by him for a ferruginous arseniate of copper. It was first described by Bournon and analyzed by Chenevix.* It occurs in copper veins traversing the older classes of rocks. It has been found in greatest abundance in Cornwall, in several copper mines in the neighbourhood of Redruth. It has been met with also at St. Leonhard in France, and at Schwarzenberg in Saxony.

Colour olive green, passing into yellowish brown and sometimes into yellowish red, also grass-green and emerald green; streak olive green.

Always crystallized. Primary form the cube. The angles or edges, and sometimes both, are replaced by tangent planes. Sometimes the faces of the cube are replaced by two faces meeting in the diagonal of the cubic face, and forming with each other an angle of 176° 30′.

Cleavage difficult and imperfect.

Fracture conchoidal, uneven.

Surface of the cube sometimes streaked parallel to the edges of combinations of the tetrahedron.

Lustre adamantine; not very distinct.

Translucent on the edges; rather sectile. Hardness 2·5. Specific gravity, as determined by Bournon, 3·000.

When exposed to a gentle heat the colour becomes red; in a higher temperature the mineral intumesces, gives out little or no arsenic, and leaves a red powder. Before the blowpipe, on charcoal, it emits copious fumes of arsenic, and melts in the reducing flame into a metallic scoria which acts on the magnetic needle.

Its constituents, according to the analysis of Berzelius,† are:

		Atoms.	
Arsenic acid,	37·82	4·88	1
Phosphoric acid,	2·53	0·56	0·11
Peroxide of iron,	39·20	7·85	1·60
Oxide of copper,	0·65	0·13	0·02
Water,	18·61	16·54	3·39
Insoluble matter,	1·76		
	100·57		

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* Phil. Trans. 1801, pp. 190, 220.

† Kong. Vet. Acad. Handl., 1824, p. 354.

If we allow for a very small quantity of phosphate of iron and of copper, it is obvious that the mineral is composed of

1 atom arsenic acid,
1 atom peroxide of iron,
3½ atoms water.

It is therefore a hydrous subsesquiarseniate of iron.

Sp. 10. *Arseniate of Iron.*

This mineral occurs at Antonio Pareira, Villa Rica, in Brazil, and at Loaysa, near Marmato, in Popayan. In the first of these places it occurs in small cavities, in a siliceous perhydrate of iron, which in the neighbourhood of these cavities contains arseniate of iron.

It occurs in small porous masses of a very pale colour; powder white. When triturated with a caustic alkaline ley, it assumes the colour of rust.

It is crystallized, but so irregularly that it has not been possible to determine the form. Berzelius observed prisms terminated by four-sided prisms with square bases.

When heated in a glass tube it gives out water without any evolution of arsenious acid. When heated before the blowpipe it becomes yellow without altering its form.

We have two analyses of this mineral which giveus its constituents as follow:

	*	†
Arsenic acid,	50·78	49·6
Peroxide of iron,	34·85	34·3
Oxide of lead,	—	0·4
Arseniate of alumina,	0·67	—
Water,	15·55	16·9
	101·85	101·2

These two analyses approach very closely to each other. As both indicate an excess it is probable that at least a part of the oxide of iron is in the state of protoxide. The mean of the two analyses gives us:

		Atoms.
Arsenic acid,	50·19	6·47
Peroxide of iron,	34·57	6·91
Water,	16·22	14·41

It is obviously composed of

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* Berzelius, Kong. Vet. Acad. Handl., 1824, p. 350.

† Boussingault. Ann. de Chim. et de Phys., xli. 75.

1 atom arsenic acid,
1 atom peroxide of iron,
2 atoms water.

If we admit, with Berzelius, that one-third of the iron is in the state of protoxide, it will follow that the mineral is a compound of

1 atom arseniate of iron,
2 atoms arseniated peroxide of iron,
6 atoms water.

Sp. 11. *Hydrous Disilicate of Iron.*

Sideroschisolite.

This mineral is found at Conghonas do Campo, in Brazil, and was sent to Germany by M. Olfers, during his residence in Brazil. It was described and analyzed by Dr. Wernekink. It occurs in cavities of magnetic pyrites and sparry iron ore in small crystals; usually in crystals.

Colour pure velvet black; powder leek-green.

Crystals very small, almost microscopic. A few occur about half a line in length. They are tetrahedrons, or sometimes hexahedral pyramids. Cleave parallel to the faces of these forms.

Lustre specular splendent.

Opaque.

Hardness 2·5; specific gravity 3.

The crystals fuse very easily before the blowpipe to an iron-black bead attracted by the magnet.

When the fragments are exposed to the flame of a candle they instantly lose their velvet-black colour, become iron-black, and are strongly attracted by the magnet.

The mineral, when in powder, dissolves completely in muriatic acid. The solution is greenish-yellow. When heated in a glass tube pure water is given out to the amount of 7·3 per cent.

The constituents, according to Wernekink's[*] analysis, are:

		Atoms.
Silica, . .	16·3 .	8·15
Protoxide of iron,	75·5 .	16·77
Alumina, .	4·1 .	1·82
Water, . .	7·3 .	6·48
	103·2	

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[*] Poggendorf's Annalen, i. 387.

If we allow the alumina to be accidental, it is obvious that the mineral is a compound of

1 atom silica,
2 atoms protoxide of iron,
$\frac{3}{4}$ atom water.

It is therefore a hydrous disilicate of iron. The small excess of protoxide of iron was probably in combination with the alumina.

Sp. 12. *Chamoisite.*

This mineral occurs in beds of small extent at Chamoisin, in the Valaïs. These beds are thick and numerous and occur in a limestone mountain abounding in ammonites, and probably therefore belonging to the lias formation. It was described and analyzed by Berthier.

Colour dark greenish-grey; powder light greenish-grey.

Fracture unequal; sometimes granular, sometimes earthy.

Magnetic, but less so than magnetic iron ore; opaque.

Hard, but easily scratched by steel.

Specific gravity from 3 to 3·4.

When heated in close vessels it gives out water and becomes black; heated in the open air it becomes ochre-red, and loses less weight than in close vessels, because it absorbs oxygen.

It dissolves in acids with effervescence, owing to a mixture of limestone. There remains a jelly, which is silica coloured by a combustible matter.

Its constituents, by Berthier's* analysis, are:

		Atoms.	
Silica, . . .	12 .	6 .	1
Protoxide of iron, .	50·5 .	11·22 .	1·87
Alumina, . .	6·6 .	2·9 .	0·48
Water and bitumen,	14·7 .	13·06 ·	2·17
Carbonate of lime, .	14·4		
Carbonate of magnesia,	1·2		
	99·4		

Probably the alumina and a small portion of the silica are accidental, as well as the carbonates of lime and magnesia. The mineral is obviously a compound of

1 atom silica,
2 atoms protoxide of iron,
2 atoms water.

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* Ann. des Mines, v. 393.

It is therefore a bihydrous disilicate of iron, and differs from the last species by containing twice as much water.

Sp. 13. *Anhydrous Silicate of Iron.*

This mineral was discovered in Slavcarrach, one of the Morne mountains, in the North of Ireland, by Mr. Doran. I ascertained its nature by analysis.

Colour dark brown, with something of the metallic lustre.

Texture foliated, and breaks into four-sided prisms, seemingly right, but the summit is very obscure.

Strongly attracted by the magnet, but without polarity; opaque; easily frangible.

Hardness 4; specific gravity 3·8846.

When heated gives out vapour containing ammonia and loses 1·97 per cent. of its weight.

Infusible per se before the blowpipe. In the reducing flame acquires the metallic lustre and the appearance of magnetic ironstone.

Dissolves in muriatic acid leaving silica.

Its constituents (abstracting the moisture) are

		Atoms.
Silica,	29·6	14·8
Protoxide of iron,	68·73	15·27
Protoxide of manganese,	1·78	0·39
	100·11	

It is obviously composed of

1 atom silica,
1 atom protoxide of iron.

Hence if we neglect the manganese as accidental it is an anhydrous silicate of iron.

Sp. 14. *Hydrous Silicate* or *Cronstedtite.*

This mineral was observed about the year 1818 at Przibram, in Bohemia, and was considered at first as a tourmalin. It was described by Zippe, and analyzed by Professor Steinmann in 1821, who gave it the name of Cronstedtite.[*]

Colour brownish black; streak dark leek green.

Massive, reniform, and crystallized in regular six-sided prisms.

Foliated; cleavage perpendicular to the axis of the prism

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[*] Schweigger's Jahrbuch, ii. 69.

distinct; the cleavages parallel to the faces of the prism less distinct.

Lustre vitreous; opaque.

Not brittle; thin laminæ elastic.

Hardness 2·5; specific gravity 3·348.

Before the blowpipe it froths a little without melting. With borax it yields a black opaque and hard bead.

When in powder it gelatinizes in concentrated muriatic acid.

Not attracted by the magnet even when in powder.

Its constituents, by Steinmann's analysis, are

			Mean.	Atoms.	
Silica, . .	22·83	22·452	22·614	11·307	1
Protoxide of iron, .	57·61	58·853	58·231	12·94	1·14
Protoxide of manganese,	3·82	2·885	3·352	0·74	0·06
Magnesia, . .	3·25	5·078	4·164	1·66	0·14
Water, . .	10·70	10·700	10·700	9·51	0·84
	98·21	99·968			

These numbers, if we neglect the small quantity of magnesia and manganese present approach pretty nearly to

1 atom silica,
1 atom protoxide of iron,
1 atom water.

The mineral is therefore a hydrous silicate of iron.

Sp. 15. *Hedenbergite.*

Bihydrous bisesquisilicate of iron.

This mineral occurs in an opening called Marmorsgrufvan, near the copper work at Tunaberg, in Södermanland. It is usually accompanied by calcareous spar, thin layers of which are frequently interspersed between the plates of the mineral. It was first described and analyzed by Hedenberg in 1807.* Hence the name Hedenbergite given to it by Berzelius.

Colour greenish black; sometimes dark green, passing into brown; streak olive green; powder olive green inclining to brown.

Massive, but composed of shining plates. These by cleavage yield rhomboids, having nearly the same angles as calcareous spar.

* Afhandlingar, ii. 164.

Fracture fibrous; opaque.

Hardness 3·5; specific gravity 3·154.

It does not become electric either by heat or friction, but it phosphoresces.

Before the blowpipe it splits, loses its lustre, becomes black, and is attracted by the magnet; does not melt per se. With borax it fuses with effervesence. The bead is at first yellow, it becomes brown, and at last black and opaque. When a little saltpetre is added it acquires a purple colour, indicating the presence of manganese. With biphosphate of soda it fuses into a green bead, which in the oxidizing flame becomes dark red. The colour is destroyed by the reducing flame, but again restored by the oxidizing flame. With carbonate of soda it fuses into a dark green mass, which blackens in a higher temperature.

Its constituents, by Hedenberg's analysis, are

			Atoms.
Carbonic acid,	1·56	0·56	0·07
Silica,	40·62	20·31	2·59
Protoxide of iron,	35·25	7·83	1
Protoxide of manganese,	0·75	0·16	0·02
Lime,	3·37	0·96	0·12
Alumina,	0·37	0·16	0·02
Water,	16·05	14·26	1·83
	97·97		

The mineral contained a little carbonate of lime. Probably the alumina and manganese were accidental. Omitting these substances as inconsiderable, it is evident that the constitution of Hedenbergite is

2½ atoms silica,
1 atom protoxide of iron,
2 atoms water.

It is therefore a hydrous bisesquisilicate of iron.

Sect. 16. *Chloropal.*

This mineral was first found near Unghwar, in Hungary, along with the opal. It was sent by Joseph Jonas, keeper of the Hungarian Museum, to Professor Bernhardi of Erfurt. It was described and analyzed in 1822 by Bernhardi and Brandes.* These gentlemen gave it the name of *chloropal*,

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* Schweigger's Jahrbuch, v. 29.

from its greenish yellow colour, and its association with the opal. Since that time specimens of it have been brought from the island of Ceylon.

Colour greenish yellow and pistachio green.

Massive; composition impalpable, earthy; fracture conchoidal, passing into earthy.

Opaque, or scarcely translucent on the edges; fragile.

Hardness 3·5; specific gravity of a conchoidal specimen 2·000; of the earthy varieties from 1·727 to 1·870. I found that of the Ceylon chloropal 2·105. It has a conchoidal fracture.

It is remarkable for a curious magnetic property. When taken from its original repository it breaks pretty readily into a kind of parallelopiped, the upper end and two adjoining lateral edges of which have the opposite magnetic pole from the lower end and the other two edges.*

Infusible before the blowpipe, but becomes black and quite opaque. With carbonate of soda it melts into a clear glass exhibiting some red points. With borax it fuses into a dark green glass having no red points.

Its constituents are as follow :—

	†	†	‡	Atoms.
Silica, . . .	46	45	53	26·5
Protoxide of iron, .	33	32	—	—
Peroxide of iron, .	—	—	26·04	5·21
Magnesia, . .	2	2	1·4	0·56
Alumina, . . .	1	0·75	1·8	0·8
Water, . . .	18	20	18	16
	100	99·75	100·24	

Bernhardi and Brandes found traces of potash and manganese, while I found a trace of lime in the minerals examined.

The two varieties do not agree in their chemical constitution. The Ceylon variety is composed of

5 atoms silica.
1 atom peroxide of iron,
3 atoms water.

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* I could not succeed in verifying this property with the Ceylon variety.

† Bernhardi and Brandes. The first specimen was conchoidal, the second earthy chloropal.

‡ By my analysis. The specimen was a conchoidal chloropal from Ceylon.

while the Hungarian variety is composed of

3 atoms silica,
1 atom protoxide of iron,
2 atoms water.

The first is a quintosilicated peroxide, while the second is a tersilicated protoxide of iron. This last, of course, must be considered as the type of the species. The Ceylon variety obviously constitutes a new species, which would require to be distinguished by a new name.

Sp. 17. *Titaniate of Iron.*

Gregorite; menachanite.

This mineral was first observed mixed with quartz sand in the bed of a rivulet which turned Trigonwell mill, near Menaccan, in the parish of St. Keverne, Cornwall. More recently in a stream near the house of Colonel Sandys, at Lanorth, in the same parish. It has been found also at Botany Bay, in New South Wales, and on the shore of the isle of Siecles, near Brittany, as is obvious from the analysis of the grains by Berthier.*

Colour greyish-black.

Occurs in small angular grains, which are imperfectly lamellar.

Fracture fine grained uneven.

Lustre glistening, between adamantine and metallic.

Opaque; yields to the knife.

Specific gravity 4·427.

The pure grains are not attracted by the magnet, but the ore is mixed with numerous magnetic grains, which are obviously iron sand.

Before the blowpipe it does not decrepitate nor melt; does not fuse with biphosphate of soda, but communicates a green colour, which becomes brown when the salt cools; fuses with borax and produces the same colour.

The constituents, by the analysis of picked grains by Dr. H. Colquhoun, in my laboratory, are as follow:

		Atoms.
Titanic acid,	57·187	10·89
Protoxide of iron,	39·780	8·84
Protoxide of manganese,	2·175	0·48
	99·142	

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* Ann. des Mines, v. 477.

If we include the oxide of manganese with that of iron, it is obvious that the constitution of the mineral is

1 atom titanic acid,
1 atom protoxide of iron.

The slight excess of the titanic acid is doubtless owing to the difficulty of freeing it completely from iron.

Sp. 18. *Iserine.*

This mineral was first found on the Riesengebirge near the origin of the stream called Iser, disseminated in granite sand, and in alluvial soil along with pyrope in Bohemia. It has been observed also in the sand of the river Don, in Aberdeenshire, in the sand of the Mersey, on the coast of Cheshire opposite Liverpool.

Colour greyish-black, inclining to iron-black.

In very small flattish-angular grains, which have a rough glimmering surface.

Cleavage seemingly conchoidal.

Opaque.

Brittle and easily frangible.

Lustre semimetallic.

Slightly attracted by the magnet.

Specific gravity, by my trials, 4·491. According to Klaproth it varies from 4·5 to 4·650.

Before the blowpipe it melts into a blackish-brown glass, which is slightly attracted by the magnet.

Its constituents, as determined by the analysis of M. H. Rose,* are:

			Atoms.
Titanic acid,	50·12	9·54	1
Protoxide of iron,	49·88	11·08	1·16
	100·00		

It therefore approaches very near to menachanite in its properties, and is probably merely a variety of that species.

Sp. 19. *Subsesquititaniate of Iron.*

This mineral appears to exist in great abundance in Brazil, where, according to M. Montlevade, it constitutes mountains or very thick banks extending a great way, and alternating with transition rocks.

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* Ann. des Mines, xii. 301.

Colour deep grey.

In compact masses, having a great tendency to divide into rhomboidal fragments.

Fracture granular, almost compact, with fine grains a little scaly.

Little or no lustre.

Full of fissures containing a pellicle of reddish-brown mica, also veins of quartz.

Opaque.

Neither its hardness nor specific gravity are noticed.

Attacked by aqua regia, which dissolves the iron.

Its constituents, according to Berthier's analysis,* are :

		Atoms.	
Titanic acid,	41	7·84	1
Peroxide of iron,	56·2	11·24	1·43
Quartz,	2·5	1·25	
Oxide of manganese,	trace		
	99·7		

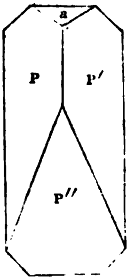
The constitution is evidently

1 atom titanic acid,
$1\frac{1}{2}$ atom peroxide of iron.

It is therefore a subsesquititaniated peroxide of iron.

Sp. 20. *Crightonite.*

This mineral was discovered by Count Bournon, in 1788; but he made it known to mineralogists only in 1813, in his *Catalogue of his collection.* It was discovered in the cavities of veins in the primary rocks of the Alps in Dauphiné, in the department of the Isere, near the town of Visans. The veins are composed principally of felspar and quartz. They contain also chlorite and anatase.



Colour black.

Always in crystals. They are very small, and have the form of acute rhomboids, having the summits replaced, and being otherwise variously modified by secondary planes.

P on P′	61° 20′
P or P on P″	118° 45′
P or P′ on a	97° 12′
P″ on a	83° 20′

by the measurement of Mr. W. Phillips. The

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* Ann. des Mines, v. 479.

only cleavage observed is parallel to the face a.

Lustre shining and semimetallic.

Brittle and easily frangible.

Has a harsh feel.

Hardness about 4·25; specific gravity not under 3.[*]

Fracture uneven, passing into conchoidal.

Before the blowpipe it fuses into a greyish-black enamel, having something of the metallic lustre. When this enamel is reduced to powder, it is slightly attracted by the magnet. In borax it dissolves with effervescence into a brownish-green glass. It fuses also with carbonate of soda, and forms a black opaque bead.

It has not been analyzed, but from the behaviour before the blowpipe it contains titanic acid and iron.

Sp. 21. *Nigrin.*

This mineral occurs at Ohlapian, in Transylvania, and was first described and analyzed by Klaproth.[†] It is said also to have been met with in the Uralian mountains, and in Ceylon.

Colour greyish-black, passing into brownish-red; powder greyish-brown.

It occurs in flat rounded grains about the size of a pea, with here and there slight indications of a crystalline form.

Foliated.

Lustre metallic.

Very hard; brittle.

Specific gravity 4·445.

Before the blowpipe per se experiences very little alteration.

Its constituents, according to the analysis of Klaproth, are:

		Atoms.	
Titanic acid,	84	16	5·14
Protoxide of iron,	14	3·11	1
Protoxide of manganese,	2	0·44	0·14
	100		

These numbers approach very nearly to

5 atoms titanic acid,

1 atom protoxide of iron.

It is therefore a *quintotitaniate of Iron.*

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[*] Cordier, Ann. des Mines, iii. 451.

[†] Beitrage ii. 235.

Sp. 22. *Oxalate of Iron.*

Humboldtine. Eisen resin of Breithaupt.

This mineral was discovered by Breithaupt in the Moor coal of Bohemia. He called it *iron resin*, from its appearance, and *mellate of iron* from its supposed composition. It was analyzed by M. Mariano de Rivero, who ascertained it to be oxalate of iron.*

Colour yellow.

Occurs in small flat pieces, consisting of a congeries of crystals, but so irregular that their shape cannot be made out.

Soft enough to be scratched by the nail.

Specific gravity, by my trials, 2·489.

When insulated and rubbed, it acquires negative electricity.

Easily decomposed by heat.

Insoluble in water and alcohol, but easily dissolved by acids. It is decomposed by ammonia, and the ammoniacal solution shoots into crystals of oxalate of ammonia.

According to Mariano de Rivero, it is composed of

		Atoms.
Oxalic acid, . .	46·14 .	10·25
Protoxide of iron, .	53·86 .	11·96
	100·00	

It is much more probable that the salt is a compound of 1 atom of oxalic acid, and 1 atom of protoxide of iron, or of equal weights of each. But it is not quite clear whether Rivero's numbers are derived from analysis, or from calculation founded on erroneous atomic quantities. I have reason to believe that Rivero has been too hasty in his conclusion, that the acid in this mineral is the oxalic. I got a small specimen of it in the summer of 1834, from Dr. Bondie of Dresden, and I requested my nephew, Dr. R. D. Thomson, to examine it. He obtained from 100 of the mineral,

Peroxide of iron, .	53·31
Alumina, . .	6·34
Lime, . . .	0·70
Magnesia, . .	0·60
Silica, . . .	0·50
	61·45

and 40 per cent. of weight was lost by ignition.

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* Ann. de Chim. et de Phys. xviii. 207.

On digesting the mineral with carbonate of ammonia and carbonate of soda, an acid in both cases combined with the alkalies. The compound with ammonia gave needles; but the quantity obtained was very small, and the salt obtained did not precipitate lime from the muriate. It was therefore not oxalic acid. The trials I made upon it, led me to infer that it was a new acid, but the quantity of the mineral in my possession was so small, that I was unable to investigate its properties in a satisfactory manner. It would be worth the attention of any chemist who possesses a sufficient quantity of the mineral. He would in all probability discover a new acid.

2. *Double Oxygen Salts.*

These are already pretty numerous, and doubtless more will be discovered as the chemical examination of ferruginous minerals is prosecuted.

Sp. 1. *Hydrous Carbonate of Iron.*

This mineral is not uncommon in lead mines at Alston Moor, where it goes by the name of *brownspar.*

Colour a dirty blackish brown; streak brown.

Consists of a congeries of small irregular rhomboids with curve faces, and entangled in each other.

Lustre pearly, nearly dull.

Opaque; rather brittle.

Hardness 3·25; specific gravity 3·404.

The crystals in the specimen examined were attached to a thin crust of brown matter, having a pearly and splendent lustre, and composed of the same constituents with the crystals, but not altered as they had been by exposure to the weather.

This mineral, by my analysis, was composed of

		Atoms.
Carbonic acid, .	18·5	. 6·72
Protoxide of iron, .	30·27	. 6·72
Peroxide of iron, .	37·65	. 7·53
Protoxide of manganese,	4·75	. 1·05
Water, . .	8·30	. 7·37
	99·47	

The carbonic acid was doubtless united to the protoxide of iron, and the peroxide to the water. The mineral consists very nearly of

8 atoms carbonate of iron.
9 atoms hydrated peroxide of iron.

I think it not unlikely that the mineral at first was a pure carbonate of iron; but that by exposure to the weather, a portion of the iron had been peroxidized, and lost in consequence its carbonic acid, which was replaced by an equivalent quantity of water.

Sp. 2. *Magnesia-Carbonate of Iron.*

Many specimens of what is usually called *sparry iron* ore, or carbonate of iron, contain also definite quantities of carbonate of magnesia.

This is the case with the sparry iron ore of Grande Fosse, near Vizille.

Colour light yellow.

Texture foliated and divisible into large rhomboids. Its constituents, determined by Berthier,[*] are

		Atoms.
Protoxide of iron,	43·6	9·68
Protoxide of manganese,	1·0	0·22
Magnesia,	12·8	5·12
Carbonic acid,	42·6	15·49
	100·0	

These numbers approach pretty nearly to
2 atoms carbonate of iron,
1 atom carbonate of magnesia.

The same carbonates united in various other proportions, may be seen in Berthier's analyses of sparry iron ore.[†] It is not unlikely, therefore, that such minerals are better entitled to rank as mixtures than peculiar species. This is the reason why I only notice them here.[‡]

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[*] Ann. des Mines (2d series), iii. 30.

[†] Ibid.

[‡] Doubtless the *breunnerite* of Mohs, which from the analysis of Stromeyer, appears to consist of
11 atoms carbonate of magnesia,
1 atom carbonate of iron and manganese,
is also a mixture, and stands nearly at the opposite extremity of the scale from the salt noticed in the text. It has a yellowish brown colour. Crystal rhomboids of 107° 22′. Specific gravity 3·1; hardness 4·25; lustre vitreous. Found in Rothen Kopf in the Zillerthal, Tyrol, imbedded in chloride slate.

Sp. 3. *Manganeso-Diphosphate of Iron.*

Pitchy iron ore. Ferruginous phosphate of iron.

This mineral was discovered by Alluau, near Limoges in France, in a vein of quartz traversing granite.

Colour blackish brown; streak yellowish grey.

Massive; cleavage in three directions perpendicular to each other. Hence the primary form must be a cube, or a right rectangular prism.

Fracture small conchoidal.

Translucent on the edges, or opaque.

Lustre resinous, inclining to adamantine; brittle.

Hardness 5 to 5·5; specific gravity, as determined by Breithaupt, 3·562. Vauquelin found it 3·439.

Before the blowpipe it melts easily into a black scoria.

Dissolves readily in nitric acid without effervescence.

Its constituents, by Berzelius's analysis,* are

		Atoms.
Phosphoric acid,	32·8	7·28
Protoxide of iron,	31·9	7·08
Protoxide of manganese,	32·6	7·24
Phosphate of lime,	3·2	
	100·5	

Leaving out the phosphate of lime as accidental, the constituents are

1 atom phosphoric acid,
1 atom protoxide of iron,
1 atom protoxide of manganese.

Hence the constitution of the mineral must be

1 atom diphosphate of iron,
1 atom diphosphate of manganese.

Sp. 4. *Alumina-Sulphate of Iron.*

This salt occurred some years ago abundantly in the shale of the wrought out coal beds, at Hurlet and Campsie, near Glasgow.

Colour snow-white.

In fine needles about an inch long, having some breadth, but no sensible thickness.

Taste sweet and astringent. Soluble in water. When heated loses water and becomes red. The constituents are as follows:

* Ann. des Mines, v. 234.

	*	†	‡	‡
Sulphuric acid, . .	34·4	30·9	35·600	28·635
Protoxide of iron, .	12·0	20·7	13·560	19·935
Alumina, . . .	8·8	5·2	7·127	2·850
Magnesia, . .	0·8	—	—	—
Water, . . .	44·0	43·2	43·713	48·580
	100·0	100	100	100

The difference between these results shows clearly, that the mineral varies a little in its composition.

The analyses of my nephew, which were made with great care, but the last of the two upon the purest specimen, give

1st.		2d.
2½ atoms sulphuric acid,	and	5·72 atoms acid,
1 atom protoxide of iron,		4·43 atoms protoxide of iron,
1 atom alumina,	.	1·26 atoms alumina,
13 atoms water,	.	43·18 atoms water.

The second of these analyses, which was on the purest specimen, gives us

3½ atoms sulphate of iron,
1 atom sulphate of alumina,
34 atoms water.

The water is equivalent to 7½ atoms, for each atom of salt in the compound, which exceed the water of crystallization of these salts when separate.

Sp. 5. *Hetopizite.*

This mineral occurs at Hureaux, in the commune of St. Sylvestre, Haute Vienne. It was first noticed by M. Alluau, who sent a specimen of it to Vauquelin for analysis. It has been described and analyzed by M. Dufresnoy.§

Colour greyish-green, with a shade of blue; but by exposure to the air it becomes violet, and acquires a semimetallic lustre.

Primary form of the crystal, derived from cleavage, a rhomboidal prism, with angles of about 100° and 80°. Occurs usually in foliated masses, which have a three-fold cleavage.

Scratches glass, but not quartz; lustre vitreous.

Specific gravity 3·524; after it has been altered by exposure it is reduced to 3·390. Soluble in acids.

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* Berthier, Ann. des Mines, v. 259.

† Phillips, Annals of Philosophy (2d series), v. 446.

‡ Analyzed in my laboratory by Dr. R. D. Thomson.

§ Ann. de Chim. et de Phys., xli. 342.

Before the blowpipe fuses into a brown enamel, with a semimetallic lustre.

Its constituents, by the analysis of Dufresnoy, are

		Atoms.
Phosphoric acid,	41·777	9·28
Protoxide of iron,	35·000	7·77
Protoxide of manganese,	16·180	3·58
Moisture,	4·40	3·9
Silica,	2·2	1·1
	99·557	

The constituents are obviously

2 atoms phosphate of iron,
1 atom diphosphate of manganese,
1 atom water.

The formula is $2f\dot{P}h+mn^2 Ph+Aq$.

Sp. 6. *Carbono-phosphate of Iron.*

This mineral occurs in beds in the Jura limestone at Vignes, west from Hayange, and is employed by the iron smelters on the Moselle. It was described and analyzed in 1827, by M. Karsten.*

Colour deep greenish-blue, and not unlike chamoisite in appearance, though quite different from that mineral in its constitution. Powder deep greenish-blue.

Texture oolitic. The grains not larger than a millet seed.

Magnetic. Specific gravity 3·71.

Dissolves slowly and with effervescence in muriatic acid; an insoluble residue of silica remains, which does not gelatinize, and therefore could not have been in combination with the iron, but only accidentally present.

The constituents, by Karsten's analysis, are

		Atoms.	
Peroxide of iron,	41·120	8·22	10·96
Protoxide of iron,	29·980	6·66	8·86
Carbonic acid,	11·873	4·31	5·74
Phosphoric acid,	3·380	0·75	1
Lime,	2·140		
Magnesia,	0·775		
Water,	2·900		
Silica,	6·990		
	99·158		

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* Ann. des Mines (second series), iii. 253.

It is pretty obvious that all the constituents, except the four first, are impurities. The carbonic acid must have been in combination with protoxide of iron. The phosphoric acid was probably in combination with peroxide of iron, in the state of diphosphate. If these suppositions be admitted, we have

5·74 atoms carbonate of iron,
1 atom diphosphate
3·14 atoms protoxide of iron,
8·88 atoms peroxide of iron,

This approaches

6 atoms carbonate of iron,
1 atom diphosphate of iron,
3 atoms of a compound of $\left\{\begin{array}{l}\text{1 atom protoxide}\\ \text{3 atoms peroxide}\end{array}\right\}$ of iron.

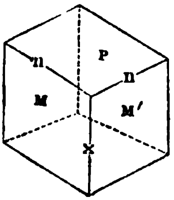
But in all probability the ore is rather a mechanical mixture, than a chemical compound.

Sp. 7. *Scorodite.*

Martial arseniate of copper—diarsenite of iron.

This mineral was first observed in Tincroft mine, Cornwall, and from Chenevix's analysis was considered as an arseniate of copper, combined with oxide of iron.* It was afterwards found in the primary mountains at Schwartzenberg, in Saxony, and was described by Breithaupt under the name of scorodite.†

Colour leek-green, which passes into white, into olive-green, and into liver-brown. The Cornish variety is pale sky-blue; streak white.



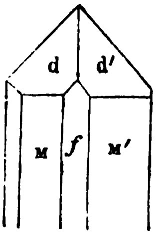
In crystals. Primary form a right rhombic prism,

M on M' 120°

But most commonly it is modified as in the margin, by the edges n, n, x being replaced by the planes d, d', f.

M on d or M' on d' 141° 26'
d on d' 103°
M or M' on *f* 149° 55'

So that *f* is a tangent plane.



Fracture uneven.

Lustre vitreous, inclining to adamantine on the surface, and to resinous in the interior.

Translucent on the edges, to semitransparent; rather brittle.

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* Phil. Trans., 1801, pp. 191, 218.

† From σκοροδον, *garlick.*

Hardness 3·5 to 4; specific gravity, according to Bournon, 3·4; according to Haidinger it varies from 3·162 to 3·3.

Before the blowpipe it emits an arsenical odour, and melts into a reddish-brown scoria, which acts on the magnet, if the arsenic has been driven off.

According to the analysis of Ficinus, its constituents are

		Atoms.
Arsenious acid,	31·4	6·61
Sulphuric acid,	1·54	0·31
Protoxide of iron,	36·25	8·05
Protoxide of manganese,	4·00	0·89
Lime,	2	0·57
Magnesia,	2	0·8
Water,	18	16·0
Gangue,	1·4	
	96·59	

In another analysis the amount of the oxides of iron and manganese, with the lime and magnesia, was 47·8 per cent., but he did not determine the proportions of each.*

If we pay no attention to the quantity wanting to complete the weight employed in the analysis, it is obvious that scorodite is a subsesquiarsenite of iron, with a little subsesquiarsenite of manganese, lime, and magnesia, and a very little sulphate of lime. The constituents are

4 atoms subsesquiarsenite of iron,
1 atom subsesquiarsenite of manganese, lime, and magnesia, with a trace of sulphate of lime.

Sp. 8. *Cacoxenite.*†

Childrenite.

This mineral was found in an iron mine at Hrbetk, in Bohemia. The iron ore is clay ironstone, which occurs in the coal formation. The cacoxenite occurs in tufts upon the surface of the stone in small veins, and bears a striking resemblance to karpholite.

Colour dull yellow; lustre silky; streak yellowish-red.

Composed of small crystals in tufts. Its specific gravity, as determined by Mr. Richardson, is 2·336; soft; sectile.

Heated alone in a glass tube gives off water, but no fluoric acid, and the colour changes to a dark red brown. Before the blowpipe alone on charcoal suffers no change except the colour becoming dark red brown. On platinum wire, with carbonate of soda, does not fuse. With borax fuses readily into a dark

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* Schweigger's Jahrbuch, iv. 198.

† From κακος, *bad*, and ξενος, a guest; because its presence is injurious to iron ore.

red-coloured bead, quite transparent in the oxidizing flame, which changes to yellow in the reducing flame; with salt of phosphorous, in the oxidizing flame, fuses into a yellow transparent bead, which does not change in the reducing flame.

Its constituents, according to the analysis of Professor Steinmann, of Prague, are

		Atoms.	
Silica,	8·90	4·42	1·11
Phosphoric acid,	17·86	3·96	1
Alumina,	10·01	4·44	1·11
Peroxide of iron,	36·32	7·26	1·83
Lime,	0·15	—	—
Water & fluoric acid,	25·95	23	5·8
	99·19		

But Mr. Richardson made a very careful analysis of it in my laboratory, and obtained

		Atoms.
Phosphoric acid,	20·5	1
Peroxide of iron,	43·1	1·89
Lime,	1·1	0·07
Magnesia,	0·9	0·08
Silica,	2·1	0·25
Oxide of manganese,	trace	—
Water,	30·2	5·99
	97·9	

It is therefore a diphosphated peroxide of iron, contining 6 atoms of water. The silica, alumina, &c., found by Steinmann, must have been impurities.

Sp. 9. *Sulpharseniate of Iron.*

Eisensinter, pittizite, pitchy iron ore.

This mineral was first described by Karsten, and analyzed by Klaproth. Stromeyer thinks that it is derived from the decomposition of mispickel; because in those parts of Saxony where it occurs, mispickel is abundant. It was first found in a mine near Freyberg; more lately in the district of Pless, in Upper Silesia, and in Britanny.

Colour blackish-brown, or greyish-black; streak lemon yellow. Massive, or incrusting other minerals;* fracture flat conchoidal, or fine grained; lustre resinous, shining, or glistening; translucent, at least on the edges; easily scratched by the knife; brittle; specific gravity, as determined by Karsten, 2·40.

Its constituents, according to the analysis of Stromeyer,† are

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* Count Bournon, in his *Catalogue*, describes a pitchy iron ore as occurring in rectangular prisms, either perfect or with two opposite angles replaced so as to convert the prism into an octahedron.

† Untersuchungen, p. 244.

			Atoms.
Arsenic acid, .	26·0591	. 3·59	. 1·73
Sulphuric acid, .	10·0381	. 2·07	. 1
Peroxide of iron, .	33·0960	. 6·62	. 3·19
Sesquioxide of manganese,	0·6417	. 0·13	
Water, . .	29·2556	. 26	. 12·5
	99·0105		

These numbers correspond with

1¾ atom arseniated peroxide of iron,
1 atom subsesquisulphated peroxide of iron,
12½ atoms water.

Sp. 10. *Thraulite.*

Hisingerite, hydrous sesquisilicate of iron.

This mineral occurs at Riddarhyttan, in Westmanland, and at Bodenmais, in Germany. It was first described and analyzed by Hisinger.[*] The variety from Bodenmais was afterwards analyzed by Professor Kobell[†] of München, who distinguished it by the name of *thraulite.*[‡]

Colour black; powder brownish yellow.

Occurs in roundish nodules an inch or more in diameter. No regular form has been observed.

Fracture uneven, or imperfect conchoidal. Splendent; opaque. Brittle; not particularly heavy.

When heated in a glass tube it gives out water; before the blowpipe it shows some symptoms of fusion, the edges being rounded; but the lustre and appearance of the fragment is not altered; after ignition it is strongly attracted by the magnet.

The constituents, according to the analyses of Hisinger and Kobell, are as follow:—

	§	§	‖	Atoms.	
Silica, . .	36·30	31·775	31·28	15·64	1·53
Peroxide of iron,	44·39	49·869	50·86	10·17	1
Water, . .	20·70	—	19·12	17	1·67
	101·39		101·26		

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[*] Poggendorf's Annalen, xiii. 505.

[†] Ibid. xiv. 467.

[‡] From θραυλος, easily frangible.

[§] Hisinger. The first specimen was from Ridderhyttan, the second from Bodenmais. Want of a sufficient quantity of the mineral prevented him from determining the water.

[‖] Kobell. The specimen was from Bodenmais.

If we take the analysis of Kobell as our standard, it is obvious that the constitution of the mineral is

$1\frac{1}{3}$ atom silica,
1 atom peroxide of iron,
$1\frac{2}{3}$ atom water.

Hisinger is of opinion, that the oxide of iron is composed of 2 atoms peroxide, and 1 atom protoxide. If that supposition be correct, thraulite consists of

1 atom sesquisilicate of iron,
2 atoms sesquisilicated peroxide of iron,
5 atoms water.

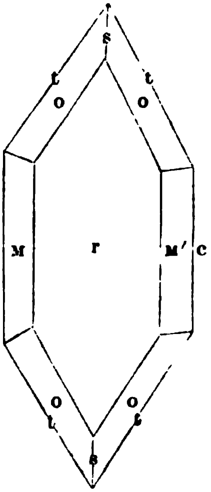
The specimens analyzed were not free from an admixture of magnetic pyrites.

Sp. 11. *Achmite.*[*]

This mineral occurs at Eger, in South Norway, in a quartz ball, in a kind of granite, which Haussmann and Von Buch considered as belonging to the transition class of rocks. It was described by Stromeyer, and analyzed by Berzelius in 1821.[†]

Colour brownish or reddish brown; in the fracture blackish green.

It occurs in crystals, the primary form of which seems to be a right oblique prism M on M′ 86° 56′. But it usually occurs in the form represented in the margin; a six-sided prism terminated by a four-sided pyramid.



The measurements of this crystal by Mitcherlich are as follow:—

M on M′ 86° 56′
M on r 133° 28′
M on e 136° 32′
s on s 35°
s on r 162° 30′
t on t 28° 19′
t on e 165° 15′·5
Edge t 104° 26′
Edge s 80°
o on r 140°

Four cleavages may be observed, two parallel to the faces M, M, and two seemingly to the diagonals of the base.

Fracture from uneven to earthy.

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[*] From ἀκμη, *the point of a sword.* Named from the pointed form of the crystals.

[†] Kong. Vet. Acad. Handl., 1821, p. 160.

Lustre vitreous.

Translucent when in very thin pieces.

Scratches glass; hardness 4; specific gravity, by my trials, 3·398.

Before the blowpipe fuses into a black bead.

Its constituents, by the analyses of Berzelius and Captain Lehunt, are as follows:—

	*	†	Atoms.
Silica,	55·25	52·016	26·01
Protoxide of iron,	31·25	28·080	6·24
Soda,	10·40	13·333	3·44
Protoxide of mangan.,	1·08	3·487	0·77
Lime,	0·72	0·876	0·25
Magnesia,	—	0·504	0·2
Alumina,	—	0·685	0·3
	98·70	98·981	

I am disposed to consider the specimen analyzed by Captain Lehunt as the purest. The analysis was conducted with great care. If we calculate from it, we have

4 atoms bisilicate of iron,

2 atoms tersilicate of soda,

1 atom bisilicates of manganese, lime, magnesia, and alumina.

The formula is $4fS^2+2NS^3+(\frac{1}{6}Al+\frac{1}{6}Mg+\frac{1}{6}Cal+\frac{3}{6}mn)S^2$. Or, if we omit the bisilicates of manganese, lime, magnesia, and alumina, as accidental impurities, achmite will be a compound of

2 atoms bisilicate of iron,
1 atom tersilicate of soda.

Its formula will be $2fS^2+NS^3$.

Sp. 12. *Krokidolite.*

This mineral was found at Orange River, near the Cape of Good Hope, in Southern Africa. The first specimens of it were brought to Europe by Lichtenstein. These were described and analyzed by Klaproth under the name of blue ironstone from the Cape of Good Hope.‡ Specimens of another variety of this mineral from the same place were

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* Berzelius. Ibid. The iron was in the state of peroxide.

† Captain Lehunt. The analysis was twice repeated in my laboratory, and the specimen was exceedingly pure.

‡ Beitrage, vi. 257.

described and analyzed by Haussmann and Stromeyer in 1830.[*] Haussmann gave the mineral the name of *krokidolite*,[†] because he considered the name imposed by Klaproth as not sufficiently free from ambiguity. The variety examined by Klaproth was *compact*, that examined by Haussmann and Stromeyer *asbestiform*.

Colour lavender blue; powder the same.

The compact variety is massive; the asbestiform is composed of fibres or strings about 1·8 inch long, and inclined to each other at angles of 106° and 74°. This fibrous matter constitutes a slaty mass about half a line thick. Between each slate a thin layer of magnetic ironstone is interposed.

Opaque; the fibres possess considerable elasticity.

Hardness 4; specific gravity of both varieties 3·200.

When heated to redness it melts easily into a black, shining, opaque, somewhat frothy glass, which is attracted by the magnet. When single fibres are held in the flame of a spirit lamp they readily melt. This enables us to distinguish this mineral with ease from asbestus.

When heated to fusion in hydrogen gas it forms an iron grey glass full of vesicles, strongly attracted by the magnet, and dissolving in muriatic acid with the evolution of hydrogen gas.

With borax it fuses very readily into a green-coloured transparent bead, which the addition of a little saltpetre renders reddish brown.

The constituents of this mineral are

	‡	§	§	Atoms.
Silica, . . .	50	50·81	51·64	25·6
Protoxide of iron, .	40·5	33·88	34·38	7·57
Protoxide of mangan.,	—	0·17	0·02	—
Magnesia, . .	—	2·32	2·64	—
Lime, . . .	1·5	0·02	0·05	—
Soda, . . .	5	7·03	7·11	1·77
Water, . . .	3	5·58	4·01	4·28
	100	99·81	99·85	

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[*] Poggendorf's Annalen, xxiii. 153.

[†] From κροκις, *woof*, from the texture of the asbestous variety.

[‡] Klaproth, Beitrage, vi. 156. The specimen examined was the compact variety.

[§] Stromeyer, Poggendorf's Annalen, xxiii. 156. Both specimens belonged to the asbestiform variety.

If we adopt the analysis of Stromeyer, because the specimens which he examined were probably the purest, the constitution of krokidolite will be

4 atoms tersilicate of iron,
1 atom sesquisilicate of soda,
2½ atoms water.

Sp. 13. *Chromiron ore.*

Chromate of iron.

This mineral was first observed in the department of the Var in France, near Gassin, in nodules in serpentine. It occurs in the same rock near Nantes, in Styria, in the Uralian mountains, in the islands of Unst and Fellar, two of the Shetlands; at Portsoy, in Banffshire, in the Bare hills, near Baltimore, and in various other parts of the United States.

Colour between iron black and brownish black; streak brown.

Massive and crystallized in regular octahedrons.

Lustre imperfect metallic.

Fracture uneven, imperfect conchoidal.

Opaque; brittle.

Hardness 5·5; specific gravity of the pure crystals 4·321.

Not attracted by the magnet, if pure.

This mineral was analyzed by Vauquelin, Laugier, Klaproth, Seybert, and Berthier;[*] but none of these chemists having employed pure specimens, their results do not agree with each other. I picked out pure octahedrons from specimens from the Bare hills, and obtained by analyzing them, the following constituents:—

Green oxide of chromium,	52·95	10·6
Peroxide of iron,	29·24	5·85
Alumina,	12·22	5·43
White matter,	3·09	
Water,	0·70	
Silica, trace,		
	98·20	

These numbers correspond with

2 atoms green oxide of chromium,
1 atom peroxide of iron,
1 atom alumina.

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[*] See Phil. Trans., 1827, p. 226.

If the green oxide of chromium be considered as acting the part of an acid, we may consider the ore as composed of

1 atom chromite of iron,
1 atom chromite of alumina.*

Sp. 14. *Arfvedsonite.*

This mineral was brought from Kargardluarduk, in Greenland, by Sir Charles Giesecké. It was known by the name of *ferruginous hornblende*, till Mr. Brooke found that the form of its crystals did not agree with that of hornblende. This led him to distinguish it by the name of *Arfvedsonite*.

Colour pure black. On some parts of the edge it has a slight tinge of blue, but none of green.

The specimens which I have seen are in large oblique four-sided prisms without terminations. The angles of the prism, by the measurement of Brooke, are 123° 55′ and 56° 5′; while those of amphibole are 124° 30′ and 55° 30′.

The prism splits easily parallel to its longitudinal faces, and may be obtained in pretty thin plates, but no cleavage can be observed parallel to the base. We are therefore ignorant whether the prism be right or oblique.

Lustre resinous.

Opaque.

Hardness 4·5; specific gravity 3·369. Its constituents, by my analysis, are

		Atoms.
Silica,	50·508	25·25
Peroxide of iron,	35·144	7·03
Sesquiox. of mangan.,	8·920	1·78
Alumina,	2·488	1·10
Lime,	1·560	0·44
Moisture,	0·960	
	99·580	

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* Berthier is of opinion that the silica found in this ore by Vauquelin, by himself, and by some other analists, is essential to the mineral, and endeavours to prove his opinion by the phenomena of the analysis. *Traité des Essais par la voie seche*, ii. 262. I picked out a quantity of octahedrons from the Baltimore ore, in which silica had been found abundantly, and on analyzing them obtained the same constituents as given in the text, with merely a trace of silica. Indeed it would be difficult to conceive the chemical nature of chromium ore, such as it is exhibited by the analyses hitherto made. Earthy matter may be detected by the eye in most specimens of chrome iron ore, and how it could be separated unless pure crystals be picked out, I do not understand.

Omitting the alumina and lime as accidental impurities, the mineral is obviously a compound of

4 atoms tersilicate of iron,
1 atom tersilicate of manganese.

The formula is $4fS^3 + mnS^3$.

Sp. 15. *Knebelite.*

This name was given by Dobereiner to a mineral, a specimen of which he got from Major Von Knebel, but the locality of which is unknown.

Colour grey; spotted dirty white, red, brown, and green.

Massive; external surface uneven and full of holes.

Fracture imperfect conchoidal.

Lustre glistening.

Opaque; hard; brittle.

Specific gravity 3·714.

Infusible per se before the blowpipe, but with borax it melts into a dark olive-green bead.

Its constituents, as determined by Dobereiner, are

		Atoms.
Silica,	32·5	16·25
Protoxide of iron,	32	7·11
Protoxide of manganese,	35	7·77
	99·5	

These numbers approach pretty near

1 atom silicate of iron,
1 atom silicate of manganese.

Sp. 16. *Columbite.*

Tantalite.

The first specimen of this mineral noticed by chemists, is one still in the British Museum, which was analyzed by Mr. Hatchett, and found to contain a new metal, to which he gave the name of *Columbium.* This specimen had been sent to Sir Hans Sloane by Governor Winthrop. The locality was unknown; but Dr. Torrey has detected the mineral in a remarkable rock at Haddam, in New England, and rendered it probable that it was from this place that Mr. Winthrop's specimen had been procured.* The same mineral occurs at Kimito, in Finland; but its nature remained unknown till its

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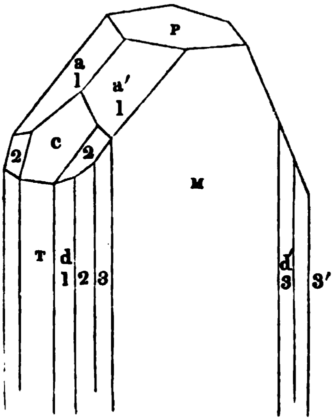
* Annals of Philosophy (second series), viii. 359.

analysis by Ekeberg detected in it the same metal which had been previously discovered by Hatchett, and which he called *tantalum*. It has been found also at Bodenmais, in Bavaria.

Colour iron black, sometimes with a tinge of blue; streak dark brownish black.

It occurs in single crystals and in small crystalline masses. The crystals are mostly incomplete, but present the general form of flat quadrangular prisms striated longitudinally. The primary form appears to be a right rectangular prism. The figure in the margin represents all the secondary faces hitherto observed.



P on T 90°
T on M 90°
P on $\underset{1}{a}$ or $\underset{1}{a'}$ 136° 30′
P on c 120°
T on $\underset{1}{d}$ 156° 30′
T on $\underset{2}{d}$ 114° 30′
T on c 150°

According to the measurement of Mr. W. Phillips.

Fracture imperfect, conchoidal, or uneven.

Lustre imperfect metallic.

Opaque.

Hardness 5·25; specific gravity, as determined by Ekeberg, 7·963. Berzelius found the specific gravity to vary from 7·236 to 7·655.* The specimen analyzed by Nordenskiöld 7·264.

On charcoal it suffers no change before the blowpipe. It is slowly but perfectly fusible with borax.

The constituents of the Finland columbite, according to Berzelius' analysis,† are

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* Afhandlingar, iv. 263 and vi. 238.

† Ibid. iv. 264. Nordenskiöld analyzed another specimen from Tamela. Its constituents were

Columbic acid, .	83·44
Protoxide of iron, .	13·75
Protoxide of manganese,	1·12
Oxide of tin, .	trace
	98·31

We see from this, that the iron may be substituted for the manganese in this mineral. (See Berzelius, Jahresbericht, 1833, p. 190.)

		Atoms.
Columbic acid, .	83·2 .	3·27
Protoxide of iron, .	7·2 .	1·6
Protoxide of manganese,	7·4 .	1·64
Oxide of tin, . .	0·6 .	
	98·4	

These numbers obviously correspond with

1 atom columbate of iron,
1 atom columbate of manganese.

The columbite from Brodbo, also analyzed by Berzelius, was not so pure.

The constituents of Kimito columbite, determined by the same chemist, are

		Atoms.
Columbic acid, .	85·85 .	3·37
Peroxide of iron, .	14·41 .	2·88
Sesquioxide of mangan.,	1·79 .	0·36
Oxide of tin, .	0·80	
Lime, . .	0·56	
Silica, . .	0·72	
	104·13	

Doubtless the iron and manganese in the mineral were in the state of protoxides.

The only difference between this variety and the preceding is, that most of the oxide of manganese is wanting in it. Instead of being a compound of 1 atom columbate of iron, and 1 atom columbate of manganese, this variety is composed of

8 atoms columbate of iron,
1 atom columbate of manganese.

Sp. 17. *Wolfram.*

Scheelate of iron and manganese. Tungstate of iron and manganese.

This ore is a frequent companion of tinstone in veins and beds. It is said also to occur in lead veins traversing greywacke. It is found in almost all the Saxon and Bohemian tin mines, and in many parts of Cornwall. In the Principality of Anhalt, it occurs in veins in greywacke. In the island of Rona it was discovered in a vein of graphic granite in gneiss. It is found likewise in Siberia, and in the United States of America.

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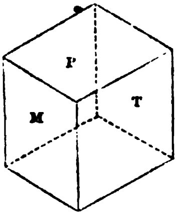
* Afhandlingar, vi. 237.

Colour greyish and brownish black; streak dark brownish black.

It occurs massive and in crystals. The primary form is a right oblique angled prism.

M on T 117° 22′



According to the measurement of Mr. W. Phillips. The edges of the prism are most frequently replaced by faces, which sometimes are so large as nearly to conceal the primary faces of the prism, or at least to reduce them to a very small size.

Texture foliated; fracture uneven.

Lustre imperfect metallic; opaque; not very brittle.

Hardness 5; specific gravity 7·155.

Before the blowpipe decrepitates, but in a sufficiently elevated temperature, may be melted into a globule, whose surface is covered with crystals having the metallic lustre. With borax fuses into a green globule. With biphosphate of soda it melts into a transparent bead having a deep red colour.

Its constituents, according to the best analyses hitherto made, are

	*	†	‡
Tungstic acid,	74·666	73·511	73·60
Protoxide of iron,	17·594	20·745	11·20
Protoxide of manganese,	5·640	5·744	15·75
Silica,	2·100	—	—
	100	100	100·55

The result of Berzelius' analysis gives the following atomic numbers:

Tungstic acid,	4·81
Protoxide of iron,	3·9
Protoxide of manganese,	1·25

These approach pretty nearly

3 atoms tungstate of iron,
1 atom tungstate of manganese.

The specimen analyzed by Mr. Richardson, was a compound of 3 atoms tungstate of iron, and 4 atoms tungstate of manganese.

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* Berzelius, Afhandlingar, iv. 304.

† Vauquelin, Annals of Philosophy (2d series), xi. 330.

‡ Analyzed by Mr. Richardson in my laboratory. The specimen was from Bohemia. Its specific gravity was 7·001.

Sp. 18. *Ilmenite.*

This name has been given to a variety of titaniferous iron ore, brought from Ilmen sea near Minsk, by M. Menge, and deposited in the Royal Mineralogical Museum at Berlin. It was first described by M. G. Rose,* and analyzed by Mosander.†

Colour brownish black; streak black.

Crystallized, and the form of the crystals is the same as that of anhydrous peroxide of iron.

Lustre metallic, shining.

Translucent; brittle.

Slightly magnetic.

Hardness 5·75; specific gravity from 4·766 to 4·808.

Behaviour before the blowpipe similar to that of titaniferous iron ore. When fused with biphosphate of soda in the oxidizing flame, the colour is green as long as it is hot; but on cooling it becomes reddish brown. In the reducing flame it is reddish while hot, but on cooling becomes greenish, and at last almost colourless.

Its constituents, as determined by the analysis of Mosander, are as follows:

			Mean.	Atoms.
Titanic acid, ...	46·92	46·67	46·79	8·94
Peroxide of iron, . . .	10·74	11·71	11·22	2·24
Protoxide of iron, . . .	37·86	35·37	36·61	8·13
Protoxide of manganese, .	2·73	2·39	2·56	1·00
Magnesia, ...	1·14	0·60	0·87	
Lime, ...	—	0·25		
Protoxide of chromium, .	—	0·38		
Silica, ...	—	2·80		
	99·39	100·17		

These numbers approach pretty nearly to
4 atoms titaniate of iron,
1 atom dititaniated peroxide of iron.

Sp. 19. *Titaniferous Iron Ore.*

This mineral seems to have been first observed at Arendal in Norway. It occurs also at Egersund, in the valley of Gastein in Salzburg, in Bohemia, at Maisdon in the department of Loire Inferîeure, in Brazil, in the United States, and

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* Poggendorf's Annalen, ix. 286.

† Kong. Vet. Acad. Handl., 1829, p. 220.

doubtless in many other localities. Its characters are not always the same, and the probability is, that more than one species are at present confounded under the name of *titaniferous iron ore.*

Colour iron grey, but frequently more inclining to white; streak black.

Massive and crystallized. The primary form, according to Mohs, is a rhomboid of 85° 59′.

Texture foliated; fracture conchoidal.

Opaque; brittle.

Lustre imperfect metallic, to perfect metallic.

Hardness 5 to 5·5; specific gravity from 4·488 to 4·787.[*] Berthier found the specific gravity of the titaniferous iron from Maisdon, which is very impure, only 3·65.[†]

Sometimes attracted by the magnet, and sometimes not. The one from Brazil is even possessed of poles.

Before the blowpipe the thin edges are rounded, but it does not fuse. With reagents it behaves as the minerals composed of titanic acid and oxide of iron, already described.

The following table exhibits the constituents of this mineral, according to the best analyses hitherto made:

	‡	‡	‡	§	§	§	‖	¶
Titanic acid,	24·19	23·59	20·41	39·04	42·57	41·08	41·0	9·0
Peroxide of iron,	53·01	58·51	55·23	29·16	23·21	25·93	56·2	44·0
Protoxide of iron,	19·91	13·90	19·48	27·23	29·27	29·04	—	—
Protoxide of mangan.,	—	—	—	0·21	—	—	trace	—
Alumina,	—	—	—	—	—	—	—	3·0
Magnesia,	0·68	1·10	0·73	2·30	1·22	1·94	—	10·0
Lime,	0·33	0·86	0·32	0·96	0·50	0·49	—	—
Oxide of chromium,	—	0·44	—	0·12	0·33	—	—	—
Oxide of tin,	—	—	3·64	—	—	—	—	—
Oxide of cerium,	—	—	—	—	—	0·58	—	—
Silica,	1·17	1·88	0·80	0·81	1·65	0·07	2·5	34·0
	99·29	100·28	100·61	99·33	98·75	99·18	99·7	100

It is obvious at a glance, that the titaniferous iron from Arendal, differs essentially in its composition from that of

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[*] Mosander, Kong. Vet. Acad. Hand., 1829, p. 226.

[†] Memoires de Berthier, i. 158.

[‡] Mosander, Kong. Vet. Acad. Hand., 1829, p. 227. The specimens were from Arendal, and in crystals. The second specimen was not attracted by the magnet, the third was attracted, and the first was a mixture of the two.

[§] Mosander, ibid. p. 228. The specimens were from Egersund, and amorphous.

[‖] Berthier, Ann. des Mines, v. 479. The specimen was from Brazil.

[¶] Berthier, Memoires, i. 158. The specimen was from Maisdon.

Egersund; while this last agrees pretty nearly with that from Brazil.

The mean of the first three analyses (neglecting every constituent except the titanic acid and oxides of iron) gives us

		Atoms.
Titanic acid,	22·73	4·13
Peroxide of iron,	55·58	11·12
Protoxide of iron,	17·76	3·94

Or very nearly

1 atom titanic acid,
3 atoms peroide of iron,
1 atom protoxide of iron.

The mineral then is a tetratitaniate of iron, composed of

3 atoms tetratitaniated peroxide,
1 atom tetratitaniated protoxide.

The mean of the next four analyses gives us

		Atoms.
Titanic acid,	40·92	7·79
Peroxide of iron,	26·1	5·22
Protoxide of iron,	28·51	6·33

These numbers correspond nearly with

7 atoms titanic acid,
5 atoms peroxide of iron,
6 atoms protoxide of iron.

So that the mineral approaches a dititaniate of iron, and must be a compound of

5 atoms dititaniated peroxide,
6 atoms dititaniated protoxide.

The last analysis, if we allow every thing to be impurity except the titanic acid and peroxide of iron, exhibits a compound of

1 atom titanic acid,
5 atoms peroxide of iron.

It is therefore a pentatitaniated peroxide of iron.

Thus the analyses already made indicate at least three distinct species of titaniferous iron ore, and doubtless others will be discovered hereafter.

It is probable that this mineral is rather a double than a simple salt of iron, so that its proper place would be the next section. To this also may be referred *ilmenite*, which hitherto has been considered as a titaniferous iron ore, because the analyses of Mosander and Rose have sufficiently demonstrated that it is a double salt.

3. *Triple Salts of Iron.*

These are not numerous, though doubtless as the examination of ferruginous minerals is advanced, the number will increase.

Sp. 1. *Ankerite.*

Rohwand, rohe wand, rosszahn, wandstein of the Stirian and Carinthian miners, poratomous lime haloid of Mohs.

This mineral was first made a species by Mohs. It occurs in the Rathhausberg, in Salzburg, upon beds in mica slate, and in many places extending from Stiria all along the chain of the Alps.

Colour white, with various tints of grey, red and brown; streak white.

It occurs in rhomboidal crystals, with angles of 106° 12′; so that it differs sensibly from the fundamental form of calcareous spar.

Structure foliated; fracture uneven.

Slightly translucent. Brittle. Lustre pearly.

Hardness 3·5 to 4. Specific gravity 3·080.

It occurs often in twin crystals, and not unfrequently in granular masses. It is often mixed with calcareous spar.

Its constituents, as determined by the analysis of Berthier,[*] are

Carbonate of lime, .	51·1
Carbonate of magnesia,	25·7
Carbonate of iron, .	20·0
Carbonate of manganese,	3·0
	99·8

Uniting the carbonate of manganese with the carbonate of iron, these constituents are equivalent to

8 atoms carbonate of lime,
5 atoms carbonate of magnesia,
3 atoms carbonate of iron.

Before the blowpipe it becomes black, and acts on the magnetic needle.

Sp. 2. *Pyrosmalite.*[†]

This mineral was discovered by Messrs. Clason and Henry Gahn in the iron mine of Bjelke, at Nordmark, in Werm-

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[*] Traité des Essais par la voie seche i. 494.

[†] From *πυρ*, *fire*, and *ὀσμη*, *odour*.

land. It was named by Haussmann, from the strong smell of chlorine which it emits when heated before the blowpipe.

Colour externally liver-brown, internally light greenish-yellow; streak paler.

Found only crystallized in six-sided prisms, varying in length from a few lines to an inch, but seldom larger.

From the cleavage planes, the primary form appears to be the regular six-sided prism.

Fracture uneven, rather splintery.

Lustre pearly.

From translucent to opaque; rather brittle; hardness 4·5; specific gravity, as determined by Hisinger, 3·081.

Before the blowpipe it becomes blackish-red brown, and gives out fumes of muriatic acid. In a strong heat it melts into a black slag, which at last becomes a round globule, attracted by the magnet. Fuses easily and in considerable quantity in borax. The colour of the bead shows the presence of iron and manganese. In biphosphate of soda it fuses with great difficulty.

Its constituents, as determined by Hisinger and Berzelius,[*] are

		Atoms.
Silica, ...	35·850 .	17·92
Chlorine, ...	3·760 .	0·83
Peroxide of iron, .	35·480 .	7·09
Sesquioxide of manganese,	23·444 .	4·69
Lime, ...	1·210 .	0·34
Water, ...	3·600 .	3·2
	103·344	

The increase of weight shows that in the mineral the iron and manganese are in the state of protoxides.

Pyrosmalite appears to be composed of sesquisilicates. The numbers approach to

7 atoms sesquisilicate of iron,
5 atoms sesquisilicate of manganese,
½ atom sesquichloride of iron,
3 atoms water.

Sp. 3. *Commingtonite.*

This mineral has been found at Commington, Massachusetts,

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[*] Afhandlingar, iv. 317.

in a rock which, judging of the specimen in my possession, is composed of quartz, garnet and commingtonite.

Colour greyish-white.

In imperfectly crystallized masses, consisting of needles slightly diverging.

Lustre silky.

Opaque, or only translucent on the edges.

Hardness 2·75; specific gravity 3·2014.

Infusible per se before the blowpipe. With carbonate of soda fuses with effervescence into a dark glass. Fuses with borax or biphosphate of soda into a black glass bead, showing the presence of much iron and manganese.

Its constituents, determined by the analysis of Dr. Thomas Muir, in my laboratory, are as follows:

		Atoms.	
Silica,	56·543	28·27	16·34
Protoxide of iron,	21·669	4·81	2·78
Protoxide of mangan.,	7·302	1·73	1
Soda,	8·439	2·11	1·22
Moisture,	3·178	2·83	1·6
	97·631		

The bases are obviously in the state of tersilicates. The numbers approach

3 atoms tersilicate of iron,
$1\frac{1}{3}$ atom tersilicate of soda,
1 atom tersilicate of manganese,
$1\frac{1}{2}$ atom of water.

The formula is $3fS^3+NS^3+mnS^3+1\frac{1}{2}Aq$.

Sp. 4. *Nontronite.*[*]

This mineral was discovered at Nontron, in the department of Dordogne, about the year 1826. There is in that department an important deposite of manganese, known by the name of manganese of Peregueux, which occurs in nests in alluvial clay. The *nontronite* was found by M. Lanoue in this manganese, at the village of Saint Pardoux. It is disseminated in amorphous nodules, usually very small, and never larger than the fist. These nodules are never pure; they easily break into smaller pieces, quite irregular, and each enveloped in a thin black coating of manganese. They are often mixed with

[*] Berthier, Ann. de Chim. et de Phys. xxxvi. 22.

yellow micaceous clay; so that when a piece of the mineral is polished, it looks like serpentine.

Nontronite, when pure, has a straw-yellow colour, sometimes with a tint of green.

Massive and compact; fracture uneven and dull.

Opaque. Unctuous to the touch. Very friable.

Hardness scarcely 2.

Takes a good polish, and then has a resinous lustre; under the pestle it flattens and shows ductility, instead of falling into powder.

Does not exhale the odour of clay when breathed upon; does not act on the magnetic needle.

When plunged into water, numerous air bubbles are disengaged, and it becomes translucent on the edges, without losing its form or falling to powder. If it be taken out after some hours' immersion, and wiped dry and weighed, it will be found to have increased $\frac{1}{10}$th in weight.

When heated in a glass tube, it gives out water and becomes red.

It dissolves readily in muriatic acid.

Its constituents, as determined by Berthier, are as follows

		Atoms.
Silica,	44	22
Peroxide of iron,	29	6
Alumina,	3·6	1·6
Magnesia,	2·1	0·8
Water,	18·7	16·6
Clay,	1·2	
	98·6	

These numbers correspond with

7½ atoms tersilicated peroxide of iron,
2 atoms bisilicate of alumina,
1 atom silicate of magnesia,
20 atoms water.

The formula is $7\frac{1}{2}fS^3+2AlS^2+MS+20Aq$.

Sp. 5. *Volkonskoite.*

This mineral was discovered in Mount Jessmictski, in the district of Okhausks, and the government of Perne. It is found in thin veins and in nests.

Colour fine grass-green.

Texture compact.

Fracture conchoidal or uneven.

Dull; assumes a polish when rubbed by the fingers.

Very soft; feels smooth; specific gravity not given.

When heated in a glass tube, it gives out a good deal of water, and assumes the colour of goose dung. When calcined in a platinum crucible, it loses 32 per cent. of its weight, and assumes a brown colour like that of burnt coffee.

It gelatinizes with hot and concentrated muriatic acid, yet not more than half the chromium contained in the mineral is dissolved, the rest being left mixed with the silica.

The constituents of this mineral, as determined by the analysis of Berthier,[*] are

		Atoms.
Green oxide of chromium,	34·0	6·8
Peroxide of iron,	7·2	1·44
Magnesia,	7·2	2·88
Silica,	27·2	13·6
Water,	23·2	20·62
	98·8	

These numbers correspond with

4 atoms bisilicate of chromium,
2 atoms bisilicate of magnesia,
1 atom chromite of iron,
14 atoms water.

The formula is $4ChS^2+MgS^2f\bar{C}h+14Aq$.

But from the uncommon nature of these compounds, and the imperfect action of the muriatic acid, Berthier considers it as a mixture of hydrate of chromium, and silicate of iron and magnesia. Were we to adopt that view of its constitution, it would consist of

5 atoms terhydrate of chromium,
2 atoms tersilicate of magnesia,
1 atom tersilicate of iron.

But if this were the constitution of volkonskoite, no good reason could be assigned why only one half of the hydrate of chromium dissolves in muriatic acid.

Sp. 6. *Polylite.*[†]

The mineral to which I have given this name constitutes a

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[*] Memoires par Berthier, ii. 263.

[†] From πολυς, *many*, and λιθος, *a stone*, on account of the numerous constituents of which it is composed.

bed about ¼th inch thick, in magnetic iron ore, at Hoboken, in New Jersey.

Colour black.

Composed of plates, but only one cleavage is discernible. It resembles *hornblende*, or still more nearly *arfvedsonite*, in its appearance.

Lustre vitreous and splendent.

Opaque; brittle.

Hardness 6·25; specific gravity 3·231.

Before the blowpipe becomes lighter coloured, but does not fuse. With carbonate of soda fuses with difficulty into a brown frit, transparent while red hot, but becoming opaque on cooling. With borax fuses very slowly into a black transparent glass.

Its constituents, determined by my analysis, are

		Atoms.
Silica, . .	40·040 .	20·02
Protoxide of iron, .	34·080 .	7·5
Protoxide of manganese,	6·600 .	1·5
Alumina, . .	9·425 .	4·2
Lime, . .	11·540 .	3·3
Water, . .	0·399	
	102·084	

If we unite the protoxides of iron and manganese, these numbers give us the constitution of polylite as follows:

9 atoms silicates of iron and manganese,
4 atoms silicate of alumina,
3⅓ atoms bisilicate of lime.

The formula will be $9(\frac{5}{6}f+\frac{1}{8}\underline{m}n)S+4AlS+3\frac{1}{3}CalS^2$.

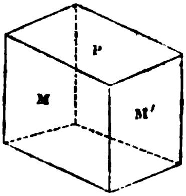
Sect. 3. *Sulphur Salts of Iron.*

These consist of combinations of one or more sulphur acids with one or more sulphuretted bases, one of which is always sulphuret of iron. Only two such salts are at present known, but doubtless the number will increase as the chemical examination of the different iron ores become more extensive and more complete.

Sp. 1. *Arsenical Pyrites.*

Mispickel, marcasite, sulpho-arsenite of iron.

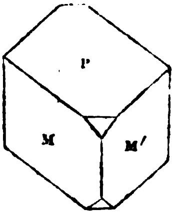
This mineral is pretty common both in beds and veins. It panied by ores of silver, lead and tin. It is plentiful in some of the mining districts of Saxony and Bohemia. It occurs at Andreasberg in the Hartz, at Tunaberg in Sweden, at Huel Maudlin, and other mines in Cornwall, and in many other localities.



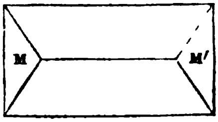
Colour silver-white, inclining to and passing into steel-grey; streak dark greyish-black.

It occurs massive and crystallized, in the form of a right rhombic prism,

M on M′ 111° 12′



This is the primary form. Sometimes (as in the second figure in the margin) the obtuse angles of the prism are replaced by triangular planes. When these become so large as to efface the bases of the prism, the crystal is converted into a kind of elongated octahedron, as in the third figure in the margin.



Lustre metallic; fracture uneven.

Opaque; brittle.

Hardness 4·75; specific gravity 6·127.

Before the blowpipe on charcoal it gives out a copious arsenical vapour, and the crystal becomes magnetic.

The constituents of this mineral are as follows:

Arsenic,	48·1	43·4	42·88
Iron	36·5	34·9	36·04
Sulphur,	15·4	20·1	21·08
	100[*]	98·4[†]	100[‡]

If we calculate from Stromeyer's analysis, we obtain

	Atoms.
Arsenic,	9·02
Iron,	10·3
Sulphur,	10·54

This approaches nearly to an atom of each constituent. Perhaps the mineral may be considered as composed of

1 atom arseniet of iron,	1 atom arsenic, 1 atom iron,
1 atom sulphoarsenite of iron,	1 atom sulphide of arsenic, 1 atom sulphuret of iron.

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[*] By my analysis. [†] By Chevreul's analysis.

[‡] By Stromeyer's analysis, Schweigger's Jour. x. 404.

Sp. 2. *Berthierite.*[*]

Haidingerite of Berthier.

This mineral occurs in veins near the village of Chazelle, in Auvergne. Attempts were made to work it, but the antimony obtained was so bad that it could not be sold. M. Berthier recognised it as a new mineral species, and gave it the name of Haidingerite; but as this name had been already appropriated to another mineral, Poggendorf substituted that of Berthierite, from the discoverer of the new species.

Colour iron black; surface often covered with iridescent spots.

Usually in masses, confusedly foliated, and much mixed with quartz, carbonate of lime, and iron pyrites. It exhibits occasionally the rudiments of prismatic crystals, which serve to distinguish it from sesquisulphide of antimony.

Specific gravity not determined.

Fuses readily before the blowpipe.

A portion of it, freed as much as possible from impurities, being analyzed by Berthier, gave the following constituents:

		Atoms.
Sulphur, .	28·3 .	14·15
Antimony, .	48·3 .	6·03
Iron, .	14·9 .	4·25
Zinc, .	0·3 .	0·07
Quartz, .	3·2	
Iron pyrites,	3·2	
	98·2	

These atoms correspond very nearly with

1½ atom sesquisulphide of antimony,
1 atom sulphuret of iron.

It is therefore a sesquisulpho-antimonite of iron.

This is not the only compound of sesquisulphide of antimony and sulphuret of iron. Berthier has lately pointed out two more.[†]

The first of these is found in the mine of Martouret, at no great distance from Chazelle. It is homogeneous in appearance, though much mixed with stony matter. Its texture is fibrous, with the fibres parallel; cross fracture granular, and almost dull. The colour is grey-blue, but less blue, and

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[*] Berthier, Ann. de Chim. et de Phys. xxxv. 351.

[†] Memoires par Berthier, ii. 273.

having less lustre than sesquisulphide of antimony. Its constituents, by Berthier's analysis, are

		Atoms.
Gangue,	60·0	—
Sesquisulphide of antimony,	33·7	3·06
Sulphuret of iron,	6·3	1·15
	100	

This is very nearly 3 atoms of sesquisulphide of antimony to 1 atom of sulpuret of iron. The mineral is therefore a

Tersulpho-antimonite of Iron.

The second species is found at Aglar, in the department de la Creuse. It is associated with sesquisulphide of antimony and with iron pyrites. It has an iron-grey colour; its fracture is granular and fibrous. Its composition, determined by the analysis of Berthier, is

		Atoms.
Quartz,	7	—
Sesquisulphide of antimony,	75	6·8
Sulphuret of iron,	18	3·27
	100	

So that it is a compound of 2 atoms sesquisulphide of antimony and 1 atom of sulphuret of iron. It is therefore a

Bisulpho-antimonite of Iron.

GENUS XVI.—MANGANESE.

Manganese is also a very abundant metal, though much less so than iron. Having a great tendency to combine with oxygen, it never occurs in the metallic state, except when in combination with some other substance, as with sulphur or arsenic. The oxides of manganese are most abundant; and, being three in number, and variously mixed and united, that part of mineralogy constituted a perfect chaos, which was first reduced into order by the valuable labours of Haidinger, accompanied by the analytical investigations of Dr. Turner, which pointed out the constitution of the different species determined by the crystallographic skill of Haidinger.*

The species of manganese minerals at present known amount to about 24. About 11 of these consist of combina-

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* Edin. Trans. xi. 119 and 143.

tions of manganese with some simple substance, while the rest are salts, having oxide of manganese for at least a part of the base. We shall therefore subdivide this genus into two sections.

Sect. 1. *Manganese combined with Simple Bodies.*

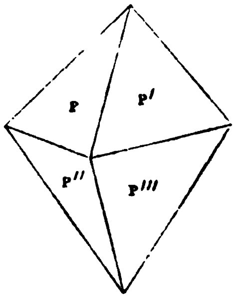
Sp. 1. *Haussmannite.*

Red oxide of manganese, black manganese, pyramidal manganese.

This species has hitherto been found only in the porphyry formation near Ihlefeld in the Hartz. It is found in a vein by itself, as was first observed by Professor Gustavus Rose. It was first accurately described by Mr. Haidinger, and analyzed by Dr. Turner.

Colour brownish black; streak dark reddish or chestnut brown.

Massive and granular, also crystallized in octahedrons composed of two four-sided pyramids with square bases.



P on P′ or P″ on P‴, 105° 45′, according to the measurement of W. Phillips, 105° 25′, according to Haidinger.

P on P″, or P′ on P‴, 117° 30′, as measured by Phillips, 117° 34′, as by Haidinger.

The summits of the pyramids are sometimes replaced by low four-sided pyramids. Occurs often in twin crystals.

Lustre imperfect metallic; opaque.

Hardness 4·5 to 5; specific gravity 4·722.

Its constituents, as determined by Turner, are

Red oxide of manganese,*	98·098
Oxygen, . .	0·215
Water, . .	0·435
Barytes, . .	0·111
Silica, . .	0·337
	99·196

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* This is the oxidum manganeso-manganicum of Arfvedson; a compound of

1 atom protoxide, . .	4·5
2 atoms sesqui-oxide, .	10
	14·5

Admitting every thing but the red oxide to have been accidental impurity, this ore of manganese is analagous to magnetic iron in its composition. The shape of this last species is the regular octahedron, which differs considerably from the octahedron that constitutes the primary form of Haussmanite.

Sp. 2. *Braunite.*

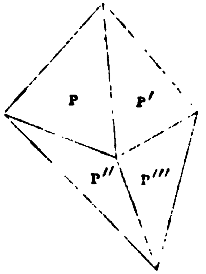
Anhydrous sesqui-oxide of manganese. Brachytypous manganese ore.

This species was first recognised as peculiar by Mr. Haidinger, and to him we owe the first accurate descriptions of it. It occurs in veins in Thuringia, in the porphyry at Oehrenstock near Ilmenau, at Elgelsburg, Friedricksrode, and in other places. At Leimback in the county of Mansfield, it exists in cavities of white quartz, which appear to have been filled originally with some other substance. It occurs also at St. Marcel in Piedmont, in Wales, and near Launcestown, Cornwall; and doubtless in many other localities.

Colour dark brownish black; streak of the same colour.

Massive and crystallized. The primary form is an octahedron with a square base, differing exceedingly little from the regular octahedron. The inclination of the faces, according to Haidinger, are

P on P′, or P″ on P‴, 109° 53′
P on P″, or P′ on P‴, 108° 39′



Sometimes the summits of the pyramids are replaced by planes parallel to the base. Sometimes the two pyramids are separated by the intervention of a more acute octahedron, in which

P on P′ 96° 33′
P on P″ 140° 30′

Lustre imperfect metallic.

Opaque; brittle.

Hardness 6 to 6·5; specific gravity 4·818.

Its constituents, according to the analysis of Turner, are

		Atoms.
Protoxide of manganese,	86·940	19·22
Oxygen,	9·851	9·85
Water,	0·949	
Barytes,	2·260	
Silica,	trace	
	100	

The atoms of oxygen are very nearly half the atoms of protoxide of manganese. It is clear therefore, that the mineral consists essentially of sesquioxide of manganese.

Sp. 3. *Manganite.*

Hydrous sesquioxide of manganese.

This mineral occurs in great abundance in the manganese mines at Ihlfeld in the Hartz, in veins traversing porphyry. It is found likewise at Christiansand in Norway, and Udenäs in Sweden. Specimens of it in small specular crystals, have been brought from Nova Scotia.

Colour dark brownish-black, inclining to iron black; streak reddish-brown.

Occurs granular and columnar, and frequently crystallized. The primary form is a right rhombic prism of 100° and 80°. The edges of the prism are often replaced by one, or even two faces.

Lustre imperfect metallic.

Opaque in large masses; but in thin splinters it transmits a little light, and appears of a bright brown when held between the eye and the sun.

Brittle.

Hardness 4 to 4·25; specific gravity from 4·312 to 4·328.

Its constituents, according to the analysis of Turner, are

		Atoms.
Protoxide of manganese,	80·92	17·98
Oxygen, . . .	8·98	8·98
Water, . . .	10·10	8·97
	100	

It is obvious that the constitution of this mineral is

2 atoms sesquioxide of manganese,
1 atom water.

It is therefore a hydrous sesquioxide, and differs from the preceding species by containing water.

Sp. 4. *Pyrolusite.*

Grey ore of manganese, wad, anhydrous binoxide of manganese.

This is at once the most abundant and the most important of all the ores of manganese. It is found both in primary and secondary mountains. Many important mines of it occur in Thuringia. Ehrensdorf near Maehrisch Triebau, in Moravia, annually yields a great deal of it. Upton Pyne, near Exeter, supplies most of the manganese consumed in Great Britain, amounting annually to about 30,000 tons.

Colour iron-black.

Massive, columnar and crystallized in delicate needles, the form of which has not been made out. Haidinger gives the figure of a crystal in his possession, constituting a four-sided prism, with angles of about 86° 20′ and 93° 40′, the lateral edges of which are replaced by single planes.

Lustre metallic.

Rather sectile; opaque.

Hardness 2 to 2·8; specific gravity, when pure, 4·97; but it is as light as 4·819.

Its constituents are as follows:

	[*]	[†]	[‡]
Binoxide of manganese,	98·14	97·835	99·242
Water,	1·86	1·120	—
Barytes,	—	0·532	—
Silica,	—	0·513	0·840
Peroxide of iron,	—	—	0·130
	100	100	100·212

It is obvious from these analyses, that when pure it contains nothing but binoxide of manganese. Binoxide of manganese, when heated, lets go one-fourth of its oxygen, and is converted into sesquioxide. The atom of manganese being 3·5 and that of oxygen 1, it is obvious that the atom of binoxide weighs 5·5. It gives out, when heated, 0·5 oxygen and leaves 5 sesquioxide. So that this ore, when quite pure, gives out exactly the $\frac{1}{11}$th of its weight of oxygen. Hence the purity of such an ore is easily determined by the quantity of oxygen which it gives out.

Sp. 5. *Hydrous Binoxide of Manganese.*

This mineral was discovered by Berthier,[§] who found it in manganese from three different localities; namely, Groroi, in the department of Mayenne; Cautern, in the country of the Grisons, and Vecdessos, in the department of Arriege. In none of these places is it found pure, being always mixed with more or less of manganite or hydrous sesquioxide of manganese.

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[*] Arfvedson, Afhandlingar, vi. 229.

[†] Dr. Turner.

[‡] By my analysis. The specimen was very pure and crystallized in needles.

[§] Memoires par Berthier, ii. 230.

At Groroi the mineral is found in rounded pieces in a bed of sand and clay, which supplies the ironstone smelted in that department. It is in coherent pieces, full of small irregular holes.

Colour brownish-black; dull; here and there metallic. Its powder has a light chocolate colour. By ignition it loses 24 per cent. of its weight in water and oxygen without changing its form, but acquiring a reddish colour.

It dissolves slowly in concentrated sulphuric acid, and colours that acid a fine violet-red. Oxalic acid attacks it readily, even without heat. $2\frac{1}{8}$ times its weight of this acid are required to disoxidize it completely. Sulphurous acid dissolves it almost instantly. The constituents of the Groroi mineral, as determined by Berthier, are

		Atoms.
Protoxide of manganese,	62·4	13·86
Oxygen,	12·8	12·8
Water,	15·8	14·04
Peroxide of iron,	6·0	1·2
Clay,	3·0	
	100	

It is obvious that the whole protoxide of manganese in the mineral to be converted into deutoxide, would require 13·8 atoms of oxygen; but only 12·8 atoms were obtained. Hence the mineral must have been a mixture or compound of

11·8 atoms binoxide,
2 atoms sesquioxide,
14 atoms water.

It is obvious that every atom of the oxides of manganese in the mineral, was combined with an atom of water. The Groroi manganese then is a compound of

6 atoms binoxide of manganese,
1 atom sesquioxide of manganese,
7 atoms water.

Or if with Berthier we consider the sesquioxide as an accidental impurity, the constitution of the mineral will be

1 atom binoxide of manganese,
1 atom water.

The specimens from Vecdessoss and Cautern are similar to those from Groroi. The following are their constituents:

1. Vecdessoss.

		Atoms.
Protoxide of manganese,	68·9	15·31
Oxygen,	11·7	11·7
Water,	12·4	11·02
Clay,	7·0	
	100	

Obviously a compound of
8·1 atoms binoxide of manganese,
7·2 atoms sesquioxide of manganese,
11 atoms water.

Here the quantity of sesquioxide is much greater than in the last, and there is also a slight deficiency in the water.

2. Cautern.

		Atoms.
Protoxide of manganese,	46·5	10·33
Oxygen,	7·1	7·1
Water,	8·8	7·82
Oxide of iron,	3·6	
Quartz,	33·6	
	99·6	

It is obvious that this mineral was a compound of
3·93 atoms binoxide of manganese,
6·4 atoms sesquioxide,
7·82 atoms water.

Here the proportion of sesquioxide is still farther increased, and there is also a deficiency in the water, though less than in the Vecdessoss specimen.

From this great variation in the quantity of sesquioxide in the different specimens, there can be little hesitation in adopting Berthier's opinion, that it is merely an accidental impurity.

Sp. 6. *Hydrous Sesquibinoxide of Manganese.*

This species, not hitherto noticed by mineralogists, seems to occur in considerable quantity in the neighbourhood of Cork. The proprietor some years ago brought a cargo of it to Glasgow for sale; on trial it was found to yield too little oxygen to answer the purposes of the manufacturer. I was induced to make a regular analysis of it, because it differed in its appearance from any of the ores of manganese which I had seen.

Colour brownish-black.

It was in small pieces, not much larger than the size of a pea, which were composed of fine particles.

Lustre imperfect metallic, almost dull.

Opaque.

Hardness 4·25; specific gravity 3·31245.

Its constituents, determined by three different analyses, are as follows:

		Atoms.	
Silica,	22·90	11·45	7½
Sesquioxide of manganese,	23·48	4·69	3
Binoxide of manganese,	17·22	3·13	2
Perox. of iron, with trace of copper,	28·64	5·73	4
Water,	8·05	7·15	4·75
	100·29		

From the phenomena during the analysis, it was obvious that neither the silica nor the oxide of iron were in chemical combination with the manganese. The constitution (abstracting these two bodies) is

3 atoms sesquioxide of manganese,
2 atoms binoxide of manganese,
5 atoms water.

Each atom of the oxide of manganese was combined with an atom of water. It comes to be a question, whether the mineral now described be not a variety of Berthier's hydrous binoxide, which constitutes the last species. The circumstance of the proportions of the two oxides being to each other as 3 to 2, has induced me to place it separately.*

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* Mr. Richardson lately analyzed, in my laboratory, a black ore of manganese from Muirkirk, having something of the metallic lustre, which seems to approach somewhat to the Cork ore; only it is much purer. Its specific gravity was 4·3479, and its constituents

		Atoms.	
Binoxide of manganese,	52·69	12·12	3·03
Sesquioxide of manganese,	33·41	8·46	2·11
Water,	2·92	3·27	0·82
Barytes,	7·49	1	0·25
Silica,	1·14		
Alumina,	0·74		
Peroxide of iron,	1·22		
	99·61		

Here the ratios approach that of 3 to 2. The water not amounting to an atom, the mineral was probably anhydrous. The barytes also is too

Sp. 7. *Varvacite.*[*]

This mineral occurs in Warwickshire, and was first noticed, named and analyzed, by Mr. R. Phillips.[†]

Colour grey, not differing much from that of pure binoxide, only less bright.

It is composed of thin plates and fibres, without any regular crystalline shape.

Lustre metallic.

Opaque.

Hardness 2·5; specific gravity from 4·283 to 4·531.

Its constituents, according to the analysis of Mr. Phillips, are

		Atoms.
Protoxide of manganese,	81·12	18·02
Oxygen, . . .	13·48	13·48
Water, . . .	5·40	4·8
	100	

These numbers are equivalent to

8·96 atoms binoxide of manganese,
9·08 atoms sesquioxide of manganese,
4·8 atoms water.

It is obvious that the constitution of varvacite (as Mr. Phillips has shown) is

2 atoms binoxide of manganese,
2 atoms sesquioxide of manganese,
1 atom water.

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small in quantity to constitute a chemical compound. Perhaps, from the absence of water, this specimen may be entitled to rank as a peculiar species. I shall therefore give a short description of it here.

The colour is bluish black, and it has something of the metallic lustre.

Texture compact and almost earthy; though there occur small particles in it having greater lustre than the rest, and exhibiting some slight indications of a foliated structure.

Fracture earthy and even.

It soils the fingers, yet it scratches calcareous spar, and has a hardness that may be estimated at 3·75; specific gravity 4·3479.

Not altered before the blowpipe per se, but when heated on charcoal it becomes brown, but does not melt.

With carbonate of soda fuses into a bluish green bead, opaque when cold.

With borax in the oxidizing flame, fuses into a transparent amethyst coloured bead, which becomes colourless in the reducing flame.

With biphosphate of soda the phenomena are the same.

[*] Because it occurs in the county of Warwick.

[†] Phil. Mag. (2d series), v. 209.

Thus we have a third compound of these two oxides in atomic proportions, and from the appearance and qualities of varvacite, there is every reason to consider it as a chemical combination.

Sp. 8. *Psilomelanite.*

This name has been given by Haidinger to a species of manganese ore, which has hitherto been confounded with *pyrolusite*, though it differs materially in its constitution from that species. It is one of the most generally diffused species, and often occurs mixed with Haussmannite and pyrolusite. In this way it is found in various parts of Germany, at Restormel in Cornwall, and at Upton Pyne, near Exeter.

Colour bluish black and greyish black, passing into dark steel grey; streak brownish black, shining.

Massive, reniform, botryoidal; but has not yet been observed in crystals.

Lustre imperfect, metallic.

Opaque; brittle.

Hardness 5 to 6; specific gravity 4·145.

Its constituents, according to the analysis of Dr. Turner, are

Red oxide of manganese,	69·795
Oxygen, . . .	7·364
Barytes, . . .	16·365
Silica, . . .	0·260
Water, . . .	6·216
	100

Red oxide being a compound of 4·5 protoxide of manganese, and 0·333 oxygen, it is obvious that 69·795 of it may be resolved into

Protoxide, .	64·966
Oxygen, .	4·829
	69·795

We may therefore represent the constituents thus:

		Atoms.
Protoxide of manganese,	64·966 .	14·44
Oxygen, . . .	12·193 .	12·19
Barytes, . . .	16·365 .	1·72
Silica, . . .	0·260	
Water, . . .	6·216 .	5·52
	100	

These numbers are equivalent to

	Atoms.
9·94 atoms binoxide of manganese, or	5·68
4·5 atoms sesquioxide, . .	2·57
1·75 atoms barytes, . .	1
5·52 atoms water, . . .	3·15

These atomic quantities may be perhaps considered as united in the following way:

$11\frac{1}{3}$ atoms binoxide, 2 atoms barytes,	2 atoms sexmanganite of barytes.
$6\frac{1}{3}$ atoms water, 5 atoms sesquioxide,	5 atoms hydrated sesquioxide.

I have ascertained by direct experiments, that binoxide of manganese combines with bases like an acid, and that the usual proportions combining, are six atoms of binoxide with one atom of base.*

Sp. 9. *Newkirkite.*

I give this name to a species of manganese ore which is found at Newkirchen in Alsace. It constitutes another of the many species long confounded under the name of *grey ore of manganese.*

Colour a brilliant black.

Lustre metallic, splendent.

Occurs in small needles which, when viewed through a powerful microscope, assume the appearance of a right rect-

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* Fuchs has analyzed a variety of this species, from Bayreuth, which contains potash as a constituent instead of barytes. Its constituents were

Protoxide of manganese,	81·8
Oxygen, . . .	9·5
Potash, . . .	4·5
Water, . . .	4·2
	100

This is obviously equivalent to

		Atoms.	
Sesquioxide of manganese,	86·24 .	17·25 .	23
Binoxide of manganese, .	5·06 .	0·92 .	1·22
Potash, ...	4·5 .	0·75 .	1
Water, ...	4·2 .	3·73 .	5
	100		

It is obvious at a glance, that the chemical constitution of this variety differs from that of the psimolenanite given in the text. See Berzelius, Jahresbericht, 1833, p. 180.

angular prism with a square base. But they are not susceptible of measurement. These needles form a coating on red hematite.

Opaque; rather sectile.

Hardness 3 to 3·5; specific gravity 3·824.

Its constituents, determined by the analysis of Mr. William Muir, in my laboratory, are as follows:

			Atoms.
Binoxide of manganese,	56·30	10·23	5·11
Peroxide of iron,	40·35	8·07	4·03
Water,	6·70	6	3
	103·35		

Perhaps the constitution of this mineral may be represented by

3 atoms water, 3 atoms binoxide,	3 atoms hydrated binoxide.
2 atoms binoxide, 4 atoms peroxide of iron,	2 atoms biferrate of manganese.

Sp. 10. *Sulphuret of Manganese.*

Manganblende. Swartzerz.

This rare mineral has hitherto been found only at Nagyag in Transylvania, in a vein accompanying tellurium ore; and according to Mr. W. Phillips, also in Cornwall.

Colour iron black; streak dark green.

Massive. It is said also to occur crystallized in cubes; surface rough.

Lustre imperfect metallic; opaque.

Hardness 3·5 to 4; specific gravity from 3·950 to 4·014.

Before the blowpipe it melts with difficulty, and only on its thinnest edges.

When reduced to powder and digested in muriatic acid, or dilute sulphuric acid, sulphuretted hydrogen gas is evolved. This proves that it is a sulphuret of manganese.

Arfvedson[*] has shown that it contains nothing but sulphur and manganese, and a trace of iron. By long exposure to heat he drove off the whole of the sulphur, and reduced the manganese to the state of *red oxide*. 4·94 parts of the mineral thus treated, became 4·25 parts of red oxide. But red oxide is composed of

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[*] Kong. Vet. Acad. Handl., 1822, p. 435.

Manganese,	.	3·5
Oxygen,	.	1·333
		4·833

Consequently 4·25 contain 3·077 manganese. Therefore the mineral is composed of

Manganese,	.	3·077 or 3·5
Sulphur,	.	1·863 or 2·119
		4·940

Or a little more than 1 atom of sulphur, united to 1 atom of manganese. If we consider the analysis as rigidly exact, then the mineral is a compound of

16 atoms sulphuret of manganese,
1 atom bisulphuret of manganese.

So that it resembles magnetic pyrites, which is a mixture or compound of sulphuret and bisulphuret of iron, in various proportions.

Sp. 11. *Arseniet of Manganese.*

This mineral has been noticed and examined by Mr. Robert John Kane, in Dublin.* The specimen was from Saxony, weighed about 2½ ounces, and was attached to a mass of galena.

Colour greyish-white.

Texture foliated.

Fracture in one direction uneven, fine, granular and shining; in the opposite direction it is dull and warty; and in that direction it breaks easily.

Hard; brittle.

Specific gravity 5·55.

Before the blowpipe it burns with a blue flame, and falls to powder. In a stronger heat, an arsenical fume rises and coats the charcoal with a white dust.

It dissolves in aqua regia without leaving any residue.

According to the analysis of Mr. Kane it is composed of

			Atoms.
Manganese,	45·5	.	13
Arsenic,	51·8	.	10·9
Iron,	trace		
	97·3		

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* Quarterly Journal of Sciences (new series), vi. 381.

Probably the loss was chiefly arsenic. It is not improbable therefore, that the mineral is a compound of

1 atom arsenic,
1 atom manganese.

It would, in that view of its constitution, be a simple arseniet of manganese.[*]

Sect. 2. *Oxygen Salts of Manganese.*

These amount to about eleven, and consist partly of simple salts, partly of double salts, and partly of triple salts.

1. *Simple Oxygen Salts.*

Sp. 1. *Carbonate of Manganese.*

Dialogite, rhodochrosite, and (when mixed with silicate of manganese) allagite, photizite, rhodonite.

This species occurs most commonly in veins along with the ores of silver, lead and copper. It is said also to have been found in transition mountains along with other ores of manganese. It is not uncommon in the Saxon mines, also at Nagyag and Kapnic, in Transylvania, near Elbingerode in the Hartz, &c.

Colour various shades of rose-red, partly inclining to brown; streak white.

Massive and crystallized in obtuse rhomboids, with angles of about 107° 20′, according to the measurement of Mr. Brooke.

Lustre vitreous, inclining to pearly.

Translucent in different degrees.

Brittle.

Hardness 3·5; specific gravity of the crystallized variety from Kapnic, as determined by Haidinger, 3·592.

Before the blowpipe its colour is changed into grey, brown or black, and it decrepitates strongly, but is infusible without addition. With borax it fuses into a violet-blue bead.

When exposed to the air, the natural colour is changed into brown.

It effervesces briskly in nitric acid.

Its constituents, according to the analysis of Du Menil,[†] are

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[*] Poggendorf's Annalen, xix. 145.

[†] Mohs' Mineralogy, ii. 107.

		Atoms.
Carbonic acid,	33·75	12·27
Protoxide of manganese,	54·60	12·13
Protoxide of iron,	1·87	0·41
Silica,	4·37	2·18
Lime,	2·50	0·71
	97·09	

It is obvious that it is a simple carbonate of manganese. The iron and lime are in the state of bisilicates, and only accidental impurities.

Sp. 2. *Disilicate of Manganese.*

Foliated black manganese ore.

Hitherto this mineral has only been met with in Piedmont, and it has been but imperfectly described. I have not myself had an opportunity of seeing it.

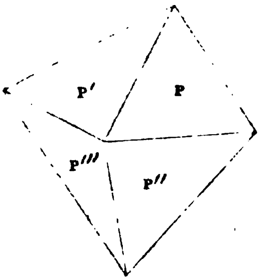
Colour iron black.

Massive, and crystallized in octahedrons.

P on P'' or P' on P''' 117° 30′

P on P' or P'' on P''' 105° 45′

according to the measurement of Mr. W. Phillips.



Powder brown.

Opaque; very hard.

Specific gravity not noticed.

On charcoal in a strong heat, it fuses on the edges and preserves its colour. With borax or biphosphate of soda it fuses easily, with the usual indications of manganese.

Its composition, as determined by Berzelius,* is

		Atoms.
Silica,	15·17	7·58
Red oxide of manganese,	75·80	15·47
Alumina,	2·80	1·24
Peroxide of iron,	4·14	0·81
	97·91	

If we admit the manganese in this mineral to be in the state of sesquioxide, it is obvious that during the analysis it sustained a loss of 2·6 oxygen, and that the sesquioxide

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* Mineralogie, p. 277.

amounted to 78·4 per cent., equivalent to 15·7 atoms; now the silica constitutes 7·58 atoms, or nearly the half. If, therefore, we admit the alumina, iron and small excess of silica to be accidental impurities, the mineral is a disilicate of sesquioxide of manganese.

Sp. 3. *Silicate of Manganese.*

This species, so far as my information extends, has hitherto been found only at Franklin, in New Jersey. I got specimens of it from Dr. Torrey, about the year 1825. These specimens I subjected to analysis, and an account of the mineral was published by me in 1828, in the Annals of the Lyceum of Natural History of New York.

Colour light brownish-red.

Massive; structure foliated. Two cleavages are very distinct at right angles, or nearly so, to each other. There is a third cleavage perpendicular to the two others, but it is very imperfect. Hence the primary form seems to be a right oblique prism, which differs only by 3° or 4° from a right angle.

Lustre shining and vitreous; opaque.

Hardness 6·25; specific gravity 4·078.

Powder light red, becomes brown by ignition and loses 2·7 per cent. of its weight.

It dissolves, by digestion, in dilute muriatic acid without effervescence.

Its constituents, by my analysis, are as follows:

		Atoms.
Silica, . .	29·64	. 14·82
Protoxide of manganese,	66·60	. 14·8
Peroxide of iron,	0·92	
Moisture, .	2·70	
Alumina, .	trace	
	99·86	

Admitting the iron and moisture to be accidental impurities, it is obvious that the mineral is a silicate of manganese, composed of

1 atom silica,
1 atom protoxide of manganese.

Sp. 4. *Sesquisilicate of Manganese.*

This mineral, like the preceding, so far as I know, has been found hitherto only at Franklin, in New Jersey. I received several specimens of it from Dr. Torrey about the year 1825, but they were all very impure, and so mixed that it was not in my power to draw up accurate descriptions, or even to deduce proper consequences from the analyses which I made. One mineral, to which Dr. Torrey had given the name of *manganesian garnet*, I analyzed; but the specimen was very impure. I concluded that it is a compound of

4 atoms silicate of manganese,
1 atom silicate of iron,

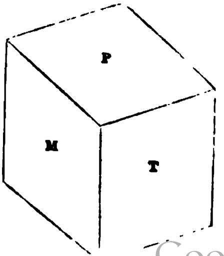
and therefore gave it the name of *ferrosilicate of manganese*. Under that name, an imperfect description, and analysis of it was published in the Annals of the Lyceum of New York for 1828.

Another of the specimens which I received from Dr. Torrey, was a mixture of small yellow grains (probably *garnet*,) and a blackish matter in scales or small plates. These plates I analyzed, and found them composed of *sesquisilicate of manganese*, mixed with a little sesquisilicate of iron. Under the name of *sesquisilicate of manganese*, an imperfect description and analysis of them is inserted in the same number of the Annals of the Lyceum.

Since that time, I have received much finer specimens of this mineral by the kindness of Mr. Nutall. These specimens enabled me to select much purer pieces for an analysis, than I had before. The result of a new investigation has been, that the mineral which I called *ferrosilicate of manganese*, is in reality a sesquisilicate, and consequently identical with the small black plates to which I had already given that name.

Colour brown, with a very slight shade of red.

Texture foliated. Crystallized in six or eight-sided prisms, which are said to be several inches in length, and an inch in diameter; but I have never seen any of these prisms. Texture foliated, with a threefold cleavage, indicating for the primary form of its crystal a doubly oblique prism. M on T (as near as I could measure by the common goniometer) 56° 30′. The inclination of P, the base of the prism, to the axis, is about 108°.



Lustre vitreous, shining.

Opaque.

Hardness 6·25. Specific gravity 3·586.

The constituents, determined by the analysis of a very pure specimen, are

			Atoms.
Silica,	42·40	21·2	1·88
Protoxide of manganese,	50·72	11·27	1
Protoxide of iron,	6·76	1·5	0·13
	99·88		

This obviously corresponds with

8 atoms sesquisilicate of manganese,
1 atom tersilicate of iron.

And if we admit the tersilicate of iron to be an accidental impurity, the mineral will be a pure sesquisilicate of manganese.

Sp. 5. *Bisilicate of Manganese.*

Red mangankiesel.

This mineral was first observed at Longbanshyttan, Wermeland, Sweden. It was afterwards observed in Cornwall, in a manganese quarry about a mile and a half south-west of Callington. It occurs also on Blackdown, near Tavistock in Devonshire. I have specimens from the United States, and various other localities might be mentioned.

Colour rose-red, paler than that of the carbonate of manganese.

Massive. According to Rose two cleavages may be determined, making with each other an angle of about 87° 5′, which is the angle of *pyroxene*.

Fracture flat conchoidal.

Lustre intermediate between pearly and resinous.

Translucent on the edges; brittle.

Hardness 7; specific gravity, as determined by Berzelius, 3·538. I found that of a specimen from Franklin, New Jersey, 3·383, but it was impure.

Before the blowpipe it becomes dark brown, and fuses into a reddish-brown globule.

Its constituents are as follows:

Silica,	48·00	40·58
Protoxide of manganese,	48·98	38·92
Protoxide of iron,	trace	13·50
Lime,	3·12	—
Magnesia,	0·22	—
Water,	—	3·00
Carbonic acid,	—	3·23
	100·32*	99·23†

The specimen analyzed by Berzelius, which was obviously much purer than mine, gives the following numbers as the atomic constituents:

		Atoms.
Silica,	24	2·2
Protoxide of manganese,	10·88	1
Lime,	0·9	
Magnesia,	0·08	

Admitting the lime and magnesia, and a small portion of the silica, to be accidental impurities, it is obvious that the mineral is a compound of

2 atoms silica,
1 atom protoxide of manganese.

Or it is a bisilicate of manganese.

In the American specimen analyzed by me, there existed a little carbonate of iron and a little bisilicate of iron, doubtless accidentally mixed with the bisilicate of manganese, which constituted the greatest portion of the mineral, and gave it its character.

2. *Double Salts.*

Sp. 1. *Huraulite.*

This mineral occurs at Hureaux in the Commune of St. Sylvester (Haute Vienne). It was found by M. Alluau about the year 1824, and sent to Vauquelin for analysis. Vauquelin inserted an analysis of it in the *Annales des Chimie et de Physique.*‡ Since that time, a more minute description and detached analysis have been published by M. Dufresnoy.§

Colour reddish yellow.

Crystallized. The crystals are small, not exceeding the

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* By Berzelius's analysis. The specimen was from Longbanshyttan. Schweigger's Jour. xxi. 254.

† By my analysis. The specimen was from Franklin, New Jersey.

‡ Tom. xxx. p. 302.

§ Ann. de Chim. et de Phys. xli. 338.

head of a pin. Primary form a right oblique prism, with angles of 117° 30′ and 62° 30′. In most of the crystals this prism terminates in two faces, meeting like the roof of a house, and forming with each other an angle of 88°. Sometimes the oblique edges of the prism are replaced by tangent planes.

Lustre vitreous; transparent.

Rather hard; specific gravity 2·270.

Fuses readily before the blowpipe into a bluish bead, having the metallic lustre.

When heated gives out much water.

Its constituents, as determined by M. Dufresnoy, are

		Atoms.	
Phosphoric acid, .	38·00 .	8·44 .	6·8
Protoxide of iron, .	11·52 .	2·56 .	2·08
Protoxide of manganese,	33·305 .	7·40 .	6
Water, . .	18·00 .	16 .	13
	100·825		

These numbers approach pretty nearly to

6 atoms phosphate of manganese,
2 atoms diphosphate of iron,
13 atoms water.

This mineral constitutes a small vein in granite, in the neighbourhood of Limoges.

Sp. 2. *Bustamite.*[*]

This mineral was first noticed as new, by M. Bustamente of Mexico. It occurs accompanied by quartz and manganese at Real de Minas de Fetela, and at Ionotlæ, in the province of Publa, Mexico.

It has the form of spherical masses, having a radiated or almost laminated structure. Its colour is pale grey, with a slight tint of green or red. Slightly translucent when in thin splinters. Hardness 6·5; specific gravity 3·12 to 3·25.

Its constituents, according to the analysis of Dumas, are

		Atoms.
Silica, ...	48·90 .	24·45
Protoxide of manganese,	36·06 .	8·01
Lime, ...	14·57 .	4·16
Protoxide of iron, . .	0·81 .	0·18
	100·34	

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[*] Ann. des Mines (2d series), i. 272.

These numbers are obviously equivalent to
2 atoms bisilicate of manganese,
1 atom silicate of lime.
The formula is $2mnS^2+CalS^2$.

Sp. 3. *Ferruginous Silicate of Manganese.*

This mineral occurs at Sparta in New Jersey, and was noticed and examined by Messrs. Keating and Vanuxem, according to whom, it is a *silicate of zinc.* I got specimens of it from Dr. Torrey, about the year 1825, examined its composition, and published an account of it under the name of *ferruginous silicate of manganese,* in the Annals of the Lyceum of Natural History of New York, for 1828.

Colour brown with a slight shade of red; powder flea brown.

It occurs crystallized in six-sided prisms, terminated by low three-sided pyramids. The faces and edges of these pyramids are imperfect and dull, as if they had undergone partial fusion or corrosion. Hence it is impossible to measure the angles. According to Dr. Troost, the primary form is a cube. From this shape it passes into the rhomboidal dodecahedron. But I do not see how a cube could be converted into a regular six-sided prism, terminated by trihedral summits. This seems to require a rhomboid for the primary form. My own measurements led to the inference, that the primary form is an obtuse rhomboid, with angles of 124° and 56°. But the crystals in my possession are so imperfect, that no confidence can be put in any conclusion founded on them.

Foliated; but rather imperfectly so, and I could make out no distinct cleavages.

External lustre glimmering, internal shining, semimetallic; opaque; brittle.

Hardness 2·25; specific gravity 3·014 to 3·034.

Dissolves with effervescence in muriatic acid, some carbonic acid gas being evolved.

I found it composed of

		Atoms.
Silica, . .	30·650 .	15·32
Protoxide of manganese,	46·215 .	10·27
Peroxide of iron, .	15·450 .	3·09
Moisture and carbonic acid,	7·300 .	6·48
	99·615	

By exposing 100 grains of the mineral to a red heat, I extricated from it 0·1 cubic inch of carbonic acid gas, 0·16 cubic inch of oxygen gas, and 0·74 cubic inch of azotic gas. It is obvious from this, that the quantity of carbonic acid is too small to enter into the calculation of the constituents of the mineral.

The atomic numbers approach

3 atoms silicate of manganese,
1 atom sesquisilicate of iron,
2 atoms water.

From the phenomena during the analysis, it was evident that a portion of the manganese was in the state of sesquioxide. A corresponding portion of the iron was of course in the state of protoxide. But the portion of the mineral in my possession was too small to enable me to investigate the subject more completely.

Sp. 4. *Carbo-Silicate of Manganese.*

Horn-mangan.

This species was discovered by mine-commissioner Jasche, at Ilsenberg in the Lower Hartz, and described by him in a small book published in 1807. It was subjected to a chemical analysis in 1819 by Dr. Du Mesnil of Wunstorf.* Soon after, an analysis by Dr. Rudolph Brandes, together with a description by Professor Germar of Hallé, was given to the public.†

Colour chestnut brown, yellowish brown, and sometimes greenish or even bluish grey.

Massive.

Fracture flat conchoidal, uneven and splintery.

Lustre glimmering or dull.

Translucent, at least on the edges.

Hard enough to scratch glass; brittle.

Specific gravity of the splintery variety, according to Germar, 3·89; of the conchoidal variety, according to Jasche, from 3·10 to 3·50.

Phosphoresces before the blowpipe, and softens on the edges. Gives a hyacinth red colour to borax.

Its constituents, according to the analysis of Brandes,‡ are as follows:

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* Gilbert's Annalen, lxi. 190. As M. du Mesnil's analyses are not accompanied by descriptions, it is not easy to identify his species. I have not, on that account, ventured to use his analysis in the text.

† Schweigger's Jour. xxvi. 103.

‡ Ibid. 121.

	*	†	‡
Silica,	34	31	35
Carbonic acid,	8	10	5
Protoxide of manganese,	54·857	54·929	57·162
Water,	2·0	1·5	2·50
Oxide of iron,	0·5	0·5	0·25
Lime,	trace	1·0	0·101
Alumina,	trace	0·5	0·25
	99·357	99·429	100·263

The following table exhibits the atomic numbers deduced from these analyses:

	Atoms.			Mean.
Silica,	17	15·5	17·5	17
Carbonic acid,	2·9	3·63	1·83	2·44
Protoxide of mangan.,	12·19	12·20	12·70	12·36

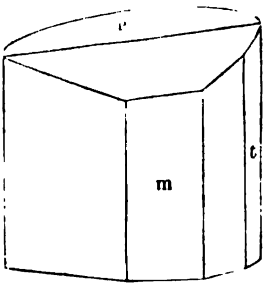
The mean of these numbers gives us pretty nearly (allowing for a small excess of manganese)

1 atom carbonate of manganese,
4 atoms bisilicate of manganese.

Sp. 5. *Babingtonite.*

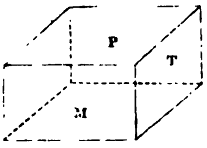
This name was given by Mr. Levy to some crystals which he observed on *albite* from Arendal, which, from their shape, he considered as constituting a peculiar species.§

Colour black; lustre splendent, and probably vitreous.



The crystals were usually eight-sided prisms, as in the margin. In some, the plane m and the opposite plane were wanting, reducing the number of faces to six. These crystals cleave easily and with brilliant surfaces, parallel to the planes P, t. Mr. Levy considers the primary form to be a doubly oblique prism, in which

P on M 92° 34′
P on T 88°
M on T 112° 30′



Hard enough to scratch glass; opaque.

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* The conchoidal variety. † The uneven variety.

‡ The splintery variety. § Annals of Philosophy (2d series), vii. 275.

Specific gravity not determined.

Mr. Children* found its behaviour before the blowpipe as follows:

It decrepitates when heated in a glass tube, giving out water; but is not altered in its appearance.

Fuses per se into a black enamel.

With carbonate of soda in the oxidizing flame, it fuses into a dark green opaque globule, the colour of which is heightened by nitre. In the reducing flame, the colour became nearly black. To borax it gave a violet colour, which in the reducing flame became bluish green.

Mr. Children found the constituents to be silica, oxides of iron, and manganese, and lime; but the quantity of the mineral in his possession was not sufficient for a chemical analysis.

3. *Triple Salts of Manganese.*

Sp. 1. *Helvine.*

This mineral was discovered in 1815 or 1816, at Schwartzenberg in Saxony, in beds of talc slate in gneiss, by Mohs. It was named by Werner and described by Freisleben.

Colour wax yellow, inclining to honey yellow and yellowish brown. It is said also to have occasionally a siskin green colour; streak white.

It occurs in very small crystals, which appear at first sight to have the form of irregular octahedrons. According to Cordier, the primary form is an acute rhomboid, the plane angles of which are 72° and 108°. The two summits of this rhomboid are usually replaced by planes perpendicular to the axis. This face is inclined to the adjacent planes of the rhomboid at an angle of 105° 30′. Sometimes this truncature of the summit is slight, but in general it cuts off about ⅓d of the axis at both extremities of the rhomboid, and thus converts it into an irregular octahedron.†

Lustre vitreous, inclining to resinous.

Translucent on the edges; fracture uneven.

Hardness 6·5; specific gravity, as determined by Gmelin, 3·166.

Before the blowpipe on charcoal, it melts in the reducing flame into a globule, having nearly the colour of the original assay. In the oxidizing flame the colour becomes dark, and

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* Annals of Philosophy (2d series), vii. 277.

† Ann. des Mines, iii. 10.

the fusion more difficult. With borax it yields a transparent glass, often coloured by manganese.

It may be dissolved (if in powder) in muriatic acid, and sulphuretted hydrogen gas is given out abundantly.

It was analyzed by Professor C. G. Gmelin,* who obtained the following constituents:

		Atoms.	
Silica, . .	33·258	16·63	13·5
Glucina with some alumina,	12·029	3·7	3
Protoxide of manganese,	31·817	7·07	5·74
Protoxide of iron, .	5·564	1·23	1
Sulphuret of manganese,	14·000	2·54	2·06
Loss by ignition, .	1·155		
	97·823		

He examined the mineral for fluoric acid, but could detect none.

The presence of sulphuret of manganese, renders it difficult to form an accurate conception of the nature of this mineral. So far as we know at present, it does not enter into chemical combination with oxygen salts. We must therefore consider it as an accidental mixture. The other constituents seem to be

1 atom bisilicate of iron,
3 atoms bisilicate of glucina,
6 atoms silicate of manganese.

The sulphuret of manganese amounts to two atoms.

It would be desirable that the nature of this curious mineral could be still more completely investigated. But its scarcity has hitherto put it out of the power of chemists to make the requisite experiments on it.

GENUS XVII.—NICKEL.

The ores of nickel are few in number, and what is curious, the metal is rarely met with except in combination with sulphur or arsenic, or both. These ores occur most commonly in veins which traverse the primitive formations.

The species of nickel ores hitherto observed, amount only to eight. Of these, three are salts, and five combinations of nickel with sulphur or arsenic.

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* Poggendorf's Annalen, iii. 55.

1. *Nickel combined with Simple Bodies.*

Sp. 1. *Sulphuret of Nickel.*

Haarkies.

This mineral was first found in Adolphus mine at Johann Georgenstadt. It has been found also near Salzburgh, in the Hartz, and in Cornwall in Huel Chance mine, near St. Austle.

Colour intermediate between steel grey and brass yellow.

It occurs in small capillary crystals, the shape of which has not been ascertained.

Lustre metallic, shining; opaque; brittle.

Heavy; but the specific gravity has not been determined.

When heated in a glass tube it exhales sulphurous acid. On charcoal, before the blowpipe, it half melts into an agglutinated mass, which is metallic, malleable, and magnetic, and consists wholly of nickel.

Klaproth, from an analysis made by him, concluded it to be native nickel.[*] Berzelius having examined it by the blowpipe, concluded that it was a sulphuret of nickel. This opinion was confirmed by Arfvedson,[†] who subjected it to a chemical analysis, and found its constituents

		Atoms.
Sulphur,	34·26	17·13
Nickel,	64·35	19·8
	98·61	

This approaches pretty near

1 atom sulphur,
1 atom nickel.

Indeed the analysis comes much nearer these numbers than Arfvedson has allowed it. There is no reason to doubt, then, that haarkies is a simple sulphuret of nickel.

Sp. 2. *Arseniet of Nickel.*

Cupfer nickel.

This is the most common species of nickel ore. It occurs usually in veins; very rarely in beds. It is found both in primary and secondary rocks. Thus it occurs at Schneeberg, Annaberg, Marienberg, Freyberg, Gersdorf, and other places in Saxony, in various parts of Germany, at Allemont in Dau-

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[*] Beitrage, v. 231.

[†] Kong. Vet. Acad. Handl., 1822, p. 443.

phiné; in Cornwall it is found in Pengelly mine, and in Huel Chance. In Scotland it has been found in the Leadhills, and at Wanlockhead. It is said also to have been met with in Linlithgowshire. Many other localities might be named.

Colour copper red; streak pale brownish black.

Usually massive; but it is said to have been seen crystallized in six-sided prisms.

Fracture small conchoidal, uneven.

Lustre metallic; opaque; brittle.

Hardness 5·5; specific gravity 7·655.

Before the blowpipe on charcoal it emits arsenical fumes and melts into a bead, which darkens by exposure to the air.

The following table exhibits the constituents of this mineral according to the best analyses of it hitherto made:

	*	†	‡	Atoms.	
Nickel, .	48·90	39·94	44·206	13·6	1·18
Arsenic, .	46·42	48·80	54·726	11·5	1
Iron, . .	0·34	trace	0·337		
Sulphur, .	0·80	2	0·401		
Antimony, .	—	8	—		
Lead, .	0·56	—	0·320		
Cobalt, .	—	0·16	—		
	97·02	98·90	99·990		

The atoms, deduced from Stromeyer's analysis, (whose specimen was by far the purest,) lead to the conclusion that copper nickel is a compound of

1 atom arsenic,
1 atom nickel,

and that therefore it is a simple arseniet of nickel.

Sp. 3. *Subsesquiarseniet of Nickel.*

This mineral, though it has not been found native, but is only a produce of the smelting houses, deserves to be described on account of its character and constitution.

It occurs in crystals on the impure arseniet of nickel called *speiss*.

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* Pfaff, Schweigger's Jour. xxii. 256. The specimen was from Riegelsdorf, and obviously mixed with iron pyrites and galena.

† Berthier, Ann. des Mines, iv. 467. The specimen was from Allemont and obviously mixed with subsesquisulphide of antimony.

‡ Stromeyer, as quoted in Mohs' Mineralogy, ii. 447.

The colour is tombac brown, sometimes with a tint of steel blue.

In crystals. The shape is an octahedron with a square base. In general the summit of the pyramid is truncated, sometimes so deeply as to give the crystal the form of a table with bevelled edges.

Lustre shining, metallic.

Very brittle, easily reduced to powder, and not magnetic.

Opaque.

Specific gravity and hardness not given.

Before the blowpipe it behaves like arseniet of nickel.

The constituents of this mineral, determined by the analysis of Wöhler,* are

Arsenic, . .	44·1
Nickel, . . .	52·7
Copper, iron, and manganese,	1·6
Sulphur, . .	1·65
	100·05

Or leaving out the accidental impurities,

			Atoms.
Arsenic,	45·87	9·65	1
Nickel,	54·13	16·65	1·75
	100·00		

These numbers approach sufficiently near

1 atom arsenic,

1½ atom nickel,

to leave no doubt about the constitution of the mineral. It is a subsesquiarseniet of nickel.

Sp. 4. *Binarseniet of Nickel.*

This mineral occurs at Schneeberg. It has been described and analyzed by Dr. Hoffmann.†

Colour tin-white.

Massive, and mixed with small concretions of quartz; fracture uneven.

Lustre metallic; opaque.

Surface often covered with a thin coating of diarseniate of nickel.

Its constituents are

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* Poggendorf's Annalen, xxv. 302.

† Ibid. xxv. 491.

			Atoms.
Sulphur,	0·14	.	0·07
Copper,	0·50	.	0·12
Bismuth,	2·19	.	0·27
Arsenic,	71·30	.	15
Nickel,	28·14	.	8·65
	102·27		

Allowing the other constituents to be accidental, the mineral is a compound of

2 atoms arsenic,
1 atom nickel.

Or it is a *binarseniet of nickel.*

A variety of this mineral occurs in the cobalt mine of Riegelsdorf in Hesse, differing merely by containing a little cobalt. It is crystallized in hexahedrons, with the angles and edges truncated. Doubtless the primary form is a cube. The colour is tin-white.

Before the blowpipe, on charcoal, it gives out much arsenic, and fuses into a brittle metallic button. This button gives with borax a blue glass, indicating cobalt. If after this the button be fused with biphosphate of soda, we have the reaction of nickel; namely, a clove-brown transparent glass in the outer, and a brown opaque glass in the inner flame. Its constituents, as determined by the analysis of Mr. Booth, are

			Atoms.		
Nickel,	20·74	.	6·38	.	6·19
Cobalt,	3·37	.	1·03	.	1
Iron,	3·25	.	0·92	.	0·89
Arsenic,	72·64	.	15·29	.	14·84
	100*				

Obviously composed of

6 atoms binarseniet of nickel,
1 atom binarseniet of cobalt,
1 atom binarseniet of iron.

Sp. 5. *Antimoniet of Nickel.*

This mineral was discovered by M. Volkmar of Brunswick, it occurs in the Andreasberg mountains, associated with calcareous spar, galena and speiss cobalt, and has a strong resemblance to *copper nickel,* though it differs from it in colour.

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* Poggendorf's Annalen, xxxii. 395.

Colour in the fresh fracture light copper-red, inclining strongly to violet; powder reddish-brown.

Occurs crystallized in short six-sided prisms, which appear to be regular; sometimes they are terminated in six-sided pyramids.

Fracture uneven, passing into small conchoidal.

Lustre metallic, splendent.

Brittle.

About the hardness of copper nickel.

Specific gravity not determined.

Not acted on by the magnet.

Before the blowpipe some antimony sublimes.

Its constituents, as determined by Stromeyer, are

	1st Anal.	2nd Anal.	Atoms.	
Nickel, .	28·946	27·054	17·23	1·11
Antimony, .	63·734	59·706	15·43	1
Iron, . .	0·866	0·842		
Sulphuret of lead,	6·437	12·357		
	99·983	99·959		

The constituents are doubtless 1 atom nickel and 1 atom antimony.*

2. *Oxygen Salts.*

Sp. 1. *Diarseniate of Nickel.*

This salt has been observed at Allemont in Dauphiny, adhering to arseniet of nickel. It is supposed to be formed by the spontaneous decomposition of that mineral by the action of the air.

It is compact and has a fine apple-green colour. Its constituents, as determined by the analysis of Berthier,† are as follows:

		Atoms.	
Protoxide of nickel,	36·2 .	8·51	1·99
Protoxide of cobalt,	2·5 .	0·58	
Arsenic acid, .	36·8 .	5·07 .	1
Water, .	24·5 .	21·77 .	4·29
	100		

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* Haussmann and Stromeyer, Poggendorf's Annalen, xxxi. 134.

† Ann. de Chim. et de Phys. xiii. 56.

If we reckon the oxide of cobalt along with that of nickel, the constitution is obviously

1 atom arsenic acid,
2 atoms protoxide of nickel,
4 atoms water.

It is therefore a hydrous diarseniate of nickel.

3. *Sulphur Salts of Nickel.*

Sp. 1. *Sulpho-Arsenide of Nickel.*

Nickel glance.

This mineral occurs at Loos in Helsingland. It was first noticed by Cronstedt;[*] but Pfaff[†] first described and analyzed it.

Colour tin-white; streak similar.

Massive; texture granular. In one variety the grains are rounder, in another they are less equal.

Lustre shining, metallic; opaque.

Hardness about 5; specific gravity 6·129.

When heated it decrepitates with great violence. When ignited in a glass tube, it leaves a matter similar to copper nickel, while sulphide of arsenic sublimes. Another variety, when heated in the same way, leaves a silver-white mass, and gives out also sulphide of arsenic.[‡] Berzelius[§] subjected it to four different analyses, conducted each a different way. The result is as follows:—

Arsenic, . .	55·50	53·32	48·06	45·37
Sulphur, . .	12·67	14·40	19·29	19·34
Nickel, . .	28·17	27·00	30·80	29·94
Iron, . .	3·63	5·29	2·99	4·11
Copper with cobalt,	—	—	—	0·92
Silica, . .	0·61	—	1·00	0·90
	100·58	100·01	102·14	100·58

The mean of these analyses gives us the following numbers:

		Atoms.
Arsenic,	50·56 .	10·64
Sulphur,	16·42 .	8·21
Nickel,	28·98 .	8·91
Iron,	4·00 .	1·14

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[*] See Cronstedt's Mineralogy, by Magellan, ii. 342.

[†] Schweigger's Jour. xxii. 260.

[‡] Berzelius, Kong. Vet. Acad. Handl., 1820, p. 240.

[§] Ibid p. 241.

If we admit the iron to have been in combination with arsenic, and to have been accidental, it is obvious that the mineral contains

1 atom arsenic,
1 atom sulphur,
1 atom nickel.

If we double these atoms and consider the sulphur as combined with each of the bases, it is obvious that the two constituents of the mineral will be

$\left.\begin{array}{l}\text{1 atom sulphur,}\\ \text{2 atoms arsenic,}\end{array}\right\}$ making 1 atom disulphide of arsenic.

$\left.\begin{array}{l}\text{1 atom sulphur,}\\ \text{2 atoms nickel,}\end{array}\right\}$ making 1 atom disulphuret of nickel.

The first of these compounds is a sulphur acid, the second a sulphur base. Hence we may consider nickel glance as composed of

1 atom disulphide of arsenic,
1 atom disulphuret of nickel.

Sp. 2. *Sulpho-Antimonite of Nickel.*

This mineral was observed in Albertine, an old abandoned mine near Harzgerode, the working of which was resumed about the year 1825. It was particularly noticed by M. Zinken,[*] described by M. G. Rose,[†] and analyzed by M. H. Rose.[‡]

Colour white, exactly similar to that of arsenic pyrites.

Crystallized. The primary form is the cube. The angles of this cube are usually replaced by small planes. When these planes increase sufficiently, they convert the cube into the regular octahedron.

Lustre metallic, splendent; opaque.

Hardness 5·5; specific gravity 6·097.

Its constituents, determined by two analyses of H. Rose, are as follows:

			Mean.	Atoms.	
Sulphur,	15·98	15·55	15·76	7·88	1·14
Antimony,	55·76	54·47	55·11	6·88	1
Nickel,	27·36	28·04	27·70	12·31	1·79
	99·10	98·06			

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[*] Poggendorf's Annalen, xiii. 165.

[†] Ibid p. 167.

[‡] Ibid xv. 590.

These numbers approach to

1 atom sulphur,
1 atom antimony,
2 atoms nickel.

The simplest way in which they can be supposed united is

1 atom antimony, } making 1 atom antimoniet of nickel.
1 atom nickel, }
1 atom sulphur, } making 1 atom sulphuret of nickel.
1 atom nickel, }

The mineral would appear to be a compound of

1 atom antimoniet of nickel,
1 atom sulphuret of nickel.

GENUS XVIII.—COBALT.

The ores of this metal are rather scarce, and they occur most frequently in the primary formations. Like nickel, it is almost always associated with arsenic or sulphur.

1. *Cobalt combined with Simple Bodies.*

Sp. 1. *Sulphuret of Cobalt.*

Cobaltkies, in part.

This mineral occurs at Bastnäs in Rydderhyttan, and was first noticed by Brandt, in 1746, who made several experiments on it and showed that it contained no arsenic.* It was noticed by Cronstedt, who refers to the observations of Brandt,† and by Bergmann, who refers to Cronstedt.‡ It constitutes one of the subspecies of Werner's *white speiss-cobalt;* but its true chemical nature has not been properly pointed out in any mineralogical work that I have seen.

Colour greyish-white or light steel-grey.

Massive; occurs in kidney-form or round pieces of various sizes, showing here and there some brilliant surfaces; but no crystalline shape can be detected.

Texture compact; fracture uneven and granular; lustre metallic; opaque.

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* Kong. Vet, Acad. Handl., 1746, p. 119.

† Magellan's Cronstedt, ii. 830.

‡ Sciographia, p. 109. Withering's translation.

Not attracted by the magnet unless it has been roasted.

Neither its hardness nor specific gravity have been determined.

When heated before the blowpipe it emits the smell of sulphur, without any mixture of an arsenical odour. It assumes a dark grey colour and melts into a bead, externally dark grey, but internally light grey, shining and brittle. After this treatment it gives with borax a dark blue glass and a white regulus, which is not attracted by the magnet unless it be pulverized.

It occurs in small quantities in the new Bastnäs mine, along with actinolite and copper pyrites.

Its constituents, determined by the analysis of Hisinger,[*] are

			Atoms.
Cobalt,	43·20	13·29	1
Copper,	14·40	3·60	0·27
Iron,	3·53	1·00	0·07
Sulphur,	38·50	19·25	1·45
Gangue,	0·33		
	99·96		

If we consider the copper and iron as accidental impurities, which is exceedingly probable, the mineral is a compound of

1½ atom sulphur,
1 atom cobalt,

or a sesquisulphuret of cobalt.

If the iron be in the state of cubic pyrites, and the copper a common sulphuret, then the cobalt will be a simple sulphuret, or a compound of

1 atom sulphur,
1 atom cobalt.

Sp. 2. Sesquiarseniet of Cobalt.

Radiated white cobalt.

This mineral occurs at Schneeberg, in Saxony, and is noticed by Werner among the subdivisions of his *white cobalt.*

Colour tin-white, usually very dark, and inclining to grey.

Massive. Has not been observed in crystals.

Structure radiated; lustre metallic.

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[*] Afhandlingar, iii. 316.

Opaque; brittle; hardness 5·5.

Specific gravity not determined.

Its constituents, according to the analysis of John,* are.

			Atoms.
Arsenic,	65·75	13·84	1·60
Cobalt,	28·00	8·61	1
Iron with manganese,	6·25	1·78	0·20
	100·00		

If we admit the iron to be in the state of diarseniet, it is obvious that the cobalt is combined with 1½ atom arsenic. The mineral therefore is a ***sesquiarseniet of cobalt***, composed of

1½ atom arsenic,
I atom cobalt.

Sp. 3. *Binarseniet of Cobalt.*

Speisscobalt in part. White cobalt ore.

This species occurs chiefly in veins traversing primary rocks. It is found in various parts of Saxony, as Schneeberg, Annaberg, Freiberg and Marienberg; also at Joachimsthal, in Bohemia, and at Huel Sparnan, in Cornwall. Various other localities might be mentioned.

Colour tin-white, inclining to steel-grey; streak greyish-black.

It occurs most commonly crystallized, and the primary form is the cube, with the same modifications which characterize iron pyrites. It cleaves in the direction of the cube, the octahedron, and rhomboidal dodecahedron.

Fracture uneven.

Faces usually smooth, subject to tarnish.

Lustre metallic.

Opaque; brittle.

Hardness 5·5; specific gravity 6·466.

Before the blowpipe emits copious arsenical fumes, and melts into a white metallic globule. To borax and other fluxes it imparts a blue colour.

It affords a pink solution in nitric acid, leaving a white residue, which is itself dissolved on farther digestion.

Its constituents are as follows:

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* As quoted in Mohs' Mineralogy, ii. 455.

	*	†	Atoms.	
Arsenic,	74·2174	70·37	15·62	16¼
Cobalt,	20·3135	13·95	6·25	6½
Iron,	3·4257	11·71	0·96	1
Copper,	0·1586	1·39	0·04	
Nickel,	—	1·79		
Bismuth,	—	0·01		
Sulphur,	0·8860	0·66	0·44	
	99·0012	99·88		

The specimen analyzed by Stromeyer being by far the purest, has been chosen for determining the atomic proportions.

If we admit that the copper, and a portion of the arsenic, are in the state of sulphurets, then the mineral will consist of binarseniets, and will consist of

6½ atoms binarseniet of cobalt,
1 atom binarseniet of iron.

Sp. 4. *Terarseniet of Cobalt.*

This mineral occurs at Schneeberg in Saxony. For its description and analysis, we are indebted to Mr. Ch. Karsten.[‡]

Colour lead-grey, sometimes steel-grey; texture radiated.

Lustre metallic, in some parts splendent, in others only slightly shining.

From the mixture of quartz grains, gives fire with steel.

Has no smell of arsenic. Specific gravity, owing to the mixture of quartz, varies from 4·5 to 4·7. If we abstract the quartz grains, it will be from 6·0 to 6·7.

Its constituents, (abstracting the quartz, which varies from 0·975 to 32·325 per cent.) are as follows:

		Atoms.
Arsenic,	77·9602	16·41
Cobalt,	9·8866	3·04
Iron,	4·7695	1·36
Bismuth,	3·8866	0·48
Copper,	1·3030	0·32
Nickel,	1·1063	0·34
Sulphur,	1·0160	0·51
Magnesia,	trace	
	99·9282	

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[*] Stromeyer, Annals of Philosophy, x. 228.

[†] Ern. Hoffmann, Poggendorf's Annalen, xxv. 492. The specimen was from Sauschwart mine, Schneeberg, and was grey speisscobalt.

[‡] Ann. des Mines (2d series), i. 548.

The sulphur and bizmuth nearly correspond. We may therefore consider that metal in the state of sulphuret; as also a small portion of the iron. The other constituents are obviously in the state of terarseniets, and the mineral consists of

9 atoms terarseniet of cobalt,
4 atoms terarseniet of iron,
1 atom terarseniet of copper,
1 atom terarseniet of nickel.

Should the terarseniets of copper and nickel be only accidentally present, then the mineral would consist of

9 atoms terarseniet of cobalt,
4 atoms terarseniet of iron.

The preceding four species are all arranged by Werner, under the name of *speisscobalt.*

Sp. 5. *Cobalt Ochre.*

This mineral occurs at Saalfield, Kamsdorf, and Glucksbrunn in Thuringia, and in various other places, along with cobalt pyrites.

Colour bluish and brownish-black, and blackish-brown.

Streak shining, even in the friable varieties, with a somewhat resinous lustre.

Botryoidal, stalactitical, massive.

Fracture conchoidal, very fine earthy.

Opaque; sectile; soils but little.

Soft, sometimes passing into very soft.

Specific gravity, as determined by Breithaupt, 2·200.

Before the blowpipe it gives out an arsenical smell, and colours borax smalt-blue.

It has not been analyzed; but is considered as a compound or mixture of the oxides of cobalt and manganese.

The *yellow* and *brown* cobalt ochres are probably only varieties of the black. But an accurate chemical examination will be necessary, before their identity or difference can be considered as established.

2. *Oxygen Salts.*

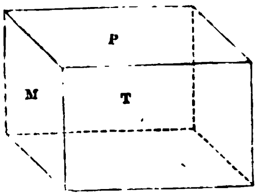
Sp. 1. *Diarseniate of Cobalt.*

Cobalt-bloom. Red cobalt ochre. Cobalt mica.

This mineral occurs in veins traversing rocks of various ages, and also in beds. The principal localities are Schneeberg and Annaberg in Saxony, Platten in Bohemia, Saalfield in Thuringia, &c.

Colour crimson-red, cochineal-red, peach-blossom red. Sometimes it is greenish-grey; streak corresponding to the colour, though a little paler.

It is found in botryoidal masses, and in short acicular diverging prisms, modified on the edges. The primary crystal is a right oblique prism.



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According to the measurement of Mr. Brooke. The terminal edges of the prism are often replaced by one or more new faces.

Lustre of the base of the prism pearly, of the other faces adamantine, inclining to vitreous.

Varies from transparent to translucent on the edges.

Sectile; thin laminæ flexible.

Hardness 1·5 to 2; specific gravity 2·948.

Alone before the blowpipe it assumes a darker colour. On charcoal it gives out abundance of arsenical fumes, and melts into a bead of arseniet of cobalt. With borax and other fluxes it yields a fine blue glass.

Its constituents, according to the analysis of Bucholz,* are

			Atoms.
Arsenic acid,	37·9	5·22	1
Oxide of cobalt,	39·2	9·22	1·77
Water,	22·9	20·35	3·9
	100		

These numbers approach

1 atom diarseniate of cobalt,
4 atoms water.

It is therefore a hydrous diarseniate of cobalt. When all traces of crystallization disappear, the mineral is distinguished by the name of *cobalt crust.*

Disulphate of Cobalt.

Red vitriol.

This mineral occurs in the rubbish of old mines at Bieber, in the neighbourhood of Hanau.

Colour flesh-red and rose-red.

It occurs investing other minerals in small masses and stalactites.

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* Gehlen's Jour. (2d series), ix. 314.

Lustre vitreous.

Semitransparent to translucent.

Friable; taste astringent; soluble in water.

To glass of borax it communicates a blue colour.

Its constituents, according to Kopp,* are as follows:

			Atoms.
Sulphuric acid,	19·74	3·95	1
Protoxide of cobalt,	38·71	9·10	2·30
Water,	41·55	37	9·36
	100·00		

These numbers approach nearest to

1 atom disulphate of cobalt,
9 atoms water.

We may consider this salt therefore as a *hydrous disulphate of cobalt.*

3. *Sulphur Salts of Cobalt.*

Sp. 1. *Sulpho-Arsenide of Cobalt.*

Glance cobalt. Bright white cobalt ore.

This species occurs most commonly in veins. Tuneberg in Sweden is one of its best known localities. It occurs also at Modum in Norway, and at Botallick, near St. Just in Cornwall.

Colour silver-white, inclining to red; streak greyish-black.

Crystals cubes, and the usual modifications of them.

Fracture imperfect conchoidal, uneven. The surface of the cubes streaked in three directions.

Lustre metallic; opaque; brittle.

Hardness 5·5; specific gravity 6·298.

Before the blowpipe gives copious arsenical fumes, and melts only after being roasted.

Its constituents are as follows:

	†	‡	§	Atoms.
Cobalt,	36·7	44	33·1012	10·18
Arsenic,	49·0	55	43·4644	9·15
Iron,	5·6	—	3·2324	0·92
Sulphur,	6·5	0·5	20·0840	10·04
	97·8	99·5	99·8820	

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* Gehlen's Jour. (2d series), vi. 157. † Tassaert, Ann. de Chim. xxviii. 100.
‡ Klaproth, Beitrage, ii. 307. § Stromeyer, Annals of Philosophy, x. 228.

If we include the iron along with the arsenic, it is evident that these numbers correspond with

1 atom cobalt,
1 atom arsenic,
1 atom sulphur.

Doubling these numbers, we have

2 atoms cobalt, } making 1 atom disulphuret of cobalt.
1 atom sulphur, }
2 atoms arsenic, } making 1 atom disulphide of arsenic.
1 atom sulphur, }

The former of these is a sulphur base, the latter a sulphur acid.

The mineral may be conceived as a compound of

1 atom disulphide of arsenic,
1 atom disulphuret of cobalt.

It appears from the analysis of Wernekink,* that there is another species of cobalt ore usually confounded with the preceding species. He found its constituents

		Atoms.
Cobalt,	43·86	13·49
Iron,	5·31	1·51
Copper,	4·10	1·02
Sulphur,	41·00	20·5
Gangue,	0·67	
	94·94	

It is evident at first sight, that the mineral analyzed by Wernekink, is an impure variety of the first species described under the genus *cobalt;* and that it is either a sesquisulphuret or sulphuret of cobalt, according as we consider the other metals united or not with sulphur in the mineral.

The specimen analyzed was from Schwaben mine, near Musen in Siegenschen. Had he given a description, I have no doubt that it would have agreed with the first species of this genus.

GENUS XIX.—ZINC.

Zinc is rather an abundant metal, and accordingly occurs in commerce at rather a low price; yet its ores are far from numerous, at least when we compare them with those of iron, manganese, lead, and copper. Zinc ores are not found asso-

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* Schweigger's Jahrbuch, ix. 306.

ciated with those of any of the four preceding genera; but they almost always accompany those of lead, and sometimes, though more rarely, they are found along with those of copper. Zinc in the metallic state occurs only in combination. In the state of oxide, it constitutes certain salts by entering into combination with an acid.

1. *Zinc combined with Simple Bodies.*

Sp. 1. *Blende, or Sulphuret of Zinc.*

Black Jack.

This mineral is very abundant in nature. It exists both in primary and secondary formations, and both in beds and in veins. It almost always accompanies the ores of lead, and frequently those of copper and tin. Hence it abounds in Cornwall and in Cumberland, Northumberland, Durham, Yorkshire, and Derbyshire. Many other localities might be pointed out, both in Great Britain and on the Continent.

Colour when pure, yellow; but it is often green, red, brown and black, owing to the presence of foreign bodies. None of these colours except the black, is bright. Streak corresponding with the colour.

Structure foliated, and it often occurs crystallized. The primary form is the rhombic dodecahedron, similar to that of garnet. The alternate angles of this dodecahedron are sometimes replaced by triangular faces. These increasing so as to cover the original faces, convert the crystal into the regular octahedron. The angles of this octahedron are occasionally replaced by tangent planes, which, when they increase sufficiently in size, convert the crystal into a cube. These three forms, the rhomboidal dodecahedron, the octahedron and cube, with their usual modifications, constitute the various forms of crystallization which blende assumes.

Lustre adamantine.

Transparent to translucent. The black varieties are often opaque; brittle.

Hardness 3·75; specific gravity 4·049.

Does not melt per se before the blowpipe, but gives out fumes of zinc, which form a white coating on the charcoal.

The following table exhibits the constituents of this ore, as determined by analysis:

	*	†	‡	‡	‡	‡	§	§
Zinc, . .	66·34	55·2	63·0	61·5	50·2	42·3	66	66·63
Iron, . .	—	8·6	3·4	4·0	10·8	7·3	1·372	20·74
Lead, . .	—	—	—	—	—	3·0	—	—
Sulphur, . .	33·66	36·2	33·6	33·0	30·2	25·9	32·628	32·63
Gangue, . .	—	—	—	1·5	6·8	21·4	—	—
	100	100	100	100	98	99·9	100	100

These numbers obviously correspond with
1 atom sulphur,
1 atom zinc.

Blende then is a simple sulphuret of zinc.

Sp. 2. *Voltzine.*

Oxysulphuret of zinc.

This mineral occurs at Rosiers, near Pont-Gibaud, in the department of Puy de Dome. It is found in a vein coating the other substances which fill the vein.

It occurs in the form of hemispherical tubercles, divisible into very thin coats, but having a conchoidal and irregular fracture.

Opaque, or feebly translucent.

Lustre pearly on the natural coats, but vitreous or resinous in other directions.

Colour yellowish red, interspersed with brown bands, seemingly coloured by an organic matter.

Hardness 4·5; specific gravity 3·66.

Its constituents, as analyzed by M. Fournet, to whom we are indebted for our knowledge of this mineral, are

			Atoms.
Sulphuret of zinc, .	81·0 .	12·96 .	4·54
Oxide of zinc, .	15·0 .	2·85 .	1
Oxide of iron, .	1·8 .	0·36	
Organic matter, .	2·2		
	100·0		

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[*] Arfvedson, Kong. Vet. Acad. Handl., 1822, p. 438.

[†] Lecanu, Ann. des Mines, ix. 418. It was a brown red lamellar blende from Cheronies.

[‡] Berthier, ibid. p. 420. The first specimen a brown blende, from Luchon, Pyrenees. The second, a dark grey specimen, from England. The third, a brown blende, from Cagolin, department of the Var. The fourth, a brown blende, from Argentiere.

[§] By my analysis.

Hence the component parts are

4½ atoms sulphuret of zinc,
1 atom oxide of zinc.

It was called Voltzite in honour of M. Voltz, engineer in chief of mines.

Sp. 3. *Seleniet of Zinc.*

This mineral was discovered in the mining district of Mexico, called El Doctor, and was examined and its nature discovered by Professor Del Rio, in 1817.

It has a grey colour, the metallic lustre, is opaque, and has a specific gravity of 5·56. Before the blowpipe it burns with a fine violet coloured flame, and exhales a strong smell, similar to that of rotten cabbage. When heated in a retort, selenium, mercury, and a little sulphur sublimes, and there remains an oxide of zinc easily soluble in acids.

Its constituents, according to the analysis of Del Rio, are as follows:

		Atoms.	
Selenium,	49	9·8	6·2
Zinc,	24	5·64	3·57
Mercury,	19	1·58	1
Sulphur,	1·5	0·75	0·47
Lime,	6		
	99·5		

The lime was an accidental impurity, derived from the gangue of the mineral. These numbers approach nearest to

3½ atoms biseleniet of zinc,
1 atom disulphuret of mercury.

Whether the disulphuret of mercury be in combination with the biseleniet of zinc, or only mechanically mixed with it, has not been ascertained.

Sp. 4. *Red Zinc.*

Manganesian oxide of zinc.

This mineral has hitherto been found only in Sussex county, New Jersey, where it occurs in considerable quantities in several localities, probably in beds. It was first noticed, described, and analyzed by Dr. Bruce.

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* Ann. des Mines (3d series), iii. 519.

Colour bright red, with a shade of yellow; streak orange yellow.

Occurs in grains which are foliated, and cleave in the direction of a regular six-sided prism, according to Mr. W. Phillips.

Cross fracture conchoidal; brittle.

Lustre adamantine.

Translucent; in thin plates transparent.

Hardness 4; specific gravity 5·432.

When exposed to the air it becomes dull, and is covered with a white coating.

Infusible per se before the blowpipe; but it gives a yellow transparent glass with borax.

Soluble in nitric acid without effervescence.

Its constituents, as determined by Berthier,* are

			Atoms.
Oxide of zinc,	88	16·58	6·9
Sesquioxide of manganese,	12	2·4	1
	100		

These numbers correspond with

7 atoms oxide of zinc,
1 atom sesquioxide of manganese,

which must be the constitution of this mineral.

The colour of the mineral, and the difficulty of separating the two constituents from each other, show that the mineral is a chemical compound. The oxide of iron found by Bruce was doubtless owing to the impurity of the specimen selected for analysis, for red zinc occurs imbedded in Franklinite.

2. *Oxygen Salts of Zinc.*

Sp. 1. *Anhydrous Carbonate of Zinc.*

Calamine in part.

This mineral is rather abundant, and is found both in veins and beds, especially in company with galena and blende. It was first accurately distinguished by Mr. Smithson.

Colour white, though seldom pure. Generally grey, green or brown; streak white.

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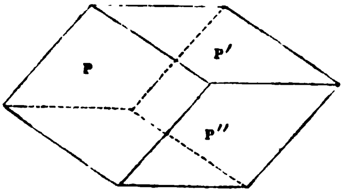
* Ann. des Mines, iv. 483.



It occurs frequently in crystals. The primary form is an obtuse rhomboid.

P on P′ 107° 40′ according to the measurement of Dr. Wollaston. It occurs also in acute rhomboids, and in long quadrilateral tables.

Structure foliated; fracture imperfect conchoidal.

Lustre vitreous, inclining to pearly; semitransparent to translucent; brittle.

Hardness 5; specific gravity, according to Smithson, 4·334. Haidinger found that of a honey-yellow crystallized variety, from Aix-la-Chapelle, 4·442.

Before the blowpipe it loses its transparency, but is infusible. The carbonic acid is driven off, and the residue acts like pure oxide of zinc.

It becomes negatively electric by friction; dissolves in acids with effervescence.

Its constituents, as determined by Smithson, are

	[*]	[*]	Mean.	Atoms.
Carbonic acid,	35·2 .	34·8 .	35 .	12·72
Oxide of zinc,	64·8 .	65·2 .	65 .	12·34
	100	100	100	

It is obviously a compound of

1 atom carbonic acid,
1 atom oxide of zinc.

It is therefore a simple carbonate of zinc.

Sp. 2. *Hydrous Dicarbonate of Zinc.*

Calamine in part.

This species frequently accompanies the preceding one. It has never been observed in crystals, but usually encrusts other minerals. It has somewhat the appearance of chalk, with a finer grain and closer texture.

Colour white or greyish, or yellowish-white.

Massive, or encrusting other bodies.

Dull; opaque.

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[*] Nicholson's Jour. vi. 76. The first specimen was from Somersetshire; it was greenish-yellow, and had a crystalline texture. The second was from Derbyshire; it was pale yellow, and in small rhomboids.

Hardness 2 to 2·5; specific gravity, as determined by Smithson, 3·584 to 3·598.

Does not phosphoresce when scraped.

When plunged into water it absorbs about one-third of its weight of that liquid.

Before the blowpipe it becomes yellow, but recovers its colour on cooling. Before the reducing flame it is entirely dissipated, abundance of flowers of zinc being deposited on the charcoal. With borax and biphosphate of soda it fuses with effervescence into a clear colourless glass, which becomes opaque on cooling, if over saturated. Carbonate of soda has no action on it.

Its constituents, as determined by Smithson,[*] are

			Atoms.
Carbonic acid,	13·52	4·91	1
Oxide of zinc,	69·36	13·21	2·69
Water,	15·10	13·42	2·73
	97·98		

If we make allowance for a small deficiency of carbonic acid, the constituents are obviously

1 atom carbonic acid,
2 atoms oxide of zinc,
2 atoms water.

It is therefore a hydrous dicarbonate of zinc.

Sp. 3. *Anhydrous Silicate of Zinc.*
Williamsite.

The only specimen of this mineral which I have seen was purchased from a mineral dealer, who informed me that its locality was Switzerland, and that it had been called Williamsite by Mr. Levy.

Colour various shades of yellow, in different parts of the specimen, always inclining strongly to brown; powder light yellow.

An amorphous mass, studded with small crystals which had the aspect of right-angled prisms, but their surfaces were so rough that they could not be measured, even by the common goniometer; fracture granular and uneven.

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[*] Nicholson's Jour. vi. 74. The specimen analyzed was from Bleyberg. I have corrected Smithson's numbers by applying more correct data to his analysis.

Lustre resinous; brittle. Crystals varying from transparent to translucent. Mass translucent only on the edges.

Hardness 5; specific gravity 3·935.

Action of the blowpipe the same as in the next species.

I subjected it to analysis, and found the constituents

		Atoms.
Oxide of zinc,	68·77	13·09
Silica,	26·97	13·48
Peroxide of iron,	1·48	
Alumina,	0·66	
Ditto, with a trace of zinc and iron,	0·78	
Water,	1·25	
	99·91	

It is obvious enough that the essential constituents are silica and oxide of zinc. The other bodies are accidental impurities. The mineral is a simple anhydrous silicate of zinc.

The mineral dealer from whom I purchased the specimen, put into my hands the following analysis, made, he told me, by Mr. Levy:

		Atoms.
Silica,	27·67	13·83
Oxide of zinc,	72·33	13·79
	100	

This analysis must have been made upon a purer specimen than mine, but it confirms the constitution of the mineral as just stated.

Sp. 4. *Hydrous Silicate of Zinc.*

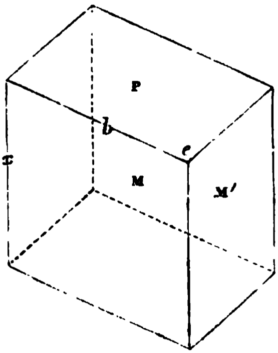
Calamine in part—electric calamine.

This species occurs in the same localities as the carbonate of zinc. It is more common in calcareous rocks than in any others. Bleiberg and Raibell, in Carinthia, are well-known localities. It is pretty common in England, and occurs at Leadhills and Wanlockhead, in Scotland.

Colour most commonly white; occasionally blue, green, yellow or brown; streak white.

It occurs massive, stalactitical and crystallized. The primary form is a right rhombic prism.

M on M′ 102° 35′



The crystals are seldom solitary, but disposed in radiated groups.

The edge *x* is often replaced by a face making an angle of 128° 40′ with M. The angle *e* is frequently replaced by a tangent plane, and the edge *b* and its opposite being replaced each by a plane, cause the extremity of the prism to terminate in two faces inclined to each other like the roof of a house.

Structure foliated or radiated.

Lustre vitreous, inclining to pearly on the base of the primary prism.

Brittle; transparent to translucent.

Hardness 5; specific gravity, according to Smithson, 3·434; according to Haidinger, 3·379.

Before the blowpipe decrepitates and emits a green light, but does not fuse. With borax or biphosphate of soda it fuses without effervescence, into a clear colourless glass; not acted on by carbonate of soda.

Becomes electric by heat; gelatinizes in nitric or muriatic acid.

Its constituents are as follows:

	*	†	Atoms.
Silica,	25·0	24·893	12·44
Oxide of zinc,	68·3	66·837	12·73
Water,	4·4	7·460	6·63
Carbonic acid,	—	0·450	
Oxides of lead and tin,	—	0·276	
	97·7	99·916	

It is obviously a hydrous silicate of zinc, composed of

1 atom silica,
1 atom oxide of zinc,
$\frac{1}{2}$ atom water.

Sp. 5. *Sulphate of Zinc.*

White vitriol—gallizenstein.

This salt occurs at Rammelsberg, near Goslar in the Hartz, at Schemnitz in Hungary, at Fahlun in Sweden, and at Holywell in Flintshire.

Colour white, sometimes inclining to peach-blossom red and violet-blue; pale; streak white.

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* Smithson, Nicholson's Jour. vi. 78.

† Berzelius, Kong. Vet. Acad. Handl., 1819, p. 141.

Occurs massive, stalactitical and investing other bodies. It is said also to occur crystallized in rectangular prisms, terminated by four-sided pyramids.

Lustre vitreous; transparent to translucent; brittle.

Hardness 2 to 2·5; specific gravity 2·036, as determined by Haidinger.

Taste astringent, metallic and very nauseous; soluble in water.

Before the blowpipe froths and covers the charcoal with white flocks.

A specimen from Rammelsberg, analyzed by Klaproth,* was composed of

			Atoms.
Sulphuric acid,	22·7	4·7	1
Oxide of zinc,	27·5	5·23	1·11
Sesquioxide of manganese,	0·5	—	—
Water,	49·3	43·83	9·32
	100·0		

These numbers approach most nearly to

1 atom sulphuric acid,
1 atom oxide of zinc,
9 atoms water.

If the analysis be correct, the native sulphate contains more water than the artificial in crystals, which contains only 7 atoms of water.

Sp. 6. *Hopeite.*†

Dr. Brewster has given this name to some crystals observed on a mineral from a calamine mine at Altenberg, near Aix-la-Chapelle.

Its colour is white.

The crystals were four-sided prisms terminated by a truncated six-sided low pyramid. The primary form seems to be a right oblique prism with angles of 81° 34′.

It is transparent, and has two axes of double refraction.

Hardness 2·5; specific gravity 2·76.

When heated it gives out a great deal of water without any trace of carbonic acid. Before the blowpipe it becomes

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* Beitrage, v. 193. Correcting the sulphuric acid by the atomic numbers.

† Edin. Phil. Trans. x. 107. Named in honour of Dr. Hope, Professor of Chemistry in Edinburgh.

milk-white, and melts into a clear colourless globule, which gives the flame a greenish tint. With biphosphate of soda it melts in all proportions into a clear colourless glass, without any siliceous residue. With borax it fuses into a clear colourless glass, which does not become opaque on cooling. With carbonate of soda it gives a scoria, which when hot is of a yellowish colour. The oxide of zinc is condensed round it in great quantity on the charcoal, and next the scoria is a reddish yellow tint, which does not vanish on cooling, and indicates the presence of cadmium. When melted with soda and moistened, it exhales no hepatic odour. A solution of cobalt communicates a fine bluish tint to the melted assay.

Hopeite is soluble without effervescence in muriatic and nitric acids. It dissolves also, though slowly, in sulphuric acid.

It seems probable from these phenomena, that Hopeite is a hydrous phosphate of zinc, with some cadmium.

3. *Sulphur Salts.*

Sp. 1. *Marmatite.*[*]

It is not improbable that black blende is frequently a chemical compound of sulphuret of zinc and sulphuret of iron, in which in all probability the sulphuret of iron acts the part of an acid, and the sulphuret of zinc that of an alkali or base. This at any rate seems to be the case with the black blende of Marmato, in the Province of Popayan, which was subjected to a chemical analysis by M. Boussingault. He extracted from two varieties of it the following constituents:

	Blende of Candado.	Blende of Salto.	Mean.	Atoms.	
Zinc, ...	43·0	41·8	42·4	9·97	2·36
Iron, ...	15·7	13·9	14·75	4·21	1
Sulphur, ...	28·6	27·8	28·2	14·1	3·34
Pyrites, ...	1·7	4·6	3·15		
Quartz, ...	8·0	8·7	8·35		
Alumina, . .	—	0·9			
Oxide of manganese,	—	0·2			
Oxygen, . .	1·7	0·9			
	98·7	98·8			

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[*] Ann. de Chim. et de Phys. xliii. 312. Named from Marmato, where the mineral was discovered.

It is obvious that the sulphur just saturates the zinc and the iron, and that the atoms of zinc are to those of iron as 7 to 3. Hence the mineral is a compound of

7 atoms sulphuret of zinc,
3 atoms sulphuret of iron.

GENUS XX.—LEAD.

This metal is more abundant than any other, if we except iron, and perhaps manganese. Its ores are numerous and beautiful. They are most commonly in veins, and occur in every kind of formation; though perhaps they are more abundant in the transition and secondary rocks than in the primary. The species of lead ores at present known amount to 34. They may be conveniently subdivided in the same way as the preceding genus.

1. *Native or United to Simple Bodies.*

Sp. 1. *Native Lead.*

It has been doubted by mineralogists whether lead occurs *native* in the mineral kingdom. But several of the statements which have appeared are too well authenticated to be doubted. The pieces of lead described by Dr. Morris, as found in one of his fields in Monmouthshire, may perhaps have been accidentally deposited.* But it has been found in small masses in the lava of Madeira.† Native lead has also been found lately in the neighbourhood of Alston, in Cumberland. It occurs in small globular masses, imbedded in galena and a slaggy substance, accompanied by red oxide of lead, crystals of blende and quartz. The vein in which it is found traverses limestone. It is about an inch thick, but widens to two or three inches as it descends. The whole mass within the vein is considerably decomposed, and the ore is found in incoherent pieces, some of which are about the size of a walnut. Many of them have a very slaggy appearance both externally and internally, while others are pure galena, distinctly cleavable, and coated by a white meally sulphate of lead produced by decomposition.‡

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* Phil. Trans. 1773, p. 20.

† Phillips' Mineralogy, p. 332.

‡ Annals of Philosophy (second series), ix. 154.

Sp. 2. *Protoxide of Lead.*

Bleiglötte.

The existence of this species was first pointed out by Mr. Smithson. It is said to occur at Badenweiler, in Baden, in quartz. It has been described and analyzed by Dr. John.* Geralt states that it has been thrown out from the volcanoes of Papocatapell and Iztaccituatl, in Mexico.†

Colour intermediate between sulphur and lemon yellow; streak lighter.

Massive; fracture in one direction earthy, in another foliated, with a threefold cleavage, indicating a four-sided prism or rhomboid for its primary form.

External lustre dull, internal semimetallic.

Opaque; semihard; brittle; easily frangible; does not soil.

Specific gravity 8·000.

Melts easily before the blowpipe.

Its constituents, as determined by John, are

		Atoms.	
Protoxide of lead,	87·382	. 6·24	. 4·5
Carbonic acid,	3·846	. 1·39	. 1
Oxide of iron and lime,	0·481		
Copper,	trace,		
Ferruginous silica,	2·404		
	94·113		

If any confidence can be put in this analysis, the mineral is a mixture or compound of

$3\frac{1}{2}$ atoms protoxide of lead,
1 atom carbonate of lead.

But the deficiency of six per cent. in the analysis, renders it doubtful whether the carbonic acid may not have been in combination with an alkaline substance not detected.

Sp. 3. *Sesquioxide of Lead.*

Native minium.

This species was discovered by Mr. Smithson in Germany, disseminated in small quantity in a compact carbonate of zinc. In general it was in a pulverulent state, but in some places showed under the microscope a flaky and crystalline texture.

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* Schweigger's Jahrbuch, ii. 109.

† Leonhard's Jahrbuch der Mineralogie und Geognosie, iii. 202.

According to M. Kapper, the shape of the crystal is a right oblique prism, with a rhombic base, the angles of which are 93 44′ and 86° 16′.*

The colour is the same as that of factitious minium, a vivid red, mixed with yellow. Mr. Smithson ascertained that it possesses the chemical properties of sesquioxide of lead.

According to him it is produced by the decay of galena, which he suspects to be itself a secondary production from the metallization of white carbonate of lead by sulphuretted hydrogen.†

Sp. 4. *Sulphuret of Lead.*

Galena, bleiglanz, blaubleierz.

This is by far the most abundant ore of lead. From it almost all the lead of commerce is extracted. It occurs both in beds and veins in primary and secondary rocks. In Cornwall veins of it pass through primary rocks. The rich mines of lead in the north of England consist chiefly of veins traversing the coal formation. At Leadhills and Wanlockhead the veins traverse transition rocks. At Strontian the vein lies between gneiss and granite. This ore is more abundantly scattered over the surface of the earth than any other. Few countries exist which are altogether destitute of it.

Colour pure lead-grey; apt to tarnish, and the iridescent colours appear in preference on the secondary faces; streak unaltered.

Occurs massive, and then is usually granular or fibrous; but it is very frequently crystallized, and then is foliated with a three-fold cleavage. Primary form a cube. Occurs also in regular octahedrons, and in the form of the leucite crystal, in consequence of the angles of the cube being replaced by three faces, which, increasing in size, obliterate the original faces of the cube. On the faces of the octahedron low three-sided pyramids are sometimes observed, converting the octahedron into an icosatetrahedron.

Lustre metallic, splendent.

Rather sectile.

Hardness 3; specific gravity from 7·532 to 7·652.

Before the blowpipe melts, and if heated with precaution on charcoal, yields globules of lead after the sulphur is burnt off.

When pure, its constituents are

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* Ann. des Mines (2d series), v. 325. † Nicholson's Jour. xvi. 127.

		Atoms.
Sulphur,	13·34	2
Lead,	86·66	13
	100·00	

When the structure is fibrous the lustre is less, and the mineral contains antimony, but whether in atomic proportions has not been ascertained.

Sp. 5. *Supersulphuret of Lead.*

This mineral is not uncommon in the north of England. The specimen which I subjected to analysis was from Ireland, but I do not know the locality.

Colour blue; lustre metallic.

Texture fine granular; massive; opaque.

Hardness 3; specific gravity 6·713.

Before the blowpipe on charcoal burns with a blue flame, then decrepitates, then melts, and finally leaves a globule of pure lead.

When 100 parts of this mineral are heated in a glass tube, 1·79 parts of sulphur sublime, and common galena remains. Hence the composition is

		Atoms.	
Galena,	98·21	6·547	7·31
Sulphur,	1·79	0·895	1
	100·00		

So that the composition is

7 atoms sulphuret of lead,
1 atom sulphur;
Or 7 atoms lead,
8 atoms sulphur.

Sp. 6. *Seleniet of Lead.*

This mineral was discovered in 1823, by M. Zinken, in the eastern part of the Hartz, in two places not far from each other, near Zorge, where it occurs in veins of iron, traversing clay slate and greenstone, disseminated in a magnesian limestone, and near Tilzerode, where the seleniet is more abundant, and disseminated in like manner in magnesian limestone. It was analyzed and imperfectly described by M. H. Rose.*

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* Ann. de Chim. et de Phys. xxix. 116.

It has so great a resemblance to fine grained sulphuret of lead, that we can scarcely distinguish the one from the other.

Colour lead-grey; lustre metallic.

Structure granular. When the grains are large, a foliated structure may be observed in them.

Opaque; rather sectile.

Hardness 3; specific gravity 7·187.

Does not sublime, nor melt when heated in a glass tube. When the tube is open at both ends a little selenium sublimes, and crystals of selenic acid are formed, which deliquesce. The assay is surrounded with fused protoxide of lead, and the apartment is filled with the peculiar odour of selenium.

On charcoal it smokes and burns with a blue flame before the blowpipe. The assay is surrounded with oxide of lead, but no metallic lead is obtained unless we mix the assay with carbonate of soda. With fluxes the presence of lead only is detected.

Its constituents, by the analysis of Rose, are

		Atoms.
Selenium,	27·59	5·52
Lead,	71·81	5·52
	99·40	

Obviously 1 atom selenium,
1 atom lead.

So that it is a simple seleniet of lead.

Seleniet of lead is found in the same place mixed or combined with some other seleniets.

1. Combined with seleniet of cobalt, it closely resembles the pure ore. It was composed of

		Atoms.	
Selenium,	31·42	6·28	6·54
Lead,	63·92	4·91	5·11
Cobalt,	3·14	0·96	1
Iron,	0·45	0·12	0·12
	98·93		

These numbers approach (including the iron with the cobalt)

5 atoms seleniet of lead,
1 atom seleniet of cobalt.

2. Combined with seleniet of copper. This variety also bears a close resemblance to pure seleniet of lead.

Its constituents were

		Atoms.	
Selenium,	29·96	5·99	6·11
Iron with trace of lead,	0·44	0·12	—
Lead,	59·67	4·59	4·69
Iron,	0·33	0·09	—
Copper,	7·86	1·96	2
Undecomposed,	1·00		
	99·26		

These numbers approach nearly to

9 atoms seleniet of lead,
4 atoms seleniet of copper.

3. Another compound of seleniets of copper and lead had a violet colour, and was more fusible than the last variety. Its constituents were

		Atoms.
Selenium,	34·26	6·85
Lead,	47·43	3·65
Copper,	15·45	3·86
Silver,	1·29	0·09
Oxides of lead and iron,	2·08	
	100·51	

These numbers indicate a compound of

1 atom seleniet of lead,
1 atom seleniet of copper.

4. Seleniet of lead occurs also mixed with seleniet of mercury in various proportions, without much affecting its external characters. Two specimens, analyzed by Rose, gave the following constituents:—

			Atoms.			
		2	1	2	1	2
Selenium,	24·97	27·98	4·99	5·59	3·53	2·66
Lead,[1]	55·84	27·33	4·29	2·10	3·04	1
Mercury,	16·94	44·69	1·41	3·72	1	1·77
	97·75	100·00				

The first seems to be composed of

3 atoms seleniet of lead,
1 atom sesquiseleniet of mercury.

The second of

4 atoms seleniet of lead,
7 atoms seleniet of mercury.

Sp. 7. *Bitelluret of Lead.*

Foliated ore of tellurium, black tellurium, tellurium glance, nagyaker erz.

This mineral has been hitherto found only in veins at Nagyag and Offenbanya, in Transylvania. It is now very rare.

Colour blackish lead-grey; streak similar.

Massive and crystallized in very small tables. The primary form appears to be a right square prism. The terminal edges and angles of the prism being replaced by faces, convert it into a table terminated by eight double faces.

Foliated; lustre metallic; opaque.

Highly flexible when in thin laminæ; very sectile.

Hardness 1 to 1·5; specific gravity 7·085.

Before the blowpipe it melts easily upon charcoal, and gives a malleable metallic button. With borax it gives a bead of gold containing a little silver. Dissolves easily in nitric acid.

Its constituents are

	*	†	Mean.	Atoms.
Tellurium, .	32·2	31·96	32·08	8·02
Lead, . .	54·0	55·49	54·74	4·21
Gold, . .	9·0	8·44	8·72	0·72
Silver, . .	0·5	trace	—	—
Copper, . .	1·3	1·14	1·22	0·30
Sulphur, . .	3·0	3·07	3·03	1·51
	100	100·10		

If we admit all the constituents, except the tellurium and lead, to be accidental impurities, it is evident that the mineral is a compound of

2 atoms tellurium,
1 atom lead;

Or it is a bitelluret of lead.

M. G. Rose has described a bitelluret of lead from Altai,[‡] which seems to be this species in a state of greater purity than it had been previously observed to be.

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[*] Klaproth, Beitrage, iii. 32. [†] Brandes, Schweigger s Jahrbuch, v. 409.

[‡] Poggendorf s Annalen, xviii. 68.

Colour tin-white, very similar in appearance to that of native antimony.

Sectile; easily reducible to a fine powder; specific gravity 8·159.

Before the blowpipe on charcoal it gives a blue tinge to the flame. In the reducing flame melts into a bead, which becomes smaller and smaller, and at last leaves nothing but a little silver. Round the assay is formed a metallic shining ring of telluret of lead; at a little farther distance a brownish yellow matter, which tinges flame blue, and is totally dissipated by heat.

Its constituents were

		Atoms.
Silver,	1·28	0·09
Lead,	60·85	4·69
Tellurium,	38·37	9·6
	100·50	

If we include the silver with the lead, it is obvious that the mineral is composed of

2 atoms tellurium,
1 atom lead.

It is therefore a bitelluret of lead, obviously in a state of much greater purity than the Nagyag bitelluret.

Sp. 8. *Chloride of Lead.*[*]

Cotunnia of Monticelli, cotunnite of Von Kobell.

This mineral was observed by Monticelli and Covelli, in the crater of Mount Vesuvius, after the eruption of 1822. It was accompanied by common salt, chloride and sulphate of copper, and other salts, and was named in honour of one of the medical men of Naples.

Colour white. In acicular crystals.

Is slightly scratched by the nail.

Lustre adamantine, inclining occasionally to silky or pearly.

Specific gravity 1·897.

Fuses very easily before the blowpipe, colouring the flame blue, and emitting a white smoke which is condensed on the charcoal. With carbonate of soda it yields globules of lead.

It dissolves in about 27 times its weight of cold water.

Its constituents, according to the analysis of Berzelius, are

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[*] Allan's Manual, p. 34.

			Atoms.
Chlorine,	25·48	.	5·66
Lead,	74·52	.	5·7
	100·00		

It is obviously a simple chloride of lead.

Sp. 9. *Dichloride of Lead.*

Berzelite.

This rare mineral has been found in the Mendip hills, in Somersetshire. It is there found in crystalline masses, having a fibrous and radiated structure disposed on earthy black ore of manganese.

Colour white, with a yellowish or reddish tinge.

Cleavage highly perfect, and easily obtained parallel to the faces of a four-sided prism of 102° 27′.

Lustre pearly on the cleavage faces.

Hardness 2·5 to 3; specific gravity 7·0 to 7·1.

Decrepitates slightly before the blowpipe, and is easily fused, the globule presenting a deeper yellow than the mineral. On charcoal it is reduced, and emits fumes of muriatic acid. Treated with peroxide of copper and biphosphate of soda, the flame assumes an intense blue colour.

Its constituents, according to the analysis of Berzelius, are

			Atoms.
Lead,	83·2	.	6·4
Chlorine,	13·77	.	3·2
Carbonic acid,	1·03		
Silica, .	1·46		
Water,	0·54		
	100·00		

It is obviously a compound of 2 atoms lead and 1 atom chlorine, or it is a dichloride of lead.*

2. *Simple Oxygen Salts.*

Sp. 1. *Carbonate of Lead.*

White lead ore. Black lead ore.†

This species, next to galena, is the most abundant of all the

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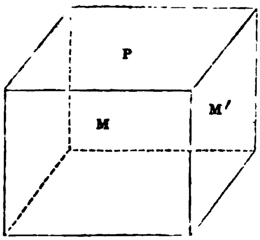
* Allan's Manual, p. 59.

† The black lead ore of Werner is a mixture of carbonate of lead and galena.

ores of lead. It occurs in veins and beds in almost every formation, and usually accompanies galena. Beautifully crystallized specimens are found in Saxony, and at Leadhills and Wanlockhead, in Scotland.

Colour white, passing into yellowish grey, smoke grey, or even into greyish black. Sometimes tinged green or blue by copper; streak white.



Massive, granular, or even in powder. The primary form obtained by cleavage is a right rhombic prism.

Mon M' 117° 18'

It occurs in tabular crystals, in six-sided prisms, in triangular dodecahedrons, and in elongated octahedrons.

The crystals have a foliated texture, and cleave parallel to the faces of the primary form, and in the direction of the shorter diagonal of the base of the prism. Cross fracture small conchoidal, or sometimes small grained, uneven.

Lustre adamantine, passing into resinous; sometimes pearly.

Transparent to translucent; rather brittle.

Hardness 3·25; specific gravity from 6·465 to 6·480.

Before the blowpipe it decrepitates, and changes its colour into yellow and red. If properly managed it yields a globule of metallic lead. Reduced to powder and thrown on ignited charcoal it yields a phosphorescent light.

Effervesces in dilute nitric acid, and is easily soluble.

Its constituents, when pure, are

Carbonic acid,	16·418	2·75
Protoxide of lead,	83·582	14
	100·000	

Or it is a simple carbonate of lead. I analyzed a pure crystallized specimen, and found the constituents,

		Atoms.
Carbonic acid,	16·406	5·966
Protoxide of lead,	8·534	5·966
Water,	0·060	
	100·000	

Sp. 2. *Sulphate of Lead.*

Prismatic lead spar—lead vitriol.

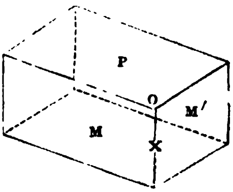
This species is much less abundant than the preceding. It is found in lead and copper veins traversing clay slate and greywacke slate, particularly in the upper parts. Fine specimens occur at Leadhills and Wanlockhead, in Parys mine, and at Mellanoweth, in Cornwall. It is found also in Germany, Spain, Siberia, and the United States of America.

Colour yellowish, greyish or greenish white, and also yellowish and smoke grey; sometimes tinged faintly green and blue; streak white.

Massive, but often also crystallized in the form of rhombic prisms with dihedral summits. But when the prism is short, the prism assumes the aspect of an octahedron. The structure is foliated, and admits of mechanical division parallel to the faces of a right rhombic prism.

M on M′ 103° 42′

which is its primary form.



The secondary forms are produced by replacing the angle O, the edge X, and terminal edges of the prism by planes, which sometimes increase so much in size as to obliterate nearly the original faces of the prism.

Lustre adamantine, inclining to vitreous or resinous.

Transparent to translucent; brittle.

Hardness 2·75; specific gravity from 6·259 to 6·298.

Decrepitates in the flame of a candle, and frequently assumes a slightly reddish tinge on the surface. In powder it fuses before the blowpipe into a white slag, which is reduced into metallic lead by the addition of carbonate of soda.

The constituents of this species are as follows:—

	*	*	†	‡	Atoms.
Sulphuric acid,	24·8	25·75	26·0191	25·655	5·13
Protoxide of lead,	71·0	70·50	72·9146	74·045	5·28
Protoxide of iron,	1·0	—	0·1151	—	
Prot. of manganese,	—	—	0·1654	—	
Water, .	2·0	2·25	0·1242	0·300	
	98·8	98·50	99·3384	100·000	

* Klaproth, Beitrage, iii. 162. † Stromeyer, Hoffmann's Handbuch, iv. 1, 43.

‡ By my analysis. The specimen was a colourless crystal from Leadhills, apparently pure.

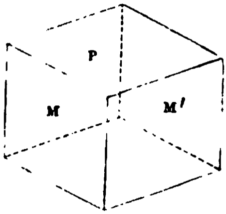
It is obviously a compound of
1 atom sulphuric acid,
1 atom protoxide of lead.
And therefore a simple sulphate of lead.

Sp. 3. *Chromate of Lead.*

Red lead ore.

This mineral was first found in the mines of Beresof, near Ekateringberg, in Siberia, in a vein traversing gneiss and mica slate. It is now very scarce in this first locality, but has been more recently found in Sabara, or Villa Rica, in Brazil.

Colour various shades of hyacinth red; streak orange yellow.



Occurs both massive and crystallized. The primary form is an oblique rhombic prism.

M on M′ 93° 30′
P on M or M′ 99° 10′

For the fullest account of the secondary forms of this mineral, the reader is referred to M. Soret, who has given a description and figure of each modification. See *Annales des Mines*, iii. 479, and v. 281.

Structure foliated; cross fracture uneven, or small conchoidal.

Lustre adamantine.

Translucent, sometimes only on the edges; sectile.

Hardness 2·75; specific gravity, by my trial, 6·000.

Before the blowpipe it becomes black, and decrepitates if quickly heated. It may be melted, however, into a shining slag, containing globules of metallic lead. Gives a green colour to borax.

Dissolves without effervescence in nitric acid, solution yellow.

When pure, the constituents of this mineral are

		Atoms
Chromic acid, .	31·71 .	4·88
Protoxide of lead, .	68·29 .	4·88
	100·00	

Or,
1 atom chromic acid,
1 atom protoxide of lead.
It is therefore a simple chromate of lead.

Sp. 4. *Melanochroite.*

Subsesquichromate of lead.

This mineral occurs in veins in a limestone rock at Beresofsk, in the Ural, along with chromate of lead, vauquelinite, phosphate of lead, a galena and quartz. It was first described, named and analyzed, by M. Hermann.*

Colour between cochineal red and hyacinth red; by exposure to the air it becomes lemon yellow; powder tile red.

Massive; but more commonly crystallized in rhombic prisms with two of the opposite faces much larger than the others, giving the crystal the aspect of a table. The crystals are small, and interwoven together like a net.

Lustre resinous, glimmering.

Translucent on the edges, almost opaque.

Very soft; slightly brittle; easily reduced to powder.

Specific gravity 5·75.

When heated it hardly gives out a trace of water. Its colour becomes darker, but resumes its original appearance when the mineral cools.

Before the blowpipe on charcoal, it cracks but does not fly off. It then fuses readily into a dark mass, which on cooling assumes a crystallized appearance. In the reducing flame lead is sublimed, and oxide of chromium and grains of lead are left on the charcoal. Fused with the fluxes it gives a green coloured bead.

Its constituents are

			Atoms.
Chromic acid,	23·31	3·58	1
Protoxide of lead,	76·69	5·47	1·52
	100·00		

These numbers correspond with

1 atom chromic acid,
$1\frac{1}{2}$ atom protoxide of lead.

It is therefore a subsesquichromate of lead.

Sp. 5. *Tungstate of Lead.*

This mineral occurs at Zinnwald, in Saxony, and was first subjected to a chemical examination by Breithaupt and Lampadius.

Colour yellowish grey.

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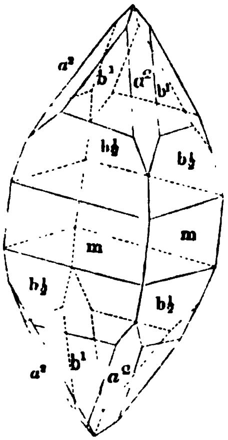
* Poggendorf's Annalen, xxviii. 162.



Usually crystallized, and the primary form appears to be an octahedron with a square base. The figure in the margin was given by Mr. Levy, as representing a crystal in possession of Mr. Turner.* The following are his measurements:

b^1 on b^1	99°	43′
a on a^2	106	47
$b_{\frac{1}{2}}$ on $b_{\frac{1}{2}}$	92	46
b^1 on b^1	131	30
a^2 on a^2	65	
$b_{\frac{1}{2}}$ on $b_{\frac{1}{2}}$	154	36
m on b^1	155	45
m on a^2	126	37
m on $b_{\frac{1}{2}}$	167	

In some crystals the planes $b_{\frac{1}{2}}$ are wanting, while others are composed of this modification alone. The crystals of this mineral bear a striking analogy to, or almost agree with those of molybdate lead.

Lustre resinous; faintly translucent.

Hardness 3; specific gravity 8·000.

Before the blowpipe it melts and gives out vapours of lead, leaving a crystalline globule of a dark colour and metallic aspect, which yields a pale grey powder. When the lead has been driven off, the assay yields with borax a yellow globule, transparent, and becoming dark red on cooling; and with biphosphate of soda, at a certain saturation, in the reducing flame, a blue globule.

I am not aware that this mineral has been regularly analyzed. From Berzelius' formula, it would seem to be a tungstate of lead, composed of

1 atom tungstic acid, .	15·5
1 atom protoxide of lead, .	14
	29·5

Sp. 6. *Molybdate of Lead.*

Yellow lead ore.

This species was first noticed by Jacquin in 1781. It occurs in many of the lead mines of Carinthia, and likewise

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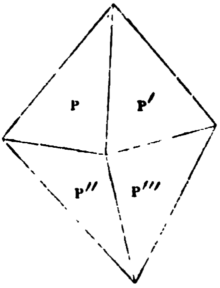
* Annals of Philosophy (2d series), xii. 364.

in limestone at Annaberg in Austria. It has been observed also in Upper Hungary, in Pennsylvania and Massachusetts, at Zimapan in Mexico, and also at Mendip in Somersetshire.

Colour wax-yellow, passing into siskin green and olive green; also into orange-yellow, yellowish-grey, and greyish-white; streak white.

Massive and crystallized. The primary form is an octahedron with a square base.

P on P′ 99° 46′
P on P″ 131° 15′



It occurs crystallized in flattish and acute octahedrons, variously modified, in crystals approaching to cubes, in tables, and in four, six, and eight-sided prisms, terminated by four-sided pyramids.

Structure lamellar; cleaves parallel to the faces of the primary form. Fracture imperfect conchoidal.

Semitransparent to translucent on the edges; brittle.

Hardness 2·75; specific gravity, according to Hatchett, 5·706. Haidinger states it 6·760.

Before the blowpipe it decrepitates briskly and assumes a darker colour, which, however, again disappears.

Alone upon charcoal, it melts and is absorbed by it, leaving behind some reduced globules of metallic lead. With borax, in the exterior flame, fuses readily into an almost colourless glass. In the interior flame we obtain a transparent glass, which, on cooling, becomes all at once dark and opaque. With biphosphate of soda fuses readily. When the proportion of molybdate of lead is small, the glass is green; when the quantity is greater, the glass is black and opaque. Fuses with carbonate of soda; a portion of the mass is absorbed by the charcoal, and reduced lead remains.

The constituents of this mineral are

	*	†	‡	Atoms.
Molybdic acid, .	34·25	37·00	40·5	4·11
Protoxide of lead,	64·42	58·40	58·0	4·17
Oxide of iron, .	—	3·08		
Silica, . . .	—	0·28		
	98·67	98·76	98·5	

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* Klaproth, Beitrage, ii. 275. † Hatchett, Phil. Trans. 1796, p. 323.

‡ Göbel. Schweigger's Jahrbuch, vii. 71. I have corrected his estimate of oxide of lead from the chloride.

The atomic numbers, deduced from Hatchett's analysis, show evidently that the mineral is composed of

1 atom molybdic acid,
1 atom protoxide of lead.

Or it is a simple molybdate of lead.

Sp. 7. *Trismolybdate of Lead.*

This mineral was first noticed by M. Boussingault, who observed it in the Paramo-Rica, near Pamplona in South America. He has published an imperfect description and analysis of it.*

It occurs in small concretions. Its colour is greenish-yellow, and its specific gravity 6·00.

Before the blowpipe on charcoal it melts easily into a globule of a dark colour; when a little carbonate of soda is added we easily obtain a button of reduced lead; while, at the same time, an infusible scoria is formed. When a new dose of soda is added, the scoria is imbibed into the charcoal, and by grinding and washing, a grey metallic powder is obtained, having the aspect of molybdenum.

Its constituents, by Boussingault's analysis, are

		Atoms.
Protoxide of lead,	73·8	5·27
Molybdic acid,	10·0	1·11
Carbonic acid,	2·9	1·05
Muriatic acid,	1·3	0·28
Phosphoric acid,	1·3	0·28
Chromic acid,	1·2	0·18
Oxide of iron,	1·7	0·34
Alumina,	2·2	0·97
Quartz,	3·7	
	98·1	

If we suppose all the acids to have been in combination with oxide of lead. It is obvious that as the other acids amount to 1·79 atoms, 1·79 atoms must be subtracted from the oxide of lead. There remain 3·48 to unite with 1·11 atoms of molybdic acid. This is very nearly

3 atoms protoxide of lead,
1 atom molybdic acid.

The mineral therefore must be a trismolybdate of lead.

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* Ann. de Chim. et de Phys. xlv. 325.

3. *Double Oxygen Salts.*

Sp. 1. *Oxido-Chloride of Lead.*

Hitherto this mineral has been observed only in a single specimen in possession of the Stockholm Academy, which was analyzed and described by Berzelius.* It was ticketed *lead spar*, from Mendip, near Churchill in Somersetshire. It was chiefly carbonate of lead, but it contained two portions of a yellower colour than the rest, which attracted the peculiar attention of Berzelius. One of these being examined by the blowpipe, proved to be molybdate of lead. The other portion constituted the present species.

Colour straw-yellow.

Easily frangible, and cleaves with a foliated texture. The cleavage planes meet under an angle of between 102° and 103°.

Before the blowpipe it decrepitates slightly, and is easily melted. The fused globule, when cold, has a deeper yellow colour than the original mineral. On charcoal it is reduced to metallic lead, and at the same time emits fumes of muriatic acid.

Dilute nitric acid dissolves it with slight effervescence, and if several fragments, taken from different parts of the specimen, be thrown into the acid at once, the effervescence occasioned by them may be observed to be different.

The constituents of this mineral are

		Atoms.
Chlorine,	8·45	1·87
Carbonic acid,	1·03	0·03
Lead,	83·667	6·43
Silica,	1·46	
Water,	0·54	
	95·147	

The carbonic acid was owing to the admixture of carbonate of lead; subtracting 0·03 atom of lead for this, there remain 6·4 atoms, 1·87 of which must have been in combination with chlorine, constituting chloride of lead. There remain 4·53 atoms of lead, which in the mineral must have been in the state of protoxide, as was the case also with the lead combined with the carbonic acid. But 4·56 atoms of lead require 4·56 oxygen to convert them to protoxide. Adding this to the 95·147 obtained by analysis, it raises the amount to 99·707.

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* Kong. Vet. Acad. Handl., 1823, p. 184.

The mineral then is a compound of

1·87 atoms chloride of lead,
4·53 atoms oxide of lead.

These numbers approach

3 atoms chloride } of lead.
7 atoms protoxide }

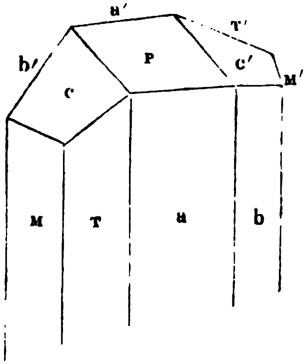
Sp. 2. *Cupreous Sulphate of Lead.*

This mineral has hitherto been found only at Leadhills. It was first analyzed and described by Mr. Brooke.[*] Sowerby had noticed it in his British Mineralogy (Vol. 3d, p. 5,) under the name of *blue carbonate of copper.*

The colour resembles that of the brightest specimens of blue carbonate of copper.

Found only in crystals similar to the figure in the margin. It cleaves easily parallel to the faces M and T.

M on T 102° 45′



Hence the primary form is probably a right oblique prism, with the above angle.

The following are Mr. Brooke's measurements of the inclination of the faces:

M on b′ 104° 50′
c 120 30
P 90
T on a 161 30
M′ on b 104 50
T′ 102 45
P on a or a′ 90

Hardness 3; specific gravity, as determined by Mr. Brooke, 5·3, but the specimen was not quite free from carbonate of lead and cupreous sulphato-carbonate of lead.

Its constituents, as determined by Brooke, are

		Atoms.	
Sulphate of lead,	75·4	3·94	1·09
Oxide of copper,	18·0	3·6	1
Moisture,	4·7	4·17	1·15
	98·1		

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[*] Annals of Philosophy (second series), iv. 117.

These numbers approach nearly to

1 atom sulphate of lead,
1 atom oxide of copper,
1 atom water.

The water and oxide of copper (as is evident from the colour of the mineral) are united together, constituting hydrate of copper. Hence the constitution of the mineral is

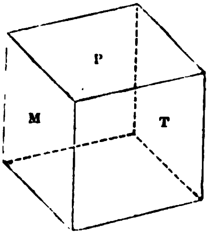
1 atom hydrate of copper,
1 atom sulphate of lead.

Sp. 3. *Sulphato-Carbonate of Lead.*

This mineral has hitherto been found only at Leadhills. It was first noticed by Bournon, as a variety of carbonate of lead. Mr. Brooke analyzed it, and published a description of it in 1820.*

Colour greenish-white or yellowish-white, sometimes inclining to grey; streak white.

The crystals are usually oblique-angled four-sided prisms, with curved faces terminated by two planes, set obliquely on the obtuse edges of the prism, but producing a horizontal edge with each other. They admit of cleavage very readily, parallel to a plane which replaces obliquely their acute lateral edges. There are two less perfect cleavages intersecting the former, at angles of 120° 45′, (according to Brooke,) and 88° 45′, (according to Haidinger). We may therefore consider the primary form as a doubly oblique prism.



M on T 120° 45′
P on M 88 45

The laminæ resulting from cleavage are flexible.

Lustre adamantine, inclining to resinous, pearly upon the perfect cleavage surface.

Translucent; sectile.

Hardness 2 to 2·5; specific gravity, as determined by Brooke, 6·8 to 7·0.

Effervesces very slightly when put into nitric acid, and leaves a quantity of sulphate of lead undissolved.

Its constituents, as determined by Brooke, are as follows:

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* Edin. Phil. Jour. iii. 117.

			Atoms.
Carbonate of lead,	46·9	.	2·8
Sulphate of lead,	53·1	.	2·8
	100		

These numbers obviously correspond with

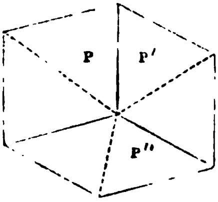
1 atom carbonate of lead,
1 atom sulphate of lead,

which, of course, constitute the component parts of this mineral.

Sp. 4. *Sulphato-Tricarbonate of Lead.*

This species, which has been met with only at Leadhills, had been noticed by Bournon, under the name of *rhomboidal carbonate of lead.* He says that it dissolves more readily in nitric acid, and with a greater effervescence than common carbonate of lead. It was first analyzed and described by Mr. Brooke.*

It occurs both in rhomboids and in prismatic crystals. The colour of the rhomboids is pale greenish, or yellowish or brownish, but when very minute they are colourless and transparent. The prismatic varieties are colourless, or of various shades of pale yellow.



The primary form of the crystal is considered to be an acute rhomboid.

P on P′ 72° 30′

Of course the supplementary angle is 107° 30′.

The six-sided prism is produced by faces replacing all the lateral angles of the rhomboid. It is also subject to modifications, producing three or four varieties of more obtuse rhomboids.

The natural planes, except in very minute crystals, are more or less rounded.

Hardness 2·5; specific gravity, as determined by Brooke, from 6·3 to 6·5.

Its constituents are as follows:

	*	†	Mean.	Atoms.	
Carbonate of lime,	72·5	72·7	72·6	4·33	3
Sulphate of lead, .	27·5	27·3	27·4	1·44	1
	100	100			

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* Edin. Phil. Jour. iii. 118. † Brooke, ibid.

‡ Stromeyer, Annals of Philosophy (second series), x. 232.

The constitution is obviously

3 atoms carbonate of lead,
1 atom sulphate of lead.

Hence the reason of the name given to this mineral by Mr. Brooke.

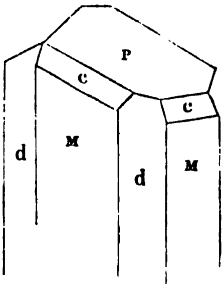
Sp. 5. *Chloro-Carbonate of Lead.*

Mureo-carbonate of lead—corneous lead.

This rare mineral has been met with at Hausbaden, near Badenweiler in Germany; in Cromford level near Matlock, Derbyshire; at Southampton, Massachusetts, and I have a specimen from Alston Moor, in Cumberland.

Colour white, and pale tints of grey, yellow and green; also bright yellow; streak white.

It has been observed only in crystals. The primary figure is a rectangular square prism. The figure in the margin is that of a crystal in the British Museum.



M on M 90°
M on d 135

Lustre adamantine.

Transparent to translucent; rather sectile.

Hardness 2·75; specific gravity, as determined by Chenevix, 6·056.

It was analyzed by Klaproth and Chenevix with nearly the same result. Klaproth's analysis,* when corrected by the application of the atomic numbers, is

		Atoms.
Chlorine,	13·56	3·01
Carbonic acid,	8·51	3·09
Lead,	39·17	3·01
Protoxide of lead,	43·32	3·09
	104·56	

The excess is owing to a slight overrating of the oxide of lead, and consequently also of the carbonic acid. If we allow for this excess, it is obvious that the constitution of the mineral is

1 atom chloride of lead,
1 atom carbonate of lead.

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[*] Beitrage, iii. 141.

Sp. 6. *Phosphate of Lead.*

Polychrome, pyromorphite, traublenblei, brown lead ore, green lead.

This mineral occurs chiefly in veins, and accompanies the other ores of lead. Fine specimens of it occur at Leadhills and Wanlockhead, at Poullaouen and Huel Goet, in Brittany, at Zschopau and other places in Saxony, in the Hartz, Bohemia and Hungary.

Colour generally green, yellow or brown, each of several shades. The fine orange-yellow crystals found at Leadhills, contain chromate of lead, to which they owe their colour; streak white, sometimes inclining to yellow.

Occurs massive, and frequently crystallized in regular six-sided prisms. The prisms not unfrequently terminate in six-sided pyramids; and the edges of the prism are often replaced by tangent planes. The angle which the lateral face of the prism makes with the corresponding face of the pyramid is 131° 45′.

Fracture imperfect conchoidal, uneven.

From semitransparent to translucent on the edges.

Lustre resinous; brittle.

Hardness 2·75; specific gravity, by my trials, varies from 6·5781 to 6·915.

Before the blowpipe it melts by itself upon charcoal, and the bead on cooling assumes a polyhedral form and a dark colour. In the reducing flame the globule becomes bluish. At the moment of crystallization it becomes luminous, and the faces become larger.

It dissolves without difficulty in hot nitric acid.

We have numerous analyses of this mineral, which it will be proper to state, that the reader may be able to judge accurately of its constitution.

Klaproth* analyzed four specimens, and obtained the following results:

Protoxide of lead, .	78·58	78·40	77·1	80
Phosphoric acid, .	19·73	18·37	19·0	18
Muriatic acid, . .	1·65	1·70	1·54	1·62
Peroxide of iron, .	—	0·10	0·1	—
	99·96	98·57	97·74	99·62

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* Beitrage, iii. 146. The first specimen was brown phosphate from Huel Goet; the second, siskin green phosphate from Zschopau; the third, grass-green phosphate from Hoffsgrund; the fourth was yellow phosphate from Wanlockhead, having a specific gravity of 6·560.

M. Charles Kersten, of Freyberg, analyzed a number of brown coloured phosphates of lead from various localities.* The following are the results which he obtained:

	1 †	2 ‡	3 §	4 ‖	5 ¶	6 **	7 ††
Protox. of lead,	72·17	75·830	81·330	81·460	82·083	82·301	82·290
Lime, . .	6·47	3·711	0·430	0·320	0·320	—	—
Chlorine, .	2·00	2·110	1·909	1·956	1·990	1·989	1·989
Phos. acid with some fluor. acid,	19·36	18·249	16·331	16·264	15·607	15·710	15·721
	100	100	100	100	100	100	100

The following table exhibits the atomic proportions deduced from these analyses:

	Atoms.						
	1	2	3	4	5	6	7
Protox. of lead,	5·15	5·41	5·80	5·81	5·86	5·88	5·88
Lime, . . .	1·83	1·06	0·12	0·09	0·09	—	—
Chlorine, . .	0·44	0·47	0·42	0·43	0·44	0·44	0·44
Phosphoric acid,	4·3	4·07	3·63	3·61	3·46	3·49	3·49

It is obvious that there is a slight error in the estimate of the phosphoric acid. It was determined by deducting the other constituents from the quantity analyzed, and considering the deficiency as phosphoric acid. But a portion of the lead in the mineral was in the metallic state, being combined with chlorine. This quantity was about 0·44 atom, or 6·16 grains of protoxide, equivalent to 5·72 grains of metallic lead. The difference 0·44 ought to have been added to the phosphoric acid.

If we examine the first of Kersten's analyses, we shall find the polysphærite consisted of

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[*] Ann. de Chim. et de Phys. xlviii. 157.

[†] The polysphærite of Breithaupt. Found in the mine Sonnenwirbel, near Freyberg, in small spheres of a brown colour, and a specific gravity of 6·092.

[‡] From Mies, in Bohemia. In small brown sphericles, having a specific gravity of 6·444.

[§] Also from Mies, crystallized, and having a specific gravity of 6·983.

[‖] From Bleystadt, in Bohemia. Colour brown, in fine crystals; specific gravity 7·009.

[¶] From England, in small brown coloured crystals.

[**] From Poullaouen, in brown coloured six-sided prisms; specific gravity 7·048.

[††] Also from Poullaouen, but amorphous. Specific gravity 7·050.

0·44 atom chloride of lead,
4·71 atom oxide of lead,
1·83 lime,
6·54 atoms of bases,
4·3 atoms phosphoric acid.

Now 6·54 is to 4·3 almost exactly as 1·5 to 1. The mineral then is composed (abstracting the chloride) of subsesquiphosphates. The constitution seems to be

1 atom chloride of lead,
4 atoms subsesquiphosphate of lime,
11 atoms subsesquiphosphate of lead.

A similar analysis of the other analyses would lead to the same result. For example, the 6th analysis shows us that the Poullaouen phosphate consists of

0·44 atom chloride of lead,
5·44 atoms oxide of lead,
3·49 atoms phosphoric acid.

5·44 is to 3·49 as 1·55 to 1. Hence the mineral is obviously composed of

1 atom chloride of lead,
8 atoms subsesquiphosphate of lead.

The variation in the quantity of lime shows that it is not chemically combined. But as apatite and phosphate of lead have the same crystalline form, we need not be surprised that one should be occasionally substituted for the other.

The following table shows the result of several analyses of this mineral, made partly by myself and partly by Mr. Blythe, in my laboratory. I have added an analysis of Wöhler, and another of Berthier, to the table.

	*	†	‡	§	‖	¶	**
Chlorine, . .	2·81	2·724	2·7	2·656	2·521	2·56	1·61
Lead, . . .	8·11	7·860	7·8	7·668	7·254	7·39	—
Phosphoric acid, .	17·93	17·400	16·85	17·600	17·200	16·01	16·93
Protoxide of lead, .	70·01	66·633	70·427	69·639	72·665	74·04	79·44
Protoxide of iron, .	0·90	1·76	1·100	2·008	0·720	—	1·62
Silica, . . .	—	—	—	—	0·040	—	—
Moisture, . .	1·00	2·00	1·000	0·800	0·400	—	—
	100·76	98·336	99·805	100·365	100·791	100·00	100

* The specimen was from Wicklow, light grass-green, in six-sided prisms. Specific gravity 6·6509.

† From Leadhills, quite similar to the preceding. Specific gravity 6·5781.

‡ From Leadhills, yellow, in six-sided prisms. Specific gravity 6·70016.

§ From Leadhills, olive green, massive, but exhibiting imperfect six-sided prisms. Specific gravity 6·631.

‖ From Poullaouen, brown, in large six-sided prisms. Sp. gr. 6·915.

¶ Wöhler, Poggendorf's Annalen, iv. 162.

** Berthier, Ann. des Mines, vii. 152. The specimen was from Chenc- e. No description is given.

It is obvious enough that these analyses lead to the same conclusion. All the phosphates of lead are composed of chloride of lead, and subsesquiphosphate of lead united together in various proportions. But usually between 1 atom chloride and 6 to 8 sesquiphosphate of lead.

Sp. 7. *Vanadiate of Lead.*

This mineral was first observed at Zimapan, in Mexico, and an analysis of it was made by M. Del Rio, in 1804, who announced the existence of a new metal in it; but the analysis being repeated by Collet Descotils, in 1805, he assured the public that the supposed new metal was nothing but chromic acid. Some years ago Mr. Johnston observed the same mineral at Wanlockhead; and I have specimens which I received from Mr. Doran, an Irish mineral dealer, who assured me that he picked them up in an old abandoned lead mine in the County of Wicklow, in Ireland.

Colour light brownish-yellow.

Streak white.

Usually in small spheres, interspersed through massive phosphate and arseniate of lead. Sometimes crystallized, and the crystals are regular six-sided prisms. I have not observed any modifications in the few crystals in my possession.

Opaque, or only slightly translucent on the edges; brittle.

Fracture even or flat conchoidal.

Lustre resinous.

Hardness 2·75; specific gravity 6·663.

Before the blowpipe on charcoal fuses with a good deal of frothing into a bead, which exactly resembles the original assay. When the fusion is continued, the matter spreads on the charcoal, and assumes at last the appearance of a black scoria. When carbonate of soda is added and the blast continued, globules of metallic lead are obtained, and a black scoriacious-looking matter continues. With borax it fuses into a bead transparent and red while in fusion, but on cooling it becomes suddenly opaque, and deep blue, if the proportion of vanadiate be considerable, but emerald green if it be small. When mixed in small proportion with biphosphate of soda, it melts into a beautiful emerald green transparent glass.

Its constituents, determined by the analysis of Dr. R. D. Thomson, in my laboratory, are

		Atoms.	
Chlorine,	2·446	0·54	
Lead,	7·063	0·54	
Protoxide of lead,	66·326	4·74	1
Vanadic acid,	23·436	7·48	1·58
Peroxide of iron and silica,	0·163		
	99·434		

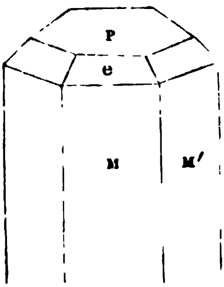
This is equivalent to

1 atom chloride of lead,
9 atoms sesquivanadiate of lead.

Sp. 8. *Arseniate of Lead.*

This mineral has been generally confounded by mineralogists with phosphate of lead. This is even done by Mohs, in his Mineralogy, though he is aware of the difference in the constitution of the two minerals. Fine specimens of it occur at Huel Unity, near Redruth in Cornwall, and in several others of the Cornish mines. It is found also at Beeralston, in Devonshire.

Colour pale yellow, passing into hair brown.



It occurs mamillary and compact, but generally crystallized in regular six-sided prisms, either perfect, or having the terminal edges replaced.

M on M′ 120°
P on M 90°
M on e 130°

Texture foliated. It cleaves parallel to the faces of the regular six-sided prism.

Lustre resinous; sectile.

Usually translucent. Said also to occur transparent, and then it is harder.

Hardness 2·75; specific gravity, as determined by Gregor, 6·41.

Before the blowpipe in a gold spoon it melts into a brownish yellow mass, which on cooling does not assume any angular form. On charcoal it gives out arsenical vapours in abundance, and a globule of metallic lead is obtained.

Dissolves easily in nitric acid, especially when assisted by heat.

Its constituents, determined by Wöler,[*] are

		Atoms.	
Chlorine,	2·56	0·56	0·15
Lead,	7·39	0·56	0·15
Arsenic acid,	21·09	2·9	0·9
Phosphoric acid,	1·32	0·29	0·09
Protoxide of lead,	67·64	4·83	1·5
	100·00		

Including the phosphoric acid with the arsenic, it is obviously a subsesquiarseniate of lead, composed of

1 atom arsenic acid,
$1\frac{1}{2}$ atom oxide of lead.

And this subsesquiarseniate is united with chloride of lead in the proportion of

7 atoms subsesquiarseniate of lead,
1 atom chloride of lead.

Sp. 9. *Cupreo-Chromate of Lead.*

Vauquelinite.

This mineral was observed by Berzelius accompanying the Siberian chromate of lead.[†]

Colour dark green, approaching olive green; powder and streak siskin green.

It occurs both massive and crystallized. The crystals are so small that their form cannot be recognised by the naked eye. When viewed with a glass they appear to be rhomboids, having nearly the same angles as chabasite; surface of the crystals specular splendent; streaked in the direction of the shorter diameter.

Soft enough to be scratched by the nail.

Fracture partly compact and having little lustre, or dull; partly earthy. In the first case the colour of the fracture is grey green, in the second pistachio green.

Before the blowpipe per se swells a little, and melts with much frothing into a dark grey bead, having the metallic lustre, round which globules of metallic lead may be observed. The greatest part of the bead remains unaltered, even in a high temperature. In borax it dissolves easily and with frothing

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[*] Poggendorf's Annalen, iv. 167. The specimen was from Johangeorgenstadt.

[†] Afhandlingar, vi. 246.

into a black opaque glass. If the proportion of the assay be small, the glass is green; and if it be kept in the exterior flame it remains transparent after cooling; but in the reducing flame it becomes, while cooling, ruby red, opaque red, or altogether black. This red colour, proceeding from copper, becomes more conspicuous when a little tin is added. With biphosphate of soda it behaves in the same way. With carbonate of soda on charcoal it fuses and is absorbed; on platinum foil it fuses readily with effervescence to a transparent mass which is green while in fusion, but becomes fine yellow on cooling. This circumstance shows the presence of chromium. The yellow mass, dissolved in a drop of water, gives a yellow colour to the liquid, and throws down lead yellow from its solutions.

Its constituents, as determined by Berzelius, are as follows:

		Atoms.
Chromic acid,	28·33	4·35
Protoxide of lead,	60·87	4·35
Oxide of copper,	10·80	2·14
	100	

Obviously a compound of
2 atoms chromate of lead,
1 atom oxide of copper.

Sp. 10. *Sexaluminate of Lead.*

Plombgomme.

This mineral occurs at Huel Goet, near Poullaouen, in Brittany. It was noticed by Gillet Laumont in 1786.*

Colour yellowish and reddish-brown, striped.

Reniform; translucent.

Hardness 4·5.

Resembles Muller's glass so much, except in colour, that it might be taken for it. When suddenly heated it decrepitates violently, but when slowly heated it becomes white and opaque.

With borax it yields a transparent colourless glass. On charcoal it does not melt, but becomes an enamel like some of the zeolites.

Its nature was first ascertained by Mr. Smithson Tennant. Berzelius analyzed it† and obtained the following constituents:

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* Jour. de Phys. 1786, p. 385.

† Ann. des Mines, v. 245.

			Atoms.
Alumina,	37	16·44	5·72
Protoxide of lead,	40·14	2·87	1
Water,	18·80	16·71	5·82
Sulphurous acid,	0·20		
Lime, oxides of iron and manganese,	1·80		
Silica,	0·60		
	98·54		

These numbers approach

6 atoms alumina,
1 atom protoxide of lead,
6 atoms water.

The alumina appears to act the part of an acid. It is a hydrous sexaluminate of lead.

4. *Triple Oxygen Salts of Lead.*

Sp. 1. *Cupreous Sulphato-Carbonate of Lead.*

This mineral has been observed only at Leadhills. It was noticed by Mr. Sowerby, in his British Mineralogy, under the name of *Green Carbonate of Copper*. It was first described and analyzed by Mr. Brooke.*

Colour deep verdigris green, inclining to mountain green, if the crystals be very delicate; streak greenish white.

It occurs in crystals which are generally very minute, and appear sometimes in small bunches, radiating from their common point of attachment to the matrix. It yields to mechanical division parallel to the planes of a right rhombic prism of 95° and 85°. The prism divides also in the direction of its shorter diagonal; and its height is to the edge of the base as 2 to 1.

Lustre resinous; translucent; rather brittle.

Hardness 2·5 to 3; specific gravity, as determined by Brooke, 6·4.

Its constituents, according to Mr. Brooke, are

			Atoms.
Sulphate of lead,	55·8	2·93	7·46
Carbonate of lead,	32·8	1·95	5
Carbonate of copper,	11·4	1·57	4
	100		

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* Edin. Phil. Jour. iii. 119.

These numbers agree nearly with

7½ atoms sulphate of lead,
5 atoms carbonate of lead,
4 atoms carbonate of copper.

Which must be the constitution of the mineral.

Sp. 2. *Hedyphan.*

This name has been given by Breithaupt to a mineral found at Longbanshyttan, in Sweden, along with brown garnet, and bisilicate of manganese.

Colour white.

Occurs in amorphous masses, traversed by numerous rents; also, according to Breithaupt, in short six-sided pyramids.

Translucent.

Lustre adamantine, passing sometimes into resinous.

Hardness 4·5 to 5; specific gravity 5·460 to 5·493.

Before the blowpipe it fuses into an opaque globule, which does not crystallize on cooling. It tinges the flame greenish-blue, without giving out any smell. When heated with biphosphate of soda it froths, and the odour of muriatic acid is perceived. When fused upon charcoal, globules of lead are obtained, and a white smoke given off with the odour of arsenic. A scoria remains which is not reducible in the interior flame, but crystallizes on cooling. No fluoric acid could be detected in it.

Its constituents, according to the analysis of Kersten,* are as follows:

		Atoms.	
Protoxide of lead,	52·950	3·78	7·4
Lime,	14·034	4·01	8·91
Chlorine,	2·029	0·45	1
Arsenic acid,	22·780	3·14	7
Phosphoric acid,	8·207	1·82	4
	100·000		

Subtracting 0·45 atom from the lead, as united with the chlorine, there remain 3·33 atoms, which, with the lime, make 7·34 atoms. The atoms of phosphoric and arsenic acid together amount to 4·96. Now 7·34 is to 4·96 very nearly as 1·5 to 1, showing that the mineral consists of subsesquisalts. The atomic numbers correspond nearly with

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* Ann. de Chim. et de Phys. xlviii. 178.

4 atoms subsesquiphosphate of lime,
2 atoms subsesquiarseniate of lime,
5 atoms subsesquiarseniate of lead,
1 atom chloride of lead.

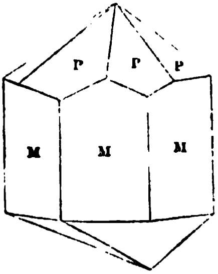
These numbers therefore must represent the chemical constitution of this mineral.

5. *Sulphur Salts of Lead.*

Sp. 1. *Zinkenite.*

This mineral was discovered by M. Zinken, at Wolfsberg, near Stolberg, in the eastern Hartz. It was named by M. G. Rose, in honour of the discoverer. To him we are indebted for the first description of it.

Colour steel grey.



Hitherto found only in crystals. The crystals are six-sided prisms, terminated by low six-sided pyramids. The faces M, M, M are longitudinally streaked.
M on M about 120°
P on P 165° 26′
according to the measurement of M. G. Rose, but the faces are not smooth enough for actual measurement. He found M on M in some cases 120° 39′, and he conjectures that the prism is not regular, but, like arragonite, made up of three right oblique four-sided prisms, with angles of 120° 39′ and 59° 21′.

Lustre strongly metallic; opaque.

Hardness 3 to 3·5; specific gravity 5·303.

The crystals are usually grouped together, and are disposed on quartz.

Before the blowpipe on charcoal zinkenite decrepitates strongly, and fuses easily like sulphuret of antimony. No metallic globule appears, but the charcoal is coated with a powder partly yellow and partly white. In a glass tube it decrepitates and melts, a white smoke fills the tube, and the smell of sulphurous acid becomes sensible, and a little oxide of lead appears. With carbonate of soda on charcoal, a little globule of lead appears.*

The constituents of zinkenite, determined by the analysis of M. H. Rose,† are

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* Poggendorf's Annalen, vii. 91.

† Ibid. viii. 99.

			Atoms.
Sulphur,	22·58	11·29	4·56
Lead,	31·84	2·45	1
Copper,	0·42	0·10	—
Antimony,	44·39	5·55	2·26
	99·23		

If we admit the copper to be combined with sulphur, and to be accidental. It is obvious that the antimony is in the state of sesquisulphide, and the lead of sulphuret; the former acts the part of an acid, and the latter of a base. The mineral is a compound of

2 atoms sesquisulphide of antimony,
1 atom sulphuret of lead.

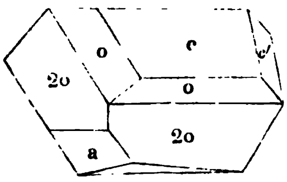
It is a ***bisulpho-antimonite of lead.***

Sp. 2. *Plagionite.**

This mineral was observed by M. Zinken at Wolfsberg. It bears a considerable resemblance to zinkenite, though its characters and constitution are sufficiently marked to entitle it to rank as a peculiar species.

Colour blackish lead-grey.

The form of the crystal is that represented in the margin, an octahedron deeply truncated in both its apices.



2o on 2o 120° 49′

according to the measurement of M. G. Rose. The three axes of the octahedron are to each other as 1 : 0·88 : 0·37.

The faces c are smooth, and have a strong metallic lustre. The other faces have less lustre, and are streaked, especially the faces 2o and o′ and the face a. The face a obviously replaces one of the angles of the octahedron.

Fracture imperfect conchoidal.

Structure foliated with two cleavages.

Brittle.

Hardness 2·5; specific gravity 5·4.

Before the blowpipe decrepitates, and fuses easily with the evolution of sulphurous acid, oxide of antimony, and oxide of

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* Zinken, Poggendorf's Annalen, xxii. 492. G. Rose, Ibid. xxviii. 421. The name is derived from πλαγιος, *oblique;* because the crystals exhibit no right angles.

lead, with which the charcoal is covered. It gives no indication of containing copper. With carbonate of soda after roasting, a button of lead is obtained, containing a little antimony, and a very minute portion of silver.

Its constituents, determined by the analysis of M. H. Rose, are

		Atoms.
Lead, .	40·52 .	3·11
Antimony, .	37·94 .	4·74
Sulphur, .	21·53 .	10·76
	99·99	

3·11 is to 4·74 very nearly as 2 to 3. It is obvious that the lead is in the state of sulphuret, and the antimony of sesquisulphide. Hence the mineral is a compound of

3 atoms sesquisulphide of antimony,
2 atoms sulphuret of lead;

or, dividing by two, of 1½ atom sesquisulphide of antimony, and 1 atom sulphuret of lead. It is therefore a *sesquisulpho-antimonite of lead*, so that it differs from zinkenite by containing half an atom less of sesquisulphide of antimony.

Sp. 3. *Jamesonite.**

This mineral was first accurately distinguished from sesquisulphide of antimony, and named by Mohs in honour of Professor Jameson of Edinburgh. It occurs in masses of considerable dimensions in Cornwall and in Hungary, but its locality is not exactly known.

Colour steel grey; streak the same.

It occurs massive and crystallized, in four-sided oblique prisms,

M on T 101° 20′

The position of the base of the prism has not been ascertained.

Fracture not observable.

Lustre metallic; opaque; sectile.

Hardness 2 to 2·5; specific gravity 5·564.

Its constituents, as determined in three separate analyses by H. Rose,† are:—

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* In honour of Mr. Jameson, Professor of Natural History in Edinburgh.

† Poggendorf's Annalen, viii. 101. In the third analysis the quantity of sulphur was not determined.

				Mean.	Atoms.
Sulphur, . . .	22·15	22·53	—	22·34	11·17
Lead, ...	40·75	38·71	40·35	40	3·09
Do. with trace of iron and zinc,	—	0·74	—	— 18	—
Copper, ...	0·13	0·19	0·21	0·14	0·03
Iron, ...	2·30	2·65	2·96	2·64	0·75
Antimony, . . .	34·40	34·90	33·47	34·26	4·28
	99·73	99·72			

If we admit the iron to have been in the state of cubic pyrites, and the copper in that of sulphuret, and both to be accidental impurities, the sulphur will be reduced to 9·64 atoms. Of this, 3·09 atoms must be united to the lead. There remain 6·55 atoms of sulphur to unite with 4·28 atoms of antimony. Now, 6·55 is to 4·28 very nearly as 1·5 to 1. So that the antimony is in the state of sesquisulphide. And the mineral is a compound of

4·28 atoms sesquisulphide of antimony,
3·09 atoms sulphuret of lead.

Or very nearly

4 atoms sesquisulphide of antimony,
3 atoms sulphuret of lead.

Or, dividing by two, we may consider it as a compound of 2 atoms sesquisulphide of antimony, and 1½ atoms sulphuret of lead. It differs from the following species by wanting half an atom of sulphuret of lead.

Sp. 4.—*Feather Ore of Lead.*

This mineral was long confounded with ***sesquisulphide of antimony***, under the name of plumose antimonial ore. It was recognised as a peculiar ore, in consequence of the chemical analysis of it by M. H. Rose. The specimen examined was from Wolfsberg, in the eastern Hartz. But it occurs also in Saxony, Hungary, and other localities.

Colour lead-grey.

Crystallized in long flexible crystals of the size of a hair, somewhat like asbestus. It fills the drusy cavities of quartz, and looks at first like a cobweb. From the extreme smallness of the size, the shape of the crystals has not been determined.

Lustre glistening, semimetallic.

Opaque; soft; specific gravity not determined; sectile.

When put into the flame of a candle it melts almost immediately, giving out a white smoke.

Its constituents, as determined by Rose,* are

		Atoms.
Sulphur,	19·72	9·86
Antimony,	31·04	3·88
Lead,	46·87	3·60
Iron,	1·30	0·37
Zinc,	0·08	0·02
	99·01	

If we consider the iron as in the state of cubic pyrites, and the zinc in that of a sulphuret, and both as accidental impurities, there will remain 9·1 atoms of sulphur, 3·6 of which must be united with the lead. There remain 5·5 atoms of sulphur to combine with 3·88 atoms of antimony, constituting very nearly sesquisulphide of antimony. But 3·88 and 3·60 being very nearly equal, it is obvious that the mineral consists of

1 atom sesquisulphide of antimony,
1 atom sulphuret of lead.

It is therefore a simple sulpho-antimonite of lead.

If we double both constituents, it will become obvious that it contains exactly half an atom of sulphuret of lead more than Jamesonite.

Sp. 5. *Nagyag tellurium ore.*

This mineral, from Nagyag, is exposed to sale in Paris, under the name of *blättererz*, though it is quite different from that mineral, and ought to constitute a species apart. I place it here, because it seems to consist essentially of a peculiar combination of sesquisulphide of antimony and sulphuret of lead, different from any of the preceding species. For its analysis and an imperfect description, we are indebted to Berthier.†

Colour iron-black, inclining to lead-grey.

It occurs in curved plates interlaced together, disseminated in bisilicate of manganese.

Lustre splendent.

Specific gravity 6·84.

Its constituents, determined by the analysis of Berthier, are

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* Poggendorf's Annalen, xv. 471.

† Memoires par Berthier, ii. 221.

		Atoms.
Gold, .	6·7	. 0·53
Tellurium,	13·0	. 4·25
Lead, .	63·1	. 4·85
Antimony,	4·5	. 0·56
Copper,	1·0	. 0·25
Sulphur,	11·7	. 5·85
	100·0	

4·85 atoms lead require 4·85 atoms sulphur to convert them into sulphuret. Doubtless the copper was in the state of sulphuret, and an accidental impurity. There remain 0·75 sulphur to combine with 0·56 antimony, constituting sesquisulphide of antimony; now 0·56 is to 4·85 nearly as 1 to 9, so that the principal part of the mineral is a compound of

1 atom sesquisulphide of antimony,
9 atoms sulphuret of lead.

The gold and tellurium probably constitute merely a mechanical mixture. If they are chemically combined with each other, as may be the case, they consist of

1 atom gold,
8 atoms tellurium.

The octotelluret of gold is to enneasulpho-antimonite of lead nearly in the proportion of 6 to 7. We may therefore consider the nagyag ore as a mixture of

6 atoms octotelluret of gold,
7 atoms enneasulpho-antimonite of lead.

It will be worth while to exhibit a tabular view of these five minerals, that the relation between them may be perceived at a glance.

Let $\mathrm{StS}^{1\frac{1}{2}}$ be the symbol for sesquisulphide of antimony, and $\dot{\mathrm{P}}\mathrm{lS}$ for sulphuret of lead.

The composition of each is as follows:

1. Zinkenite,	$2\mathrm{St}\dot{\mathrm{S}}\mathrm{l}^{1\frac{1}{2}}+\mathrm{Pl}\dot{\mathrm{S}}\mathrm{l}.$
2. Plagionite,	$1\frac{1}{2}\mathrm{St}\dot{\mathrm{S}}\mathrm{l}^{1\frac{1}{2}}+\mathrm{Pl}\dot{\mathrm{S}}\mathrm{l}.$
3. Jamesonite,	$2\mathrm{St}\dot{\mathrm{S}}\mathrm{l}^{1\frac{1}{2}}+1\frac{1}{2}\,\mathrm{Pl}\dot{\mathrm{S}}\mathrm{l}.$
4. Feather ore,	$2\mathrm{St}\dot{\mathrm{S}}\mathrm{l}^{1\frac{1}{2}}+2\mathrm{Pl}\dot{\mathrm{S}}\mathrm{l}.$
5. Nagyag ore,	$\mathrm{St}\dot{\mathrm{S}}\mathrm{l}^{1\frac{1}{2}}+9\mathrm{Pl}\dot{\mathrm{S}}\mathrm{l}.$

GENUS XXI.—TIN.

Though *tin*, where it happens to occur, is generally found in considerable quantity, it is nevertheless a much rarer metal than any of the others which have, from time immemorial, been in common use. The ores are very few, only two species being known. These are *peroxide of tin* and *cupreous sulphuret of tin.*

Sp. 1. *Peroxide of Tin.*

Tinstone, wood tin, tin ore.

This species, from which nearly all the tin of commerce is extracted, occurs only in primary rocks, where it is found both in veins and disseminated. Granite, gneiss, mica slate and clay slate are the usual formations in which it is found. It abounds in Cornwall, Saxony and Bohemia, and in the peninsula of Malacca and island of Banca, in India. It is said also to occur in Chili. In minute quantity it has been found in the rocks near Fahlun, in the Albite rock at Chesterfield, Massachusetts, and in many other places.

In Cornwall it has been smelted from time immemorial. The Tyrians appear to have traded with Cornwall for tin as early as the time of Moses; depôts of it seem to have been established on St. Michael's Mount, called Iktis (ἰκτις), by the Greeks, whence it was transported to those countries that required it.

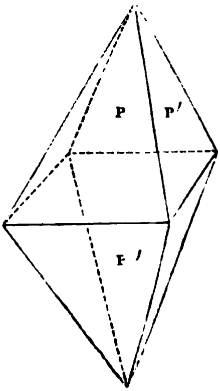
Colour various shades of white, grey, yellow, red, brown, black; streak pale grey, sometimes pale brown.

Usually in crystals. The primary form is an octahedron with a square base.

P on P′ 133° 30′

P on P″ 67° 50′

According to the measurement of Mr. W. Phillips. The angle over the apex is 112° 10′. It never occurs under this form; the nearest to it is a four-sided square prism, terminated by four-sided pyramids, or the primary form with a prism interposed between the pyramids. It occurs under a great variety of modifications, and very commonly in macles, consisting of two crystals interwoven together.



Structure foliated; surface of the prisms often vertically streaked.

Lustre adamantine.

Sometimes nearly transparent, often semitransparent; frequently opaque; brittle.

Hardness 6·5; specific gravity, by my trials, from 6·55 to 6·945.

Alone it does not melt before the blowpipe, but is reducible on charcoal, especially if assisted by the addition of a mixture of borax and carbonate of soda.

Insoluble in acids.

Its constituents are as follows:

	*	*	†	‡	§
Peroxide of tin,	99	99·5	95	93·6	96·265
Oxide of columbium,	—	—	—	2·4	—
Peroxide of iron,	0·25	0·5	5	1·4	3·395
Sesquiox. of mangan.,	—	—	—	0·8	
Silica, . .	0·75	—	—	—	6·750
	100	100	100	98·2	100·41

It consists essentially of oxide of tin; yet, in some specimens, silica appears to enter into the constitution of the mineral. The specimen analyzed by me is a compound (neglecting the peroxide of iron) of

3 atoms peroxide of tin,
1 atom silica.

Wood tin is distinguished by its fibrous texture and its brown colour, imitating the texture of wood. It was formerly very abundant in Cornwall. Fine specimens have been brought from Mexico.

Sp. 2. *Cupreous Sulphuret of Tin.*

Tin pyrites, bell metal ore.

This species has been found only in Cornwall. It occurs in a vein nine feet wide, in Huel Rock in the parish of St. Agnes, accompanied by blende and sulphuret of iron. Some other Cornish localities have been also mentioned.

Colour steel-grey; yellowish-white or brass-yellow; streak black.

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* Klaproth, Beitrage, ii. 256.

† Collet Descotils, Ann. de Chim. liii. 268.

‡ Berzelius, Afhandlingar, iv. 164. The specimen was from Finbo; colour black; specific gravity 6·55.

§ By my analysis. A reddish-brown specimen from Cornwall; specific gravity 6·945.

Usually massive, but it has been observed also crystallized in regular hexahedrons; lustre metallic; opaque; brittle.

Hardness 3·25; specific gravity 4·350, as determined by Klaproth.

Before the blowpipe sulphur is driven off, and the mineral melts into a blackish scoria without yielding a metallic button.

It dissolves in nitromuriatic acid, the sulphur being partly left behind.

The following, according to Klaproth, are the constituents of this mineral:

Sulphur,	25	30·5
Tin,	34	26·5
Copper,	36	30
Iron,	2	12
	97[*]	99[†]

If these analyses be accurate, it is not easy to avoid considering the mineral rather as a mechanical mixture than a chemical compound. The first analysis gives us

	Atoms.
Sulphur,	12·5
Tin,	4·69
Copper,	9·0
Iron,	0·57

If the iron was in the state of cubic pyrites, it would be combined with 1·14 atom sulphur. The copper would be united with 9 atoms sulphur, leaving 2·36 atoms sulphur, combined with 4·69 atoms tin. So that the tin must have been in the state of disulphuret. The mineral consisted of

0·57 atom iron pyrites,
9 atoms sulphuret of copper,
4·69 atoms disulphuret of tin.

These numbers are nearly equivalent to

1 atom iron pyrites,
8 atoms disulphuret of tin,
16 atoms sulphuret of copper.

The second analysis gives us

	Atoms.
Sulphur,	15·25
Tin,	3·65
Copper,	7·5
Iron,	3·42

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[*] Beitrage, ii. 259.

[†] Ibid. v. 228.

If the iron be in the state of cubic pyrites, it will take 6·84 atoms of sulphur. There will remain 8·41 atoms. If the copper take 7·5 atoms, there will remain only 0·90 atom of sulphur to combine with 3·65, which would make a tetrakisulphuret of tin, instead of a disulphuret. The constituents would be

3·42 atoms cubic pyrites,
7·5 atoms sulphuret of copper,
3·65 tetrakisulphuret of tin.

These correspond nearly to

1 atom cubic pyrites,
2 atoms sulphuret of copper,
1 atom tetrakisulphuret of tin.

I think it probable, from the mode of analysis followed, that the quantity of sulphur is underrated.

GENUS XXII.—BISMUTH.

The ores of *bismuth* are not numerous, and like those of tin, they consist chiefly of combinations of the metal with simple bodies. The native salts of bismuth are few. Saxony is the country where the greatest part of the bismuth of commerce is procured; though specimens of some of the ores are found in Cornwall.

1. *Native, or combined with Simple Bodies.*

Sp. 1. *Native Bismuth.*

This mineral occurs most abundantly at Johan-georgenstadt, and Schneeberg, in Saxony, and at Joachimsthal, in Bohemia. Fine specimens have been obtained from the tin mine of Altenberg. It has been met with also in France, Sweden, Norway, Connecticut, and in Botallack, and at St. Columb, and at Huel Sparnan in Cornwall, and also at Carroch in Cumberland.

Colour silver-white, with a tint of red; streak similar.

Massive, also crystallized in acute rhomboids and in regular octahedrons.

Texture lamellar, and it cleaves parallel to the faces of the regular octahedron.

Surface rough, generally covered with oxide.

Lustre metallic; sectile; opaque.

Hardness 3·25; specific gravity 9·737

It melts even at the flame of a candle. Before the blowpipe it is gradually dissipated in a yellow smoke, which is deposited on the charcoal.

Dissolves in nitric acid. When the solution is sufficiently diluted, a white curdy precipitate falls.

I am not aware that this mineral has been subjected to analysis. As the bismuth of commerce is merely the native bismuth melted out of the stony matrix in which it is found, it is obvious that native bismuth consists almost entirely of the pure metal. It is not, however, quite free from sulphur.

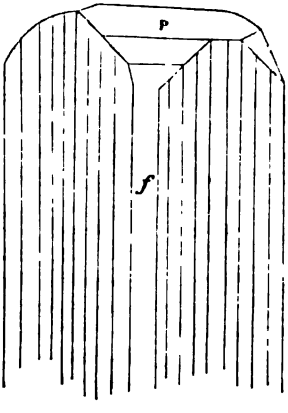
Sp. 2. *Sulphuret of Bismuth.*

Bismuth glance.

This mineral occurs chiefly in veins, though it has been found also in beds. It is rather rare. Saxony and Bohemia are the most abundant localities. But it occurs also in Cornwall, and at Riddarhyttan in Sweden.

Colour lead-grey, inclining a little to steel-grey; streak similar.

It occurs massive and crystallized in small prisms, too minute to determine the exact dimensions. It cleaves parallel to the faces P and *f*, and at right angles to *f*. There are also indications of cleavage parallel to the planes of a right rhombic prism of about 130° and 50°. The principal cleavage is parallel to the face *f*. The other faces of the prism are longitudinally streaked.



Mr. W. Phillips measured some artificial crystals of sulphuret of bismuth, and found them rhombic prisms of 91° and 89°.

Lustre metallic; opaque; rather sectile.

Hardness 2·75; specific gravity 6·549.

It is volatilized before the blowpipe, and covers the charcoal with a yellow areola. It is very fusible, and gives off continually small drops in a state of incandescence.

Dissolves readily in hot nitric acid. When the solution is diluted with water, a white precipitate falls.

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* Phil. Mag. (2d series), ii. 181.

Its constituents, as determined by the analysis of M. H. Rose,* are

			Atoms.
Sulphur,	.	18·72	. 9·36
Bismuth,	.	80·98	. 8·99
		99·70	

This is obviously

1 atom sulphur,
1 atom bismuth.

It is a simple sulphuret of bismuth.†

Sp. 3. *Ferruginous Arseniet of Bismuth.*

This mineral occurs at Schneeberg in Saxony.

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[*] Gilbert's Annalen, lxxii. 192. The specimen was from Ridderbyttan. Wehrle's analysis, noticed by Berzelius (Jahres-Bericht, 1833, p. 177), almost coincides with this. He obtained

			Atoms.
Sulphur,	. .	18·28	. 9·14
Bismuth,	. .	80·96	. 8·99
		99·24	

[†] Mr. Warrington has given us the analysis of a sulphuret of bismuth found in the western parts of Cornwall, which differs from the species described in the text, by containing a mixture of sulphurets of iron and copper, probably accidental. See Phil. Mag. (new series), ix. 29.

It occupies the cavities and fissures of a porous mass of yellow copper pyrites and silica, in the form of striated needles and bands. External colour iron-grey, internally it resembles polished steel. Specific gravity 5·85; hardness 2·7.

When heated before the blowpipe on charcoal, it inflames, and when the heat is increased for some time, it appears to be entirely volatilized, with the exception of a minute globule of brown scoriaceous matter.

Its constituents, determined by an analysis conducted with great care, were as follows:

			Atoms.
Bismuth,	. .	68·53	. 7·6
Sulphur,	. .	19·33	. 9·6
Iron,	. . .	2·90	. 0·82
Copper,	. .	2·98	. 0·74
Silica,	. . .	5·01	
		98·75	

This is obviously

7·6 atoms sulphuret of bismuth,
0·8 atom sulphuret of iron,
0·74 sesquisulphuret of copper.

Abstracting the two last compounds, which probably may not exist in chemical combination, the mineral will agree with the species described in the text.

Colour externally, dark hair brown; internally, brownish yellow.

Massive; composed of plates or columns applied to each other.

Lustre resinous; brittle.

Hardness 5·5; specific gravity 3·694.

It decrepitates briskly before the blowpipe, emits an arsenical odour, and burns with a blue flame, being either dissipated or fused into a metallic globule, according to circumstances.

Soluble in nitric and muriatic acid.

Its constituents, by my analysis, are

			Atoms.
Arsenic,	38·092	8·02	4
Bismuth,	55·913	6·21	3·09
Iron,	6·321	1·80	0·9
	100·326		

These numbers correspond with

4 atoms arsenic,
3 atoms bismuth,
1 atom iron.

Hence the mineral consists of

3 atoms arseniet of bismuth,
1 atom arseniet of iron.

Sp. 4. *Arsenic Glance.*

This mineral, which occurs at Palmbaum, near Marienberg, was first noticed by Freisleben. Berzelius announced, in the year 1827, that it was a compound of

12 atoms arsenic,
1 atom sulphur.

But it was analyzed by M. Kersten,* who found the constituents

Arsenic,	96·785
Bismuth,	3·001
	99·786

And though he searched for sulphur he could detect none. It is obvious from this, that Berzelius and Kersten experimented on two different minerals. We have no accurate description of either. But they seem rather entitled to be considered as

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* Poggendorf's Annalen, xxvi. 492.

varieties of native arsenic, than as peculiar species. Berzelius's mineral is a compound of

Arsenic,	.	96·61
Sulphur,	.	3·39
		100·00

While that of Kersten consists of

40½ atoms arsenic,
1 atom bismuth.

It seems unreasonable to consider such combinations as chemical compounds.

Sp. 5. *Telluret of Bismuth.*

This mineral was first noticed by Baron Von Born, and considered by him as a compound of silver and bisulphide of molybdenum.* It was afterwards examined by Klaproth, who stated it to be a compound of 95 bismuth and 5 sulphur.† More lately, Berzelius subjected it to the action of the blowpipe, and found it to be chiefly composed of tellurium and bismuth.‡

It was discovered first at Deutch Pilsen, in Hungary. Berzelius recognised it in a specimen from Riddarhyttan.

Colour silver-white.

Composed of broad plates laid on each other.

Lustre metallic; opaque.

Hardness 2; stains paper like sulphuret of molybdenum. Specific gravity, according to Baumgärtner, 7·514; according to Wehrle, 7·500.

May be divided into thin plates, like sulphuret of molybdenum. Found crystallized in small crystals, having the aspect of six-sided prisms, but Haidinger has shown that they consist in reality of two different rhomboids united together.§

Before the blowpipe melts the instant it is exposed to heat, and gives out a yellow metallic vapour.

Berzelius detected in it a little sulphur and selenium; but found its chief constituents to be bismuth and tellurium. Wehrle subjected it to a chemical analysis, and found its constituents to be

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* Catalogue de la Collection des fossiles de Mlle. de Raab, ii. 419.

† Beitrage, i. 253.

‡ Kong. Vet. Acad. Handl., 1823, p. 183.

§ See Poggendorf's Annalen, xxi. 596.

		Atoms.
Bismuth,	59·84	6·65
Tellurium,	35·24	8·81
Sulphur,	4·92	2·46
	100·00	

Berzelius obtained

Bismuth,	58·30
Tellurium,	36·05
Sulphur,	4·32
Matrix,	0·75
	99·42 with a trace of selenium.

It is obviously a compound of

1 atom sulphuret of bismuth,
2 atoms bitelluret of bismuth.

Its formula is $BisS+2BisTel^2$.

The so-called molybdenum silver of Deutch Pilsen, was also analyzed by Wehrle. Its specific gravity is 8·44. Its constituents

		Atoms.
Bismuth,	61·15	6·8
Tellurium,	29·74	7·43
Silver,	2·07	0·17
Sulphur,	2·33	1·16
	95·29	

It would appear to consist of

6·8 atoms telluret of bismuth,
1 atom sulphuret of tellurium,
0·17 atom sulphuret of silver.

But the analysis is imperfect in consequence of the loss of 4·71 per cent.

Sp. 6. *Oxide of Bismuth.*

Bismuth ochre.

This rare mineral has been observed at Schneeberg and Joachimsthal.

Colour greenish yellow or yellowish grey.

Massive and disseminated.

Fracture fine grained uneven, passing into foliated and earthy.

Lustre adamantine; that of the fine grained uneven, glimmering; of the foliated, shining; of the earthy, dull.

Opaque; soft, often friable; specific gravity, according to Büsson, 4·3611.

Before the blowpipe on charcoal it is easily reduced to the metallic state, and the greatest part may be afterwards dissipated.

It is said to have been analyzed by Lampadius, with the following result:

		Atoms.
Oxide of bismuth,	86·4	8·63
Oxide of iron,	5·1	1·15
Carbonic acid,	4·1	1·49
Water,	3·4	3·02
	99·0	

If the iron was in the state of protoxide, the mineral may be considered as a mixture of

$7\frac{1}{2}$ atoms oxide of bismuth,
1 atom carbonate of iron,
$2\frac{1}{2}$ atoms water.

I suspect strongly, that this species and the next will be found ultimately the same.

2. *Simple Oxygen Salts of Bismuth.*

Sp. 1. *Carbonate of Bismuth.*

This mineral was found at St. Agnes, Cornwall. It is an earthy substance of a dirty yellow colour. Mr. Gregor examined it, and found it to consist essentially of carbonic acid and bismuth. The small fragment of it in my possession, consists chiefly of earthy matter. It does not effervesce sensibly in acids, and contains only traces of bismuth. I think it likely, that ultimately bismuth ochre and carbonate of bismuth, will turn out one and the same mineral. We still want a good analysis of both. I have never been able to procure specimens of either fit for an accurate analysis.

Sp. 2. *Silicate of Bismuth.*

Bismuth blende—kieselwismuth—arsenical bismuth of Breithaupt.

This mineral is found in the neighbourhood of Schneeberg. It was first described and named by Breithaupt.*

Colour clove-brown and reddish brown; streak yellowish-grey.

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* Poggenderf's Annalen, ix. 275.

It is usually crystallized. The primary form, according to Breithaupt, is the rhomboidal dodecahedron. But it occurs also in tetrahedrons, hexahedrons, and pyramidal dodecahedrons.

Varies from opaque to semitransparent; brittle; not very difficultly frangible.

Hardness 5·5 to 6; specific gravity from 5·912 to 6·006.

When heated in a glass tube it decrepitates, giving out a trace of water.

Before the blowpipe it fuses to a dark yellow mass, and gives out a sublimate which is destitute of smell. On charcoal it fuses easily. The fused mass froths, and seems to give out a small quantity of gas. The charcoal round the assay is stained yellowish-brown, sometimes with a tint of green. With carbonate of soda it fuses easily into a button, at first greenish-yellow and then reddish-yellow. Globules of a brittle metal make their appearance, and the charcoal becomes coated with a yellowish-brown matter. No smell of arsenic could be perceived, nor any indication of the presence of sulphur.

Fused with borax in the oxidizing flame, it formed a glass yellowish-red while hot, then becoming yellowish-green, and when quite cold, opal coloured. When this glass was transferred from the platinum wire to charcoal, and the blast continued, it became grey and opaque. By little and little it frothed, and a button of reduced metal was obtained. With biphosphate of soda it entered into fusion, leaving a skeleton of silica. The glass while hot was yellow, but colourless when cold. An additional dose of the assay rendered the glass reddish-brown and then greenish-yellow while hot, but it became colourless when cold, or opal if the dose of the assay was great.

Its constituents, determined by a very careful analysis of Kersten,* are as follows:

		Atoms.	
Oxide of bismuth,	69·38	6·94	1
Silica,	22·23	11·11	1·6
Phosphoric acid,	3·31	0·73	
Peroxide of iron,	2·40	0·48	
Sesquioxide of mangan.,	0·30	0·06	
Fluoric acid and water,	1·01		
	98·63		

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* Poggendorf's Annalen, xxvii. 81.

If we admit the phosphoric acid to be in combination with the iron, forming a sesquiphosphate of iron, and if we allow that this substance is only accidental, then the mineral will be a sesquisilicate of bismuth, or a compound of

$1\frac{1}{2}$ atom silica,
1 atom oxide of bismuth.

3. *Sulphur Salts of Bismuth.*

Sp. 1. *Needle Ore of Bismuth.*

This mineral occurs in the mines of Pischminskoi and Klintzefskoi, near Berasof, in the district of Catherinenburg in Siberia, and was first described and analyzed by Karsten and John.

Colour steel-grey with a pale copper red tarnish.

Massive and crystallized in four or six-sided prisms, in which the lateral faces are longitudinally streaked.

Fracture uneven. Such of the crystals as I have seen traverse quartz.

Lustre metallic; opaque.

Hardness 5·25; specific gravity, as determined by John, 6·125.

Before the blowpipe sulphur is driven off, the assay melts and emits numerous sparkling metallic globules. A button of lead containing copper remains, which communicates a greenish blue colour to glass of borax.

Its constituents, as determined by John,* are

		Atoms.	
Bismuth, .	43·20	4·8	2·55
Lead, . .	24·32	1·87	1
Copper, . .	12·10	3·02	1·6
Nickel? . .	1·58	0·48	
Tellurium? .	1·32	0·33	
Sulphur, .	11·58	5·79	
Gold, . .	0·79	0·06	
	94·89		

The loss of 5 per cent. in this analysis, renders it impossible to deduce from it the chemical constitution of the mineral. The atoms of metals are nearly twice as numerous as those of sulphur. Hence the metals must be in the state of disul-

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* Gehlen's Jour. (2d series), v. 227.

phurets. If we admit the disulphurets of nickel, and tellurium, and the gold, to be accidental impurities, the bismuth, lead and copper, are to each other very nearly as the numbers 5, 2, 3. Hence the constituents are

5 atoms disulphuret of bismuth,
3 atoms disulphuret of copper,
2 atoms disulphuret of lead.

Were we to admit the disulphuret of bismuth to act the part of an acid, and the other two that of bases, the constitution of needle ore would be

3 atoms sulphobismuthide of copper,
2 atoms sulphobismuthide of lead.

But a new analysis is still wanting, to fix our ideas about the constitution of this mineral.

GENUS XXIII.—COPPER.

Copper probably stands next to lead in abundance. The variety of its ores is considerable. It is found native, or combined with simple bodies; and it forms a greater number of oxygen salts than any of the metals except iron, while its sulphursalts are as numerous as those of lead.

1. *Native, or combined with Simple Bodies.*

Sp. 1. *Native Copper.*

This mineral is rather common, both in veins and beds. In Cornwall it is rather abundant, in the mines around Redruth. Fine crystallized specimens come from Siberia; nor is it uncommon in Germany, Spain, Norway, America, &c.

Colour copper-red; streak unaltered.

Massive, and in strings and plates; often crystallized. The primary form is the cube; but it occurs also in octahedrons, rhombic dodecahedrons and icosahedrons.

Lustre metallic; opaque. Fracture hackly; ductile.

Hardness 2·75; specific gravity 8·5844, as stated by Hauy.

Before the blowpipe it fuses pretty easily, and is covered on cooling with a coat of oxide.

Dissolves easily in sulphuric acid; solution blue.

I am not aware that it has been subjected to analysis, but it consists almost entirely of metallic copper. If any other metal be present in minute quantity, its presence has not yet been detected.

Sp. 2. *Red Oxide of Copper.*

Red copper ore, octahedral copper ore, ziegelerz, tile ore.

This mineral occurs both in beds and veins; most commonly in primary rocks. One of the most abundant localities is Cornwall, but it occurs also in the Bannat of Temeswar, near Catherinenburg in Siberia, and at Chessy, near Lyons. The French specimens occur in sandstone, the Hungarian in gneiss. Many other localities might be named.

Colour between cochineal-red and lead-grey. When in capillary crystals almost carmine red; streak various shades of reddish-brown.

Massive and crystallized. Primary form of the crystals the regular octahedron, but it occurs also crystallized in cubes, cubo-octahedrons, rhomboidal dodecahedrons and acute rhomboids.

Lustre adamantine; sometimes imperfect metallic.

Semitransparent to translucent on the edges; brittle.

Hardness 3·5; specific gravity, according to Haidinger, 5·992.

Before the blowpipe, in the interior flame, it is reduced to a button of copper.

Soluble, with effervescence, in nitric acid; without effervescence in muriatic acid.

From the experiments of Klaproth and Chenevix, there can be no doubt that it is a suboxide of copper, composed of

2 atoms copper	= 8 or	88·88
1 atom oxygen	= 1 or	11·12
		100

Sp. 3. *Black Oxide of Copper.*

This mineral is found in most of the Cornish mines where copper pyrites or red copper ore occurs. Carrarat and Tincroft mines may be mentioned as an example.

Colour black, or bluish or brownish-black.

Rarely massive; mostly disseminated through or covering other ores of copper.

Friable; composed of dusty particles which scarcely soil the fingers.

Heavy.

Before the blowpipe it is infusible, and does not give out a sulphureous odour. With borax it yields a greenish slag.

It has not been analyzed, but is considered as a mixture of oxides of copper and iron.

Sp. 4. *Disulphuret of Copper.*

Glance copper, sulphuret of copper, vitreous copper ore, kupferglas.

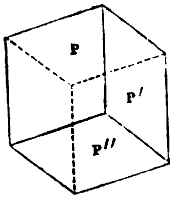
This is one of the commonest ores of copper. Fine specimens of it are found in Cornwall, near Redruth; and near Freyberg, where it is found in veins.

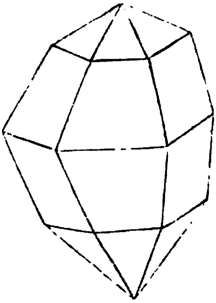
Colour blackish lead-grey; streak the same.

It occurs massive and crystallized. The primary form is an acute rhomboid.

P on P′ 71° 30′

This is the form obtained by cleavage, but the usual crystal is a regular six-sided prism, the terminal edges of which are usually replaced by planes, which, when complete, convert the crystal into a double six-sided pyramid. These pyramids are sometimes obtuse and sometimes acute, so that the dodecahedrons formed are either long or short. Sometimes the two dodecahedrons appear together in the same crystal, as in the figure in the margin.





Lustre metallic; opaque; very sectile.

Hardness 2·75; specific gravity of a very pure crystal, by my trial, 5·7022.

In the oxidizing flame of the blowpipe it melts, and emits glowing drops with a noise. In the reducing flame it becomes covered with a coat and does not melt. If the sulphur has been driven off, a globule of copper remains.

In hot nitric acid the copper dissolves, and most of the sulphur remains unacted on.

Its constituents are as follows:

	*	†	‡	Atoms.
Copper, .	78·5	76·5	77·16	19·29
Sulphur, .	18·5	22·0	20·62	10·31
Iron, .	2·25	0·5	1·45	0·41
Silica, .	0·75	—		
	100	99	99·23	

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[*] Klaproth, Beitrage, ii. 279.

[†] Ibid. iv. 37.

[‡] By my analysis. The specimen was a fine crystal from the united mines, Cornwall. Specific gravity 5·7022.

If we allow the iron to be in the state of cubic pyrites and an accidental impurity, it is obvious that the mineral is a compound of

1 atom sulphur,
2 atoms copper.

Or it is a disulphuret of copper.

Sp. 5. *Seleniet of Copper.*

From the analysis of M. H. Rose, given while giving an account of seleniet of lead (p. 552), it is evident that seleniet of copper exists among the seleniets found in the eastern part of the Hartz, but as it has not been seen in a separate state, no description can be given. Berzelius got from Svedenstjerna a small specimen of limestone through which some seleniet of copper was interspersed; it was heavy, had a silver-white colour and the metallic lustre. It dissolved completely in nitric acid. The solution was blue. It was scarcely precipitated by muriatic acid, and not at all by sulphuric acid or nitrate of barytes. Caustic ammonia in excess kept it wholly in solution. Carbonate of potash threw down carbonate of copper, and the residual liquor yielded selenium. From these experiments it appears that the mineral was a seleniet of copper, but the quantity was too small to admit of accurate analysis.*

Sp. 6. *Arseniet of Copper.*

White copper ore.

This mineral was noticed by Henkel, and was admitted by Werner as a peculiar species of copper ore, under the name of *weisskupfererz;* but it is very rare, and no locality is given by Hoffmann, but Mr. Jameson mentions Huel Garland in Cornwall, and several places in Germany and Hungary. I have never had an opportunity of seeing a specimen of this rare ore.

Colour intermediate between tin-white and brass-yellow.

Massive and disseminated.

Lustre metallic, glistening.

Fracture small and fine-grained, uneven.

Semihard; brittle; easily frangible; specific gravity, by De la Metherie, 4·500.

Before the blowpipe gives off arsenic, and melts into a greyish-black slag.

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* Berzelius, Afhandlingar, vi. 142.

It has not been analyzed, but from the action of the blowpipe it is obvious that it consists of arsenic, copper and iron. According to Henkel, it contains 40 per cent. of copper.

2. *Simple Oxygen Salts of Copper.*

Sp. 1. *Anhydrous Dicarbonate of Copper.*

This species was first observed by Dr. Heyne in the peninsula of Hindostan, near the eastern extremity of the Mysore, where it appears to occur in nests in primary rocks. It was described and analyzed by me in 1813.*

Colour dark blackish-brown, when the mineral is pure; but in general small veins of green and red may be seen traversing it. These consist of malachite and red oxide of iron; streak reddish-brown.

Massive; has not been observed in crystals.

Fracture small conchoidal.

Some indications of a foliated structure may be occasionally observed.

Sectile; opaque.

Hardness 4·25; specific gravity 2·620.

Dissolves in acids, with the exception of a little red powder, consisting chiefly of peroxide of iron.

Its constituents, by my analysis, are

		Atoms.
Carbonic acid,	16·70	6·07
Oxide of copper,	60·75	12·15
Peroxide of iron,	19·50	
Silica,	2	
	99·05	

The peroxide of iron and silica are foreign bodies, which traverse the mineral in small veins visible to the naked eye. It is obvious that the pure mineral is a compound of

1 atom carbonic acid,
2 atoms oxide of copper;

or it is a dicarbonate of copper.

I am not aware that this species has been observed in Europe. But it may be formed artificially.

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* Phil. Trans. 1814, p. 45.

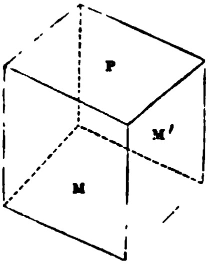
Sp. 2. *Hydrous Dicarbonate of Copper.*

Malachite—mountain green—atlaserz.

This species occurs both in veins and beds, and in rocks of various ages. Fine specimens are brought from Siberia, from Chessy in France, and Moldawa in the Bannat of Temeswar. It is rare in Cornwall.

Colour green of various kinds; grass green, emerald green, verdigris green; streak green, but rather paler.

Massive. Texture sometimes earthy, sometimes compact, and sometimes fibrous. The fibres are exceedingly slender. They are frequently fasciculated. In cavities we sometimes see minute and transparent crystals, commonly macles. These crystals yield by mechanical division an oblique rhombic prism.



P on M or M′ 112° 52′
M on M′ 107° 20′

According to the measurements of Mr. Brooke. Mr. Phillips makes the primary form a right rhombic prism.

Lustre adamantine, inclining to vitreous; sometimes silky.

Translucent, sometimes only on the edges; brittle.

Hardness 4; specific gravity 4·008, as determined by Haidinger.

Before the blowpipe it decrepitates, becomes black, remains partly infusible, and is partly converted into a black scoria. In borax it dissolves, communicating a deep green colour, and leaving a button of metallic copper.

Its constituents are as follows:—

	*	†	Mean.	Atoms.	
Carbonic acid,	18	21·25	19·62	7·13	1
Oxide of copper,	70·5	70·00	70·25	14·05	1·97
Water, .	11·5	8·75	10·125	9	1·26
	100	100			

These numbers obviously correspond with
1 atom carbonic acid,
2 atoms oxide of copper,
1 atom water.

I analyzed a specimen of pure malachite, having a silky

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* Klaproth, Beitrage, ii. 287.

† Vauquelin, Hauy's Mineralogie, iii. 491.

lustre and a specific gravity of 3·9122, by exposing it to a red heat in a bottle glass retort, to the mouth of which a tube filled with chloride of calcium was attached. The result was

			Atoms.
Carbonic acid,	19·98	7·26	1
Oxide of copper,	72·69	14·54	2
Water,	7·31	6·5	0·895
	99·98		

The carbonic acid and oxide of copper are exactly 1 and 2 atoms. The water is less than 1 atom. The mineral had been many years in my cabinet. Had it lost a little of its water?

The mineral consequently is a *hydrous dicarbonate of copper*, differing from the preceding species by the presence of an atom of water, to which it obviously owes its green colour.

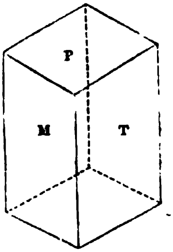
Sp. 3. *Sulphate of Copper*.

Blue vitriol.

This salt owes its existence to the decomposition of different ores of copper, especially copper pyrites. It is found dissolved in several waters, partly issuing from mines. These have received the name of waters of *cementation*. Its chief localities are Rammelsberg, near Goslar; Neusohl, in Hungary; Anglesea; Wicklow; Fahlun, &c.

Colour sky-blue of different shades, commonly deep; streak white.

Sometimes amorphous, but frequently also crystallized. The primary form is a doubly oblique prism.



P on M 127° 30
P on T 108°
M on T 123°

Lustre vitreous.

Semitransparent to translucent.

Rather brittle.

Hardness 2·25; specific gravity 2·213.

Taste metallic and nauseous; soluble in water.

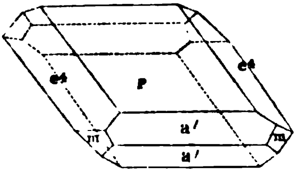
Its constituents are

			Atoms.
Sulphuric acid,	32	6·4	1
Oxide of copper,	32	6·4	1
Water,	36	32	5
	100		

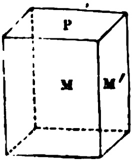
It is obviously a hydrous sulphate of copper, composed of

1 atom sulphuric acid,
1 atom oxide of copper,
5 atoms water.

Sp. 4. *Brochantite.*[*]



This name has been given by Mr. Levy to certain small emerald green transparent crystals deposited from malachite, from the Bank mines, in the government of Catherinenburg, Siberia. The crystals are thin rectangular tables bevelled on the edges, and having their angles truncated, as represented in the margin. Mr. Levy has adopted as the primary form a right rhombic prism.



Mr. Children examined a few of these minute crystals by the blowpipe, and found nothing but oxide of copper and sulphuric acid.[†]

The exact constitution and mineralogical description of these crystals must remain unknown, till they be obtained in greater quantity and of a larger size.[‡]

Sp. 5. *Tetrasulphate of Copper.*

This mineral occurs in Mexico, where it is said to be very abundant, but the particular locality is unknown. M. Berthier has analyzed it, but as he has given no description, it is impossible to give its characters.[§] Its gangue is a granular quartz rock. This rock is penetrated with red oxide of copper in a lamellar state, and with tetrasulphate of copper of a verdigris green colour. It has no lustre, has an earthy aspect.

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[*] Named in honour of M. Brochant.

[†] Annals of Philosophy (second series), viii. 241.

[‡] The Königine of Mr. Levy seems to be intimately connected with Brochantite. (See Annals of Philosophy (second series), xi. 194.) Specimens were found in the collection of the Dowager Countess of Aylesford.

Colour emerald green, or greenish black, translucent. Crystals right rhombic prisms, with angles of about 105°. Sometimes the two edges of 105°, or even the 4 edges of the prism, are replaced by tangent planes. These last crystals are barrel-shaped. By Dr. Wollaston's trials the constituents are sulphuric acid and oxide of copper.

[§] Memoires par Berthier, ii. 191.

In general it is intimately mixed with the rock, but sometimes it occurs in grains or small pieces. Berthier found the constituents,

			Atoms.
Oxide of copper,	45·9	9·18	3·99
Sulphuric acid,	11·5	2·3	1
Water,	12·1	10·75	4·67
Gangue,	30·5		
	100·0		

These numbers correspond with

1 atom sulphuric acid,
4 atoms oxide of copper,
$4\frac{2}{3}$ atoms water.

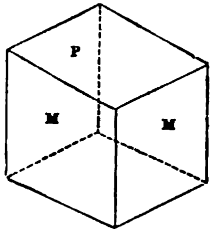
It is therefore a hydrous tetrasulphate of copper.

Sp. 6. *Hydrous Diphosphate of Copper.*

This mineral constitutes a bed in primary rocks at Libethen, near Neusohl, in Hungary.

Colour olive green, generally dark; streak olive green.

Usually in prismatic crystals, often so short as to have an octahedral form. The primary figure, according to Levy, is a right rhombic prism.



M on M′ 95° 20′

Lustre resinous; fracture conchoidal, uneven; no cleavage has been observed.

Translucent on the edges; brittle.

Hardness 4; specific gravity 3·6 to 3·8.

Its constituents, as determined by Berthier,* are as follows:

		Atoms.
Phosphoric acid,	28·7	6·37
Oxide of copper,	63·9	12·78
Water,	7·4	6·57
	100·0	

These numbers correspond with

1 atom phosphoric acid,
2 atoms oxide of copper,
1 atom water.

It is therefore a hydrous diphosphate of copper.

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[*] Ann. des Mines, viii. 334.

Sp. 7. *Pelokonite.*[*]

This mineral is found in the Tierra amarilla and the Remolinos, in China, and has been named and described by M. Richter of Freyberg.[†]

Colour bluish black; streak liver brown.

Never observed in crystals.

Fracture conchoidal.

Opaque.

Lustre vitreous, almost dull.

Brittle, but not remarkably so.

Hardness 3; specific gravity 2·567.

Dissolves easily in muriatic acid, less easily in nitric acid. The muriatic acid solution has a pistachio green colour, and contains iron, manganese, copper and phosphoric acid.

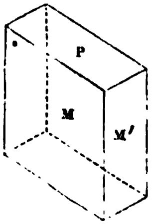
I am not aware that this mineral has been hitherto subjected to a chemical analysis.

Sp. 8. *Hydrous Subbisesquiphosphate of Copper.*

This species is found in veins traversing greywacke slate at Bonn and Virneberg, near Rheinbreitbach, on the Rhine.

Colour emerald green, verdigris green and blackish green, often darker on the surface; streak green, a little paler than that of the mineral.

It has usually a striated structure, arising from a collection of minute crystals aggregated together. The minute and separate crystals are usually dull, and of a blackish-green colour externally. The primary form of the crystal has not been well made out. Mr. Brooke, from imperfect measurements, considers it as an oblique rhombic prism.



P on M or M' 97° 30'

M on M' 37° 30'

Fracture small conchoidal, uneven.

Lustre adamantine, inclining to vitreous.

Translucent, at least on the edges.

Hardness 4·75; specific gravity, as determined by Mr. Lunn, 4·2.

Before the blowpipe it readily fuses into a reddish-black slag, adhering to the charcoal, and by the addition of carbonate of soda it is reduced to a bead of pure copper.

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[*] From *πηλος*, *black*, and *κονις*, *powder*.

[†] Poggendorf's Annalen, xxi. 590.

Its constituents, as determined by Mr. Lunn,* are

			Atoms.
Phosphoric acid,	21·687	4·82	1
Oxide of copper,	62·847	12·569	2·6
Water,	15·454	13·73	2·84
	99·988		

These numbers indicate

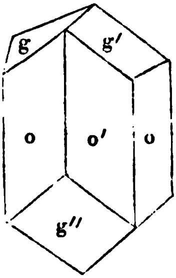
1 atom phosphoric acid,
2½ atoms copper,
3 atoms water.

It is therefore a *hydrous sub-2½phosphate of copper.*

Sp. 9. *Hydrous Sesquisilicate of Copper.*

Dioptase—achirite—emerald copper.

This mineral was brought from the Kirghese Steppes by Achir Mehemet, a Bucharian merchant. Hence the origin of the name achirite.



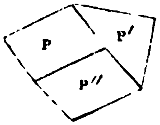
Colour emerald green, also blackish-green, and verdigris green; streak green.

It occurs in crystals, having the form of elongated rhombic dodecahedrons

g on g′ 95° 33′
o′ on o 120° 4′
g on o or g′ on o′ 133°

as measured by Mr. W. Phillips.

The primary form is an obtuse rhomboid P on P′ 126° 17′.



Structure foliated.

Fracture conchoidal, uneven.

Lustre vitreous, inclining to resinous.

Transparent to translucent; brittle.

Hardness 5; specific gravity 5·278.

It decrepitates before the blowpipe, and upon charcoal becomes black in the oxidizing flame, and red in the reducing flame, without melting. Fuses easily with borax, communicating a green colour.

Dissolves without effervescence in nitric acid, and the silica gelatinizes.

Its constituents, as determined by Lowitz,† are

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* Annals of Philosophy (second series), iii. 179.

† Nova Acta Petropol. xiii.

			Atoms.
Silica, .	33 .	16·5 .	1·5
Oxide of copper,	55 .	11 .	1
Water, .	12 .	10·66 .	0·97
	100		

These numbers obviously correspond with

1½ atom silica,
1 atom oxide of copper,
1 atom water.

It is therefore a *hydrous sesquisilicate of copper*.

By the analysis of Hess,* its constituents are

			Atoms.
Oxide of copper,	45·10 .	9·02 .	1
Silica, .	36·85 .	18·42 .	2·04
Water, .	11·52 .	10·32 .	1·14
Alumina, .	2·36		
Lime, .	3·39		
Magnesia, .	0·22		
	99·44		

This analysis leads to a different conclusion from the preceding. It indicates a bisilicate; and dioptase, according to it, differs from the following species only by containing less water.

Sp. 10. *Bisilicate of Copper*.

Kieselmalachite.

This mineral occurs at Somerville, New Jersey, in a copper mine, incrusting the ferruginous copper ore of that mine. It was first described and analyzed by Mr. George T. Bowen. More lately it has been subjected to analysis by M. Berthier.

Colour bluish-green; powder light blue.

Massive.

Fracture conchoidal; opaque; dull.

Easily scratched by the knife.

Specific gravity 2·159.

Alone before the blowpipe it becomes black, and does not melt. With borax it fuses into a glass of a bright green colour. With carbonate of soda gives globules of metallic copper.

Its constituents are as follows:

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* Memoires par Berthier, ii. 261.

	*	†	Atoms.			
			1	2	1	2
Oxide of copper,	45·175	35·1	9·035	7·02	1	1
Silica,	37·250	35·4	18·625	17·7	2·06	2·52
Oxide of iron and sand,	—	1·0	—	—	—	—
Water,	17·000	28·5	15·11	25·33	1·66	3·6
	99·425	100				

	‡	Atoms.	
Oxide of copper,	40·00	8	1
Silica,	36·54	18·27	2·28
Oxide of iron,	1·00	—	—
Quartz,	2·10	—	—
Water,	20·20	17·95	2·24
	99·84		

This is intermediate between the analyses of Bowen and Berthier.

It is obvious that the two first analyses do not belong to the same species. The first is a bisilicate, composed of

2 atoms silica,
1 atom oxide of copper,
1⅔ atom water.

The second is a bisesquisilicate composed of

2½ atoms silica,
1 atom oxide of copper,
3½ atoms water.

Berthier has given us a description of the specimen which he analyzed.

Sometimes it constitutes a thin crust of a fine green colour, transparent, having a vitreous lustre, and adhering to the surface of native copper. Sometimes it is in compact masses, having a conchoidal fracture; dull; granular; opaque, or only translucent on the edges; of a sky or blue colour, with a slight shade of green; very soft, and exceedingly light. At first it swims in water, but it gradually absorbs that liquid and then sinks to the bottom, and becomes transparent. Sometimes it is in compact masses, much heavier than the preceding variety, of a pale greenish-blue colour, and pretty hard.

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* Bowen, Silliman's Jour. viii. 118. † Berthier, Memoires par, ii. 257.
‡ Kobell, Poggendorf's Annalen, xviii. 254.

This description shows that the mineral analyzed by Berthier cannot be the same with that of Bowen.

Sp. 11. *Hydrous Sub-bisesquiarseniate of Copper.*

Erinite of Haidinger.

This mineral is found in the county of Limerick, in Ireland. The only specimen known existed in Mr. Allan's collection in Edinburgh. It was described by Haidinger, and analyzed by Dr. Turner.*

Colour emerald green, slightly inclining to grass green; streak a pale green, approaching to apple green.

It consists of masses, arranged in concentric coats, with rough surfaces, arising from the termination of exceedingly small crystals. The layers often may be easily separated from each other. They are themselves very compact, show an uneven and sometimes imperfect conchoidal fracture, and traces of cleavage.

These cleavages seem to be parallel to the broad faces of rectangular four-sided plates. These plates form crest-like aggregation.

Lustre almost dull, slightly resinous.

Translucent on the edges.

Hardness 4·75; specific gravity 4·043.

Its constituents, as determined by the analysis of Dr. Turner, are

		Atoms.	
Oxide of copper,	59·44	11·89	2·55
Alumina,	1·77	0·78	0·16
Arsenic acid,	33·78	4·66	1
Water,	5·01	4·45	0·95
	100·00		

These numbers (leaving out the alumina) correspond with

1 atom arsenic acid,
2½ atoms oxide of copper,
1 atom water.

The mineral is therefore a hydrous subbisesquiarseniate of copper.

Sp. 12. *Copper Schaum.*

Kupferschaum—bardiglione—pharmacosiderite.

This mineral occurs at Schwatz, in the Tyrol, in the Bannat

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* Phil. Magazine (second series), iv. 154.

of Temeswar, at Matlock in Derbyshire, and perhaps in other localities.

Colour pale apple green, and verdigris green, inclining to sky blue; streak of the same colour, but paler.

Massive and crystallized in octahedrons; structure radiated or foliated.

Very sectile; thin laminæ flexible.

Lustre pearly upon one of the faces, vitreous on the others.

Translucent on the edges.

Hardness 1·25; specific gravity 3·098.

It occurs in beds and veins accompanied by other ores of copper, especially *blue* copper ore.

Its constituents, determined by the analysis of Kobell,[*] are as follows:—

		Atoms.	
Arsenic acid,	25·01	3·45	1
Oxide of copper,	43·88	8·77	2·54
Water,	17·46	15·52	4·5
Carbonate of lime,	13·65	2·18	0·63
	100·00		

If the carbonate of lime be a foreign substance, as is most likely, the constitution of this mineral is

1 atom arsenic acid,
2½ atoms oxide of copper,
4½ atoms water.

It is therefore a ***hydrous subbisesquiarseniate of copper***. It differs from the preceding species merely by containing more water.

Sp. 13. *Diarseniate of Copper*.

Euchroite—emerald malachite.

This mineral was discovered at Libethen, in Hungary, in quartzose mica slate, and brought to London under the name of euchroite. It was first described by Haidinger, and analyzed by Dr. Turner.[†]

Colour bright emerald green; streak apple green.

Occurs crystallized in four-sided prisms, with angles of 117° 20′.

Cleavage indistinct.

Fracture small conchoidal, uneven.

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[*] Poggendorf's Annalen, xviii. 253.

[†] Schweigger's Jahrbuch, xv. 231, 233.

Lustre vitreous.

Transparent to translucent.

Refracts doubly, pretty strongly.

Rather brittle.

Hardness 3·75; specific gravity 3·389.

When heated it loses water, and becomes yellowish-green and friable. When heated to a certain point upon charcoal, it is reduced in an instant with a kind of deflagration, leaving a globule of malleable copper, with white metallic particles dispersed through it, which are entirely volatilized if the heat be continued.

Its constituents, as determined by the analysis of Dr. Turner, are as follows:

		Atoms.	
Arsenic acid,	33·02	4·55	1
Oxide of copper,	47·85	9·57	2·10
Water,	18·80	16·71	3·67
	99·67		

These numbers correspond with

1 atom arsenic acid,
2 atoms oxide of copper,
$3\frac{2}{3}$ atoms water.

It is therefore a hydrous diarseniate of copper.

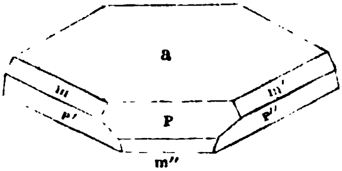
Sp. 14. *Copper Mica.*

Foliated oliven ore. Kupfer glimmer. Hexahedral arseniate of Bournon.

The localities of this species are the same as of the two succeeding ores.

Colour emerald green, grass green; streak emerald green, apple green, rather paler.

Occurs in six-sided tabular crystals, as represented in the margin.



P on a 108° 40′
P on P′ or P″ 110° 30′
P′ or P″ on a 128° 18′
a on m or m′ 124° 42′

The primary form is an acute rhomboid, of which the faces P, P′, P″ in the figure are in their relative position, and exhibit the angles.

Cleavage most perfect, perpendicular to the axis of the rhomboid; that is, parallel to the face a of the hexagonal table.

Fracture conchoidal, but scarcely observable.

Lustre of the flat faces of the hexagonal table pearly, of the other faces vitreous.

Transparent to translucent; sectile.

Hardness 2; specific gravity, as determined by Bournon, 2·5488.

It decrepitates before the blowpipe, is transformed into a black spongy scoria, and then melts into a black globule, having sometimes no vitreous appearance. Its constituents, as determined by Mr. Brooke, are

1 atom arsenic acid,
2 atoms oxide of copper,
3 atoms water.

It is a *terhydrous diarseniate of copper*, and probably is not specifically distinct from euchroite.

Sp. 15. *Prismatic Oliven Ore. Olivenite.*

Prismatic arseniate of Bournon.

This mineral occurs in several of the copper mines in the neighbourhood of Redruth, at Tingtang, Huel Garland, Huel Unity, &c. It was first described by Bournon, and analyzed by Chenevix, in 1801.

Colour various shades of olive green, passing into leek green, pistachio green, and blackish green; into liver brown, and wood brown, or also into siskin green; streak olive green, or even brown.

It occurs in fine capillary flexible threads, and in small prismatic crystals, which are mechanically divisible parallel to the planes of a right rhombic prism of 111° 45′, as measured by Brooke,* or 110° 50′ according to Phillips. Most commonly it occurs in a rhombic prism of 84° and 96°, terminated by a dihedral apex with isosceles triangular faces inclined to each other, at an angle of 112°, and rising from the acute angle of the prism.

Fracture, when visible, conchoidal, uneven.

Lustre between vitreous and resinous.

Semitransparent to opaque; brittle.

Hardness 3; specific gravity, as determined by Bournon, 4·2809; as determined by Mr. Richardson, 4·166.

Alone it remains unchanged before the blowpipe. On charcoal it melts with a kind of deflagration, and is reduced. A white metallic globule is formed, which in the process of cooling becomes coated with red oxide of copper.

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* Edin. Jour. vi. 133.

Soluble in nitric acid.

We have various analyses of this ore by Chenevix, but his methods of analysis were not of a nature to procure accurate results. Mr. Brooke* informs us that he found the constituents

1 atom arsenic acid,
2 atoms oxide of copper,
$1\frac{1}{2}$ atom water.

Kobell analyzed it in 1830,† and obtained

		Atoms.
Arsenic acid,	36·71	5·06
Phosphoric acid,	3·36	0·74
Oxide of copper,	56·43	11·28
Water,	3·50	3·11
	100·00	

The analysis of it by Mr. Richardson, in my laboratory, agrees very nearly with that of Kobell. He obtained

Arsenic acid,	39·9	1
Oxide of copper,	56·2	2·04
Water,	3·9	0·63
	100	

It is obvious from this, that it is an anhydrous diarseniate of copper; or the water, at least if an essential constituent, does not exceed half an atom.

Sp. 16. *Acicular Oliven Ore.*

Trihedral arseniate of Bournon—trihedral oliven ore—oblique prismatic arseniate of copper.

This species occurs in Cornwall, in the same localities as the preceding species.

Colour dark verdigris green, inclining to sky blue; still darker on the surface; streak pea green.

Occurs, though rarely, in very minute crystals, which may easily be mistaken for acute rhomboids, of which the acute terminations are sometimes replaced by triangular planes; but they are in fact oblique rhombic prisms, the lateral planes of which meet at angles of 56° and 124°. The inclination of the summit of the prism on the lateral planes is 95°, according to the measurement of Mr. Brooke.

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* Edin. Jour. p. 134.

† Poggendorf's Annalen, xviii. 249.

Lustre pearly on the face of perfect cleavage, on other faces resinous; translucent on the edges. Not very brittle.

Hardness 2·75. Specific gravity, by Bournon, 4·192; as determined by Mr. Richardson, 4·048.

Deflagrates before the blowpipe, and gives out arsenical vapours.

According to Mr. Brooke, its constituents are

1 atom arsenic acid,
2 atoms oxide of copper,
2 atoms water.

But it was carefully analyzed by Mr. Richardson in my laboratory, who found its constituents

		Atoms.
Arsenic acid,	39·80 .	1
Oxide of copper,	56·65 .	2·06
Water, .	3·55 .	0·57
	100	

It is therefore identical in its composition with prismatic oliven ore, being, like it, an anhydrous diarseniate of copper.

Sp. 17. *Amianthiform Diarseniate of Copper.*

A variety of Bournon's acute octahedral arseniate.

Colour light olive-green, of different shades.

Composed of a congeries of imperfect spheres, consisting each of capillary flexible threads diverging from a centre. The length of these threads varies from $\frac{1}{4}$ to $\frac{1}{2}$ inch.

Soft enough to be scratched by the nail.

Opaque; sectile; specific gravity 4·2697.

The action of the blowpipe being nearly the same on all the varieties of arseniated copper, we may refer to pages 612 and 613 of this volume.

I subjected it to analysis, and obtained

		Atoms.
Arsenic acid, .	40·61 .	1
Oxide of copper,	54·98 .	1·96
Water, . . .	4·41 .	0·7
	100·00	

It is obviously an anhydrous diarseniate, similar in its composition with the two preceding species.

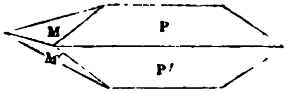
Sp. 18. *Octahedral Arseniate of Copper.*

Linsenerz, lenticular copper ore, prismatic liriconite.

This species has been hitherto found only in veins in the following Cornish mines, Huel Muttrel, Huel Garland, Huel Unity, where it is associated with the three preceding species.

Colour bluish-white, bluish-green, sky-blue, greenish-white and deep grass-green; streak similar, very pale.

The primary form of the crystal is considered to be an obtuse octahedron, in which the common base of the two pyramids is rectangular. This octahedron is usually elongated, as represented in the margin.



M on P or M′ on P′ 133° 30′
P on P′ 60° 40′
M on M′ 72° 22′

Mr. Brooke suspects the primary form to be an oblique rhombic prism.*

Fracture imperfect conchoidal, uneven.

Lustre vitreous, inclining to resinous.

Semitransparent to translucent; nearly sectile.

Hardness 2·25; specific gravity, as determined by Bournon, 2·882; according to Haidinger 2·926. I found it 2·78, but the specimen was impure.

Before the blowpipe it loses its transparency and colour, emits fumes of arsenic, and is changed into a friable scoria, containing some metallic globules. With borax gives a green glass, and is partly reduced.

According to the analysis of Mr. Brooke, its constituents are

1 atom arsenic acid,
1 atom oxide of copper,
5 atoms water.

I picked out 4·215 grains of pure crystals of this mineral, and subjected them to analysis. The analysis could not be very satisfactory, on account of the small quantity employed. But the result was as follows:

		Atoms.
Arsenic acid,	43·39	1
Oxide of copper,	30·10	1·007
Water,	26·69	3·966
	00·18	

This is obviously a compound of

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* Edin. Jour. vi. 132.

1 atom arsenic acid,
1 atom oxide of copper,
4 atoms water.

It is therefore a hydrous arseniate of copper.*

The species of arseniated copper, in a chemical point of view, may be reduced to 7:—

1. Hydrous subbisesquiarseniate of copper, composed of
    1 atom arsenic acid,
    2½ atoms oxide of copper,
    1 atom water.
2. Copper schaum, composed of
    1 atom arsenic acid,
    2½ atoms oxide of copper,
    4½ atoms water.
3. Copper mica, composed of
    1 atom arsenic acid,
    2 atoms oxide of copper,
    3 atoms water.
4. Euchroite, composed of
    1 atom arsenic acid,
    2 atoms oxide of copper,
    3⅔ atoms water.
5. Linsenerz of Trollé Wächmeister, composed of
    1 atom arsenic acid,
    2 atoms oxide of copper,
    5⅔ atoms water.

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* Trollé Wachmeister published in the Memoirs of the Stockholm Academy, for 1832, an analysis of the blue Linsenerz from Cornwall. He gives no description of the mineral which he examined, but it is evident from the result of his analysis that his mineral belonged to a different species from the mineral described in the text. He obtained*

		Atoms.	
Water, . .	22·24	. 5·65	
Oxide of copper,	35·19	. 2	
Alumina, .	8·03	. —	
Peroxide of iron,	3·41	. —	
Arsenic acid,	20·79	. 0·81	1·03
Phosphoric acid,	3·61	. 0·22	
Silica, . .	4·04		
Sand, . .	2·95		
	100·26		

The specimen was obviously very impure, but if we take the phosphoric acid along with the arsenic, the species is obviously a diarseniate of copper united with between 5 and 6 atoms water.

* Poggendorf's Annalen, xxv. 305.

6. Anhydrous diarseniate of copper, composed of
1 atom arsenic acid,
2 atoms oxide of copper,
½ atom water.

It includes species 15, 16 and 17.

7. Hydrous arseniate of copper, composed of
1 atom arsenic acid,
1 atom oxide of copper,
4 atoms water.

The constitution of these minerals will be better seen if we represent it in symbols.

1. $\underset{\cdot}{C}p^{2\frac{1}{3}}\dot{A}s+Aq.$
2. $\underset{\cdot}{C}p^{2\frac{1}{3}}\dot{A}s+4\frac{1}{2}Aq.$
3. $\underset{\cdot}{C}p^{2}\dot{A}s+3Aq.$
4. $\underset{\cdot}{C}p^{2}\dot{A}s+3\frac{2}{5}Aq.$
5. $\underset{\cdot}{C}p^{2}\dot{A}s+5\frac{2}{5}Aq.$
6. $\underset{\cdot}{C}p^{2}\dot{A}s+\frac{1}{2}Aq.$
7. $\underset{\cdot}{C}p\dot{A}s+4Aq.$

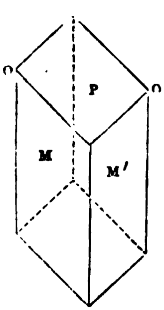
3. *Double Oxygen Salts of Copper.*

Sp. 1. *Hydro-Carbonate of Copper.*

Blue copper ore.

This species is met with in the same localities as malachite, or *hydrous carbonate of copper.*

Colour various shades of azure blue, passing into blackish-blue and Berlin-blue; streak similar, but lighter.



Massive and crystallized. By mechanical division an oblique rhombic prism may be obtained, which constitutes the primary form.

P on M or M′ 91° 30′
M on M′ 98° 50′

The terminal edges of the prism are frequently replaced by planes, which, if sufficiently enlarged, would constitute a four-sided pyramid. Sometimes the obtuse lateral edges of the prism are replaced by planes, and sometimes the angles o are replaced by triangular planes.

Texture foliated; fracture conchoidal.

Lustre vitreous, almost adamantine.

Transparent to translucent on the edges.

Brittle.

Hardness 4·25; specific gravity 3·831.

When heated it becomes black. It melts before the blowpipe on charcoal, and colours borax green in the oxidizing flame.

Dissolves with effervescence in nitric acid.

Its constituents are as follows:

	*	†	‡	Atoms.	
Carbonic acid,	24	21·25	25·76	9·36	1·93
Oxide of copper,	70	70	69·08	13·81	2·84
Water, .	6	8·75	5·46	4·85	1
	100	100	100·30		

Taking Phillips' result as probably the most accurate, the constituents are

2 atoms carbonic acid,
3 atoms oxide of copper,
1 atom water.

Hence the constitution of the mineral must be

2 atoms carbonate of copper,
1 atom hydrate of copper.

It is therefore a hydro-carbonate of copper. To the presence of water it is indebted for its blue colour.

Sp. 2. *Silico-Carbonate of Copper.*

Chrysocolla, copper green, kieselmalachite?

This species occurs along with other copper ores in Thuringia, the Hartz, Hungary, Cornwall, Norway, Siberia, Mexico, Chili, &c.

Colour emerald green, pistachio green, asparagus green, passing into sky blue; streak white, a little shining.

Texture compact without any cleavage.

Fracture conchoidal.

Lustre vitreous and very various in intensity.

Semitransparent to translucent on the edges; rather sectile.

Hardness 3; specific gravity 2·238.

Before the blowpipe on charcoal it becomes black in the interior flame without melting. With borax it melts into a green glassy globule, and is partly reduced.

When in lumps it dissolves without sensible effervescence in nitric acid; but it effervesces when in powder.

* Klaproth, Beitrage, iv. 31.

† Vauquelin, Ann. de Museum, xx. 1.

‡ Phillips, Royal Institution Jour. iv. 276.

Its constituents are as follows:—

	*	†	‡	Atoms.	
Silica, . .	26	28·37	25·31	12·65	2·32
Carbonic acid, .	7	3·00	14·98	5·44	1
Oxide of copper, .	50	49·63	54·46	10·89	2
Water, . .	17	17·50	5·25	4·66	0·84
Sulphate of lime, .	—	1·50	—		
	100	100	100		

The great difference in the proportion of carbonic acid in these analyses, renders it probable that the carbonate and silicate of copper are not chemically combined, but only mechanically mixed. Yet the specimen which I analyzed appeared, even under a strong magnifier, perfectly homogeneous.

The atomic numbers, determined from my analysis, approach

2 atoms silica,
1 atom carbonic acid,
2 atoms oxide of copper,
1 atom water.

Hence the constitution of the mineral seems to be

1 atom carbonate of copper,
1 atom bisilicate of copper,
1 atom water.

4. *Chlorine Salts of Copper.*

Sp. 1. *Hexmuriate of Copper.*

Greensand of Peru—atacamite.

This mineral was first brought to Europe by Dombey, and was supposed to occur in the state of sand in the desert of Atacama, separating Chili from Peru. But M. Mariano de Rivero informs us that it occurs in veins in the district of Tarapaca; that the Indians of Atacama extract it from these veins, reduce it to powder, and pass it through a sierce. In this state they give it the name of arenillo, and sell it all over Chili as a powder for letters.§ It is said to occur also at

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* Klaproth, Beitrage, iv. 34.

† John.

‡ By my analysis. Annals of Philosophy, vii. 322.

§ Ann. de Chim. et de Phys. xviii. 442.

Remolinos, in Chili, in brown ironstone. It has been observed investing some of the lavas from Mount Vesuvius, and at Schwartzenberg, in Saxony.

Colour olive, leek, emerald, and blackish-green; streak apple-green.

It occurs in minute crystals, of which the primary form is a right rhombic prism.

M on M′ 97° 20′

One of the most common crystals is an octahedron with a rectangular base.

Cleavage parallel to the base of the primary prism perfect. Less distinct parallel to the lateral faces of the prism.

Lustre adamantine.

Semitransparent to translucent on the edges; rather brittle.

Hardness 2·5; specific gravity 4·43.

Communicates bright blue and green colours to the flame of a candle. Before the blowpipe gives out fumes of muriatic acid, and melts at last into a globule of copper.

Dissolves without effervescence in nitric acid.

Its constituents are as follows:—

	*	*	†	Atoms.	
Muriatic acid, .	10·6	11·4	10·1	2·18	1
Oxide of copper, .	76·6	70·5	73	14·6	6·7
Water, . .	12·8	18·1	16·9	15	6·88
	100	100	100		

The atomic numbers derived from Klaproth's analysis, are

1 atom muriatic acid,
6¾ atoms oxide of copper,
7 atoms water.

But Proust's analyses rather lead to the conclusion that it is composed of

1 atom muriatic acid,
6 atoms oxide of copper,
6 atoms water.

It seems therefore to be a ***hydrous hexmuriate of copper.***

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* Proust, Ann. de Chim. xxxii. 49.

† Klaproth, Beitrage, iii. 200.

5. *Sulphur Salts of Copper.*

Sp. 1. *Variegated Copper Ore.*

Buntkupfererz—liver-coloured copper ore.

This species occurs both in primary and secondary formations, and is associated with other ores of copper. In Cornwall it has been observed in Cookskitchen, Tincroft, and Dolcoath, and in several other mines in the same county. In the Bannat, and at Mansfield it is found in beds. Ireland, Silesia, Norway, Sweden, Greenland, may also be mentioned as countries where it is found, though only in small quantities.

Colour intermediate between copper-red, and pinchbeck brown; streak pale greyish black, a little shining.

Occurs both massive and crystallized. The usual form is the cube, with the solid angles replaced by triangular planes.

Cleaves parallel to these triangular faces. Hence its primary form is the regular octahedron.

Lustre metallic; liable to tarnish, and then is iridescent; rather sectile; opaque.

Hardness 2·5; specific gravity 5·003.

Before the blowpipe it behaves almost like *copper pyrites.*

Its constituents are

	*	†	Atoms.
Copper,	63·334	61·07	15·55
Iron,	11·804	14·00	3·68
Sulphur,	24·696	23·75	12·11
Silica,	0·166	0·50	
	100	99·32	

The third column gives the mean atomic numbers deduced from both analyses. They approach pretty nearly to

4 atoms copper,
1 atom iron,
3 atoms sulphur.

The constitution of the mineral then is

2 atoms disulphuret of copper,
1 atom sulphuret of iron.

Probably the first of these sulphurets acts the part of an acid

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* Hisinger, Afhandlingar, iv. 359.

† R. Phillips, Annals of Philosophy (second series), iii. 81.

and the second of a base. It may then be considered as a *bisulphocuprite of iron*.

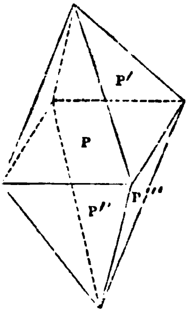
Sp. 2. *Copper Pyrites*.

Yellow copper ore.

This is one of the most abundant and important ores of copper; a very great proportion of the copper of commerce being extracted from it. It occurs both in veins and beds. In veins it is very abundant in Cornwall, and the celebrated Parys mountain in Anglesea doubtless constituted a bed. It is found also in veins in Saxony and the Hartz. Many other localities are well known, as Fahlun, Siberia, Norway, &c.

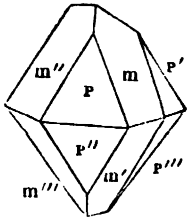
Colour brass yellow; streak greenish-black, a little shining.

It occurs both massive and in crystals. The usual shape of the crystal is a tetrahedron, with the angles replaced by small triangular planes. But Mr. Phillips has shown that the primary crystal is an octahedron with a square base.



P on P′ or P″ on P‴ 101° 52′
P on P″ or P′ on P‴ 126° 30′

The edges of the pyramids, but not their common base, are often replaced by faces m, m′, m″, &c. When these become so large as to obliterate the faces P, P′, &c., the tetrahedron with its angles truncated is formed, which is the common shape of the crystal.



Fracture uneven.

Lustre metallic; opaque; rather sectile.

Hardness 2·75; specific gravity from 4·159 to 4·160.

On charcoal it becomes black before the blowpipe, and red on cooling. It melts into a globule, which becomes magnetic if kept in the blast for some time. With borax it yields a globule of copper.

Dissolves in dilute nitric acid, leaving sulphur. The solution is green, and contains copper and iron.

Its constituents are as follows:

	*	†	‡	‡	§	‖	‖
Sulphur, . .	36·5	34·46	35·87	36·52	36·33	32	36·3
Copper, . .	30·0	31·20	34·40	33·12	32·30	32·6	32·1
Iron, . . .	31·0	30·80	30·47	30·00	30·03	29·2	31·5
Earthy matter,	1·0	1·10	0·27	0·39	2·23	3·2	—
Zinc, . . .	1·0	—	—	—	—	—	—
	99·5	97·56	101·01	100·03	100·79	97·0	99·9

	‖	‖	¶	¶	**
Sulphur, . . .	32	33·6	33·841	35·01	34·655
Copper, . . .	33·3	31·2	31·006	32·95	33·640
Iron, ...	30·0	32·2	35·630	32·04	31·535
Earthy matter, .	2·6	1·6	—	—	0·555
	97·9	98·6	100·477	100	100·385

These analyses do not differ much from each other. The analysts do not seem always to have succeeded in separating the copper completely from the iron. Abstracting the impurities, it is obvious that copper pyrites is composed of

2 atoms sulphur,
1 atom copper,
1 atom iron.

It is therefore a compound of

1 atom sulphuret of copper, probably acting the part of an acid.

1 atom sulphuret of iron, acting the part of a base.

It is a *sulphocuprate of iron.*

Sp. 3. *Bournonite.*

Endellione—triple sulphuret.

This mineral was first observed in Huel Boys, in the parish of Endellion, Cornwall. It has only been observed in veins. It was next met with at Kapnick in Transylvania; afterwards

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* Gueniveau; Nicholson's Jour. xxi. 145.

† Phillips, Annals of Philosophy (2d series), iii. 299.

‡ H. Rose, ibid. vii. 355. The first specimen was from Ramberg, the second from Furstenberg.

§ Hartwell of Abo. Ibid. p. 155.

‖ Berthier, Ann. des Mines, viii. 341.

¶ By my analysis. The specimens were from Anglesea.

** By my analysis. A fine crystal from the United Mines, Cornwall. Specific gravity 4·160.

in Auvergne. Magnificent crystals of it were found at Neudorf in Anhalt, and at Andreasberg in the Hartz.

Colour steel-grey, inclining to blackish lead-grey or iron-black, according to the physical qualities of the surface; streak unaltered.

It occurs partly crystallized in the form of rectangular prisms, variously modified, and partly imbedded. It is perfectly lamellar, affording brilliant planes by mechanical division, parallel to the lateral planes of a right rectangular prism, and likewise to both the diagonals of the base of the prism. Thus the primary form may be either a right rectangular or a right rhombic prism, with angles of 93° 30′, and 86° 30′. But the first of these figures has been preferred by crystallographers. The secondary forms are produced by planes upon the edges and angles of this primary form.

Lustre metallic; opaque; brittle.

Hardness 2·75; specific gravity, as determined by Hatchett, 5·766.

Before the blowpipe upon charcoal, it melts, smokes, and yields a black globule. In a strong heat the charcoal becomes covered with a globule of lead.

Dissolves easily in nitric acid when assisted by heat.

Its constituents are

	*	†	‡	§
Sulphur, . . .	17	18	13·50	16
Antimony, . . .	24·35	19·75	16·00	28·5
Lead, ...	41·12	42·52	34·50	39
Copper, . . .	12·80	11·75	16·25	13·5
Iron, ...	1·20	5·00	13·75	1
Silver, ...	—	—	2·25	—
Lime and silica, . .	—	—	2·5	—
	96·47	97·00	98·75	98·0

The third of these specimens was obviously impure. This seems to be the case with the fourth also; at least it contains much more antimony than any of the others. The mean of the first two analyses gives us

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* Hatchett, Nicholson's Jour. ix. 16. Correcting some of his estimates.

† Klaproth, Gehlen's Jour. v. 34. Specimen from Altensegen in Clausthal.

‡ Klaproth, Beitrage, iv. 86. From Andreasberg.

§ Klaproth, ibid. p. 87. From Nanslo in Cornwall.

		Atoms.	
Sulphur,	17·5	8·75	2·72
Antimony,	22·05	5·26	1·64
Lead,	41·81	3·21	1
Copper,	12·27	3·07	0·95
Iron,	3·10	0·88	0·27

These numbers approach nearly to

5½ atoms sulphur,
3 atoms antimony,
2 atoms lead,
2 atoms copper.

But M. H. Rose* has lately subjected this mineral to a careful analysis, and obtained the following constituents from crystals from Pfaffenberg, near Neudorf.

		Atoms.	
Sulphur,	20·31	10·15	3·21
Antimony,	26·28	3·28	1·03
Lead,	40·84	3·14	0·99
Copper,	12·65	3·16	1
	100·08		

These numbers are obviously

3 atoms sulphur,
1 atom antimony,
1 atom lead,
1 atom copper.

Hence the mineral must be composed of

1 atom sulphide of antimony,
1 atom sulphuret of lead,
1 atom sulphuret of copper.

The first of these acts the part of an acid, and the other two of bases. Bournonite is a compound of

1 atom disulpho-antimonite of lead,
1 atom disulpho-antimonite of copper.

Sp. 4. *Grey Copper Ore.*

Fahlerz—fahl ore.

This mineral occurs along with the other species. There is some risk in pointing out localities, because various species have been certainly confounded together under the name of grey copper ore.

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* Poggendorf's Annalen, xv. 573.

Colour steel-grey, or iron-black; streak unaltered, sometimes inclining to brown.

Massive and crystallized in tetrahedrons, which is considered the primary form. But no regular structure is visible. Nor have the crystals been sufficiently examined to detect their true form.

Lustre metallic; opaque; rather brittle.

Hardness 2·75; specific gravity, as determined by Haidinger, from 4·798 to 5·104.

To determine the chemical constitution of this difficult species, M. H. Rose has analyzed seven carefully selected and pure crystallized specimens from different localities.* These analyses having thrown a new light on the subject, it will be requisite to state the results here.

1. Grey copper ore from St. Marie aux Mines, in Alsace. It is accompanied by quartz and grey oxide of manganese; streak black.

		Atoms.
Sulphur,	26·83	13·41
Antimony,	12·46	1·59
Arsenic,	10·19	2·14
Iron,	4·66	1·33
Zinc,	3·69	0·86
Silver,	0·60	0·04
Copper,	40·60	10·15
Quartz,	0·41	
	99·44	

The atoms of antimony, arsenic, and copper, are 13·88, and those of sulphur 13·41. Hence these metals must be in the state of simple sulphurets.

The atoms of antimony and arsenic are nearly ⅓ of those of copper. Hence the essential constituents of this specimen seem to be

$$1 \text{ atom sulphide of} \left\{ \begin{array}{l} \text{antimony,} \\ \text{arsenic,} \end{array} \right.$$

3 atoms sulphuret of copper.

$$\text{The mineral is a trisulpho-} \left\{ \begin{array}{l} \text{antimonite} \\ \text{arsenite} \end{array} \right\} \text{of copper.}$$

2. From Gersdorf, by Freyberg. It occurs in veins in gneiss, with crystallized fluor spar and sulphate of barytes. Streak black.

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[*] Poggendorf's Annalen, xv. 576.

		Atoms.
Sulphur,	26·33	13·16
Antimony,	16·52	2·06
Arsenic,	7·21	1·5
Iron,	4·89	1·39
Zinc,	2·76	0·64
Silver,	2·37	0·17
Copper,	38·63	9·76
	98·71	

Here, to make the atoms of the copper thrice the number of those of antimony and arsenic, we must add the atoms of zinc and silver. This specimen, like the last, consists of

1 atom sulphide of { antimony, arsenic,
3 atoms sulphuret of copper, silver, zinc.

But the antimony bears a much greater proportion to the arsenic than in the first specimen.

3. From Kapnick in Hungary. It occurs in fine crystals along with crystallized quartz, galena, iron pyrites, and yellow blende; streak dark red.

		Atoms.
Sulphur,	25·77	12·88
Antimony,	23·94	2·99
Arsenic,	2·88	0·60
Iron,	0·86	0·24
Zinc,	7·29	1·71
Silver,	0·62	0·04
Copper,	37·98	9·49
	99·34	

To make the atoms of copper thrice those of the antimony and arsenic, it will be necessary to add to them a little of the zinc, but not the whole.

This specimen, like the preceding, consists of

1 atom sulphide of { antimony, arsenic,
3 atoms sulphuret of copper.

But the antimony exists in 5 times as many atoms as the arsenic.

4. From Dillenburg. It occurs in veins in greywacke; streak cherry-red. Crystals frequently mixed with iron pyrites.

		Atoms.
Sulphur,	25·03	12·51
Antimony,	25·27	3·16
Arsenic,	2·26	0·47
Iron,	1·52	0·43
Zinc,	6·85	1·58
Silver,	0·83	0·06
Copper,	38·42	9·60
	100·18	

This is obviously similar to the others, consisting of

1 atom sulphide of { antimony,
arsenic,
3 atoms sulphuret of copper.

5. From Zilla, near Clausthal. It is crystallized in tetrahedrons, usually incrusted with copper pyrites. It occurs in veins in greywacke along with galena, sparry iron ore and brown spar; streak dark red.

		Atoms.
Sulphur,	24·73	12·36
Antimony,	28·24	3·53
Iron,	2·27	0·64
Zinc,	5·55	1·30
Silver,	4·97	0·36
Copper,	34·48	8·62
	100·24	

Here there is no arsenic at all. To make the atoms of copper thrice those of antimony, we must add the zinc and silver. The specimen is composed of

1 atom sulphide of antimony,
3 atoms sulphuret of copper.

6. From the Wenzel mine, near Walfort in Furstenberg. It occurs in veins in talky gneiss, with crystals of sulphate of barytes and some galena; streak black.

		Atoms.
Sulphur,	23·52	11·76
Antimony,	26·63	3·33
Iron,	3·72	1·06
Zinc,	3·10	0·72
Silver,	17·71	1·28
Copper,	25·23	6·31
	99·91	

Here, to make the atoms of copper thrice those of antimony, we must add all the other metals. The specimen consists of

1 atom sulphide of antimony,

$$3 \text{ atoms sulphuret of} \begin{cases} \text{copper,} & 2 \\ \text{silver, zinc, iron,} & 1 \end{cases}$$

7. *From Habacht-Fund mine, near Freyberg.* This mineral at Freyberg is called crystallized Weissgültigerz. But its composition is quite different from the Weissgültigerz of Freyberg analyzed by Klaproth. It is crystallized in tetrahedrons, and occurs along with galena, copper pyrites, rothgüld, brown spar, grey oxide of manganese, blende, and quartz.

		Atoms.
Sulphur,	21·17	10·58
Antimony,	24·63	3·08
Iron,	5·98	1·7
Zinc,	0·99	0·23
Silver,	31·29	2·27
Copper,	14·81	3·70
	98·87	

Here the whole metals taken together, do not amount to three times the number of atoms of the antimony. I suspect the reason to be, that the atom of silver is reckoned twice as heavy as it ought to be. If that supposition be allowed, this specimen like the rest, will consist of

1 atom sulphide of antimony,
3 atoms sulphuret of copper, silver, and iron.

From the preceding analyses, grey copper ore appears to consist essentially of

1 atom sulphide of antimony,
3 atoms sulphuret of copper,

united together. The antimony is sometimes partly replaced by arsenic; and the copper, by silver, iron, and even zinc; but the pure mineral is a ***trisulpho-antimonite of copper.***

Sp. 5. *Tennantite.*[*]

This mineral occurs in veins in several of the Cornish copper mines, as Dolcoath, Cookskitchen, and Tincroft, near Redruth; and in Huel Virgin, Huel Jewel, and Huel Unity, near St. Day. It was first described as a peculiar species by Mr. Phillips.

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[*] Quarterly Jour. vii. 95. Named in honour of Mr. Smithson Tennant.

Colour blackish lead-grey; streak reddish-grey.

Occurs crystallized in cubes, octahedrons, and rhomboidal dodecahedrons. Mr. Phillips considers the regular octahedron as the primary form; but Mr. Brooke thinks that the tetrahedron agrees better with some of the secondary modifications.

Lustre metallic; opaque; brittle.

Hardness 3; specific gravity, as determined by Mr. Richard Phillips, 4·375.

Before the blowpipe it decrepitates a little and burns with a blue flame, emitting copious arsenical vapours, and melting into a black scoria, which affects the magnetic needle.

Its constituents, as determined by Mr. R. Phillips, are

		Atoms.
Sulphur,	28·74	14·37
Arsenic,	11·84	2·49
Copper,	45·32	11·33
Iron,	9·26	2·64
Silica,	5·00	2·5
	100·16*	

The sulphur is combined with the arsenic and copper, converting them respectively into sulphurets, while the iron (doubtless in the state of oxide) is united to the silica. If we admit the silicate of iron to be a foreign body, Tennantite will consist of

1 atom sulphide of arsenic,
4½ atoms sulphuret of copper.

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* Mr. Hemming has given the analysis of a specimen of Tennantite from Trevisane mine, in the parish of Gwennap.† He obtained

		Atoms.	
Sulphur,	21·8	10·9	4½
Arsenic,	11·5	2·42	1
Copper,	48·4	12·1	5
Iron,	14·2	4·0	1·65
Silica,	5·0	2·5	
	100·9		

If this analysis be correct, the mineral examined constitutes a new species, the constituents of which are

1 atom subsesquisulphide of arsenic,
5 atoms subsesquisulphuret of copper,
1⅔ atoms subsesquisulphuret of iron.

Unless we were to consider the iron as united to the silica, as in the specimen examined by Mr. Phillips.

† Phil. Mag. x. 157.

It is therefore a *sulphur salt*, the sulphide of arsenic acting the part of an acid, and the sulphuret of copper as a base.

6. *Selenium Salts of Copper.*

Sp. 1. *Eukairite.*[*]

Argentiferous seleniet of copper.

This mineral was detected by Berzelius in the Swedish geographical collection of minerals among the specimens from Skrickerum, an abandoned mine in Smoland.[†]

Colour lead grey.

Lustre metallic; opaque.

Not crystallized.

Soft enough to be scratched by the knife, and it acquires a silvery lustre.

Takes an impression from the hammer.

Melts easily before the blowpipe, giving out a strong vapour of selenium, and leaves a lead-grey globule, from which the selenium has not been fully expelled. If this globule be melted with borax, it communicates the usual colour of copper, and a grey brittle metallic globule of seleniet of silver remains behind.

When it is dissolved in boiling nitric acid, and the solution is afterwards diluted with water, a white powder precipitates, which is seleniate of silver.

Its constituents, as determined by Berzelius, are

			Atoms.
Selenium,	26	5·2	1·84
Copper,	23·05	5·61	1·98
Silver,	38·93	2·83	1
Foreign earthy matter,	8·90		
	96·88		

These numbers correspond with

2 atoms selenium,
2 atoms copper,
1 atom silver.

Hence the constitution of the mineral is

2 atoms diseleniet of copper,
1 atom seleniet of silver.

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[*] From ευ and καιρος, *opportunity*, so named because the mineral was found soon after the discovery of selenium.

[†] Afhandlingar, vi. 136.

Probably the first of these acts the part of an acid, and the second of a base. The mineral then may be considered as ***biselenio-cuprate of silver.***

GENUS XXIV.—MERCURY.

The minerals belonging to this genus are few in number, amounting only to five species. None of them consist of oxygen salts of mercury. Indeed almost all the mercury of commerce is extracted from one ore—cinnabar or sulphuret of mercury.

Sp. 1. *Native Mercury.*

Pure fluid mercury is occasionally met with, though in no great quantity. The most important localities are Idria in Carniola, and Almaden in Spain. It occurs in smaller quantities in the Palatinate, in Hungary, Peru, &c.

Colour tin-white.

Liquid; opaque; lustre metallic.

Specific gravity 13·568.

Entirely volatile before the blowpipe.

Easily soluble in nitric acid.

Consists of pure mercury.

Sp. 2. *Native Amalgam.*

This species is rare, but it occurs occasionally in the Palatinate at Moschellandsberg, and at Rosenau in Hungary. It was found also in the mine of Sala, in Sweden, and it is said also in France and Spain.

Colour silver-white; streak the same.

Massive and crystallized. The primary form is the rhombic dodecahedron. It occurs also in octahedrons. They frequently have their edges replaced by planes, which, when they increase so as to conceal the octahedral planes, convert the crystal into a dodecahedron. Sometimes the edges of the dodecahedron are replaced by one, two or even three planes, and sometimes the alternate angles are replaced by planes.

Lustre metallic.

Opaque; brittle.

Emits a grating noise when cut with a knife.

Hardness 3·25; specific gravity, as determined by Haidinger, 13·755.

Before the blowpipe the mercury is driven off, and a globule of pure silver is obtained.

Two kinds of amalgam have been distinguished; the one solid, the other liquid. The liquid specimens are solutions of the solid amalgam in mercury.

The constitution of this mineral is as follows :—

	*	†
Mercury,	64	72·5
Silver,	36	27·5
	100	100

It is obvious that the composition of the two specimens analyzed is different. Klaproth's specimen was composed of

		Atoms.
Mercury,	5·12	1·96
Silver,	2·61	1

Or of 2 atoms mercury,
1 atom silver.

While Cordier's specimen is composed of

		Atoms.
Mercury,	5·8	2·9
Silver,	2	1

Or of 3 atoms mercury,
1 atom silver.

In fact therefore they constitute two distinct species of amalgam.

Sp. 3. *Sulphuret of Mercury.*

Cinnabar—corallinerz—liver ore.

This species, the most important of all the ores of mercury, occurs chiefly in beds. In this state it is found in gneiss, at Reichenau in Upper Carinthia, and at Hortenstein in Saxony. At Dumbrawa, in Transylvania, it occurs in greywacke. At Hermager, Windisch-Kapell, and other places in Carinthia, it occurs in beds and veins in calcareous spar. But its most important repositories are Idria in Carniola, and Almaden in Spain. In both of these places it seems to occur in bituminous shale. Several other localities may be mentioned, as the Palatinate, Mexico, Peru, China, Japan, &c.

Colour several shades of cochineal red, the darker varieties

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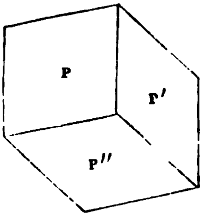
* Klaproth, Beitrage, i. 183. † Cordier, Phil. Mag. xiv. 41.

inclining to leaden-grey; streak scarlet red.



Massive and crystallized. The primary form of the crystal is an acute rhomboid.

P on P′ 72°

It occurs also in regular six-sided prisms, formed by the lateral angles of the rhomboid being replaced by tangent planes. These, when they increase sufficiently, obliterate the planes of the rhomboid and form the six-sided prism. The angle at the summit and base of the rhomboid is sometimes replaced by six faces, which convert the rhomboid into a crystal with 18 faces. Sometimes both of these replacements appear on the same crystal.

Fracture conchoidal.

Lustre adamantine, inclining to metallic in dark coloured varieties.

Semitransparent, translucent on the edges, or opaque; sectile.

Hardness varies from 1 to 4·25; specific gravity 8·098.

Completely volatile before the blowpipe when pure.

Soluble in nitric acid.

What is called *liver ore*, is merely a compact variety, slightly mixed with foreign matter.

The constituents of this species are as follows:—

	*	†	‡
Mercury,	84·50	85	81·80
Sulphur,	14·75	14·25	13·75
Charcoal,	—	—	2·30
Silica,	—	—	0·65
Alumina,	—	—	0·55
Iron,	—	—	0·20
Copper,	—	—	0·02
Water,	—	—	0·73
	99·25	99·25	100

The mean of these analyses, leaving out the impurities of the liver ore, is as follows:—

		Atoms.
Mercury,	83·8	6·71
Sulphur,	14·25	7·12

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[*] Klaproth, Gehlen's Jour. v. 435. Specimen from Japan.

[†] Klaproth, Ibid. p. 436. Specimen from Neumarktel.

[‡] Klaproth, Ibid. p. 440. Liver ore from Idria.

These numbers show obviously that the mineral is composed of

1 atom sulphur,
1 atom mercury.

Or it is a simple sulphuret of mercury.

Sp. 4. *Dichloride of Mercury.*

Corneous mercury—native calomel.

This rare mineral is found occasionally along with cinnabar in secondary rocks. Its chief locality is Moschellandsberg, in Deux Ponts; but it occurs also at Idria, in Carniola, and at Almaden, in Spain.

Colour yellowish-grey or ash-grey; also yellowish and greyish-white; streak white.

It occurs in crusts, and also crystallized in four-sided prisms terminated by pyramids. The primary form is a right square prism. But the lateral edges of the prism are often replaced by tangent planes. The prism is often terminated by a four or eight-sided pyramid.

Lustre adamantine.

Translucent, at least on the edges; sectile.

Hardness 1·5; specific gravity 6·482, as determined by Haidinger.

Before the blowpipe on charcoal is entirely volatilized.

Insoluble in water.

I am not aware that it has been subjected to a rigid analysis, but artificial calomel is composed of

		Atoms.
Chlorine,	15·26	1
Mercury,	84·74	2
	100·00	

And there can be no doubt that the composition of the native mineral is the same.

It is proper, however, to mention that Mr. Woulfe affirms that native calomel generally contains some sulphuric acid.[*]

Sp. 5. *Chloride of Mercury.*

Native corrosive sublimate.

The existence of this species is affirmed by some mineralogists; but I have never seen a specimen of the mineral, nor met with any description of it.

[*] Phil. Trans. 1776, p. 618.

GENUS XXV.—SILVER.

Silver has a strong affinity for sulphur, and it is found very commonly combined with that substance, or in the state of a sulphur salt. In this respect it resembles lead and copper. The sulphur salts of these three genera amount to 16—a greater number than belong to all the other genera united. Silver exists pretty commonly in the native state, but oxygen salts of silver are very rare.

I. *Native, or combined with Simple Bodies.*

Sp. 1. *Native Silver.*

This species occurs chiefly in veins traversing gneiss, clay slate, and other primary and transition rocks. It is found most abundantly in Mexico and Peru. Fine specimens have been taken out of Huel Mexico and Huel Duchy, in Cornwall. Considerable quantities of it occur occasionally in the mining districts of Saxony and Bohemia.

Colour silver, more or less subject to tarnish; streak unaltered, shining.

Massive, in strings and plates. Also crystallized in cubes and regular octahedrons. These crystals are found in great perfection in the mine of Kongsberg, in Norway.

Ductile; opaque.

Hardness 4·25; specific gravity, as determined by Gellert, 10·338.

Native silver consists generally of silver alloyed with copper. That of Curcy, analyzed by Berthier,* is composed of

		Atoms.	
Silver, .	90 .	6·54 .	2·6
Copper, .	10 .	2·5 .	1
	100		

Native silver is found in some rare cases alloyed with a notable quantity of gold. In that case the colour is yellowish or greenish-white. Perhaps such combinations ought rather to be referred to native gold than to native silver. The following table exhibits two examples of the constitution of such specimens:

---

* Ann. des Mines, xi. 72.

	[*]	[†]
Silver,	72	36
Gold,	28	54
	100	100

The first of these specimens was an alloy of
7 atoms silver,
3 atoms gold;
The second of 3 atoms silver,
5 atoms gold.

This last is doubtless rather a specimen of native gold than native silver.

Sp. 2. *Antimoniet of Silver.*

Antimonial silver ore.

This mineral accompanies the other ores of silver in veins traversing primary and transition rocks. It is not common, but has been found at Andreasberg in the Hartz, in Suabia, at Casalla, near Guadancanal, in Spain, and in other places.

Colour between silver and tin-white.

Usually amorphous, but it has been observed in six-sided prisms, with faces somewhat convex and longitudinally streaked.

Structure foliated; lustre metallic; opaque.

Hardness 3·5; specific gravity, according to Hauy, 9·4406.

Before the blowpipe the antimony evaporates in a grey smoke, and leaves a brownish slag, which tinges borax green. On charcoal the assay leaves finally a globule of silver.

Its constituents are

	[‡]	[‡]	[§]	[‖]
Silver,	84	76	77	78
Antimony,	16	24	23	22
	100	100	100	100

It is obvious that the last three specimens belong to the same species; but the proportions in the first analyzed specimen being quite different, it must belong to a different species.

The first is a compound of

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[*] Fordyce, Phil. Trans. 1776, p. 532.

[†] Klaproth, Mohs' Mineralogy, ii. 435.

[‡] Klaproth, Beitrage, ii. 298.

[§] Klaproth, ibid. iii. 175.

[‖] Vauquelin, Hauy, iii. 392.

3 atoms silver,
1 atom antimony.

Or it is a *trisantimoniet of silver*. The second of

2 atoms silver,
1 atom antimony.

Or it is a *diantimoniet of silver*.

The two species analyzed by Klaproth were from Wolfach. He has given no other description of them except that the first is fine granular, and the second coarse granular. The specific gravity of the second species he found 9·820. Perhaps the specific gravity given by Hauy belongs to the first species. At any rate, if any confidence can be put in Klaproth's experiments, two distinct species of antimoniet of silver exist.

Sp. 3. *Arseniet of Silver.*

Arsenical silver ore.

This mineral, about which very little is known, occurs deposited in arsenic at Andreasberg in the Hartz.

Colour nearly that of native silver, but it is commonly tarnished externally of a blackish colour.

It occurs in small globular and reniform masses, which have a curved lamellar structure.

Lustre metallic; opaque; sectile.

Harder than antimoniet of silver.

Specific gravity not determined.

Before the blowpipe arsenical fumes are driven off, leaving a globule of impure silver, surrounded by slag.

Its constituents, according to Klaproth,* are

		Atoms.	
Iron,	44·25	12·64	25·3
Arsenic,	35	7·36	14·72
Silver,	12·75	0·92	1·84
Antimony,	4	0·5	1
	96		

These numbers do not indicate a chemical compound, but rather a mixture. If we were to suppose the arsenic to be combined with the iron in the ratio of 2 atoms iron to 1 of arsenic, there would remain 2 atoms of arsenic and 1 atom of antimony to combine with 2 atoms of silver, which would make (including the antimony with the arsenic) a sesquiarseniet of

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* Beitrage, i. 187.

silver mixed with a diarseniet of iron. But a new and more accurate analysis would be required before any confidence can be put in such conclusions.

Sp. 4. *Bitelluret of Silver.*

This mineral was observed by Messrs. Humboldt, G. Rose and Professor Ehrenberg, in the Museum of Barnaul on the Ob, during a journey which they made some years ago to Siberia. It was found in nests in the new mine Sawodinski, about 40 wersts from the rich silver mine of Siränowski, on the river Buchthorma, in Siberia. The specimens in the Museum consisted of two masses, each about a cubic foot in size. These specimens were found in nests in a rock consisting of talc slate, which contained small quantities of iron pyrites, black blende, and copper pyrites. It was described and analyzed by M. G. Rose.*

Colour intermediate between lead grey and steel grey; lustre metallic, splendent.

Massive; structure coarse granular, without any signs of cleavage.

Malleable, but rather less so than sulphuret of silver.

Hardness 2·25; specific gravity from 8·412 to 8·465.

Before the blowpipe on charcoal it melts to a black globule, and on cooling, white points or dendrites of silver make their appearance on its surface. These appear more readily if the assay be heated by means of the reducing flame. When heated in a glass tube it melts, and gives a yellow colour to the glass. In an open tube it melts also, but a small quantity of a white sublimate rises, which may be made to collect in drops. When fused with biphosphate of soda, the bead, while hot, is transparent, but it becomes opal coloured on cooling. When fused with carbonate of soda, a bead of pure silver is obtained.

Soluble in cold nitric acid, and more rapidly if the acid be heated.

Its constituents are

			Mean.	Atoms.
Silver,	62·42 .	62·32 .	62·37 .	4·53
Tellurium,	36·96 .	36·89 .	36·92 .	9·23
Iron, .	0·24 .	0·50 .	0·37	
		99·62	99·66	

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* Poggendorf's Annalen, xviii. 64.

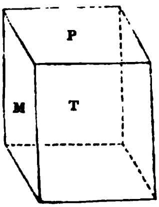
These numbers obviously correspond with
2 atoms tellurium,
1 atom silver.
It is therefore a bitelluret of silver.

Sp. 5. *Flexible Sulphuret of Silver.*

Ferro-sulphuret of silver.

The locality of this mineral, which was first described by Bournon,[*] is not known. Bournon suspected his specimen to be from Hungary. Mr. Brooke has a specimen from Himmelsfurst in Saxony.

Colour nearly black; lustre metallic; opaque.



Massive and in small tabular crystals. The primary form, according to Brooke, is a right oblique-angled prism.

M on T 125°

The edges of the prism, both lateral and terminal, are often replaced by one or two planes.

Composed of thin flexible laminæ.

Very soft, yielding readily to the knife.

According to Dr. Wollaston it is composed of silver, sulphur and a little iron.[†]

Sp. 6. *Sulphuret of Silver.*

Silver glance, vitreous silver, gaserz.

This important species is found almost exclusively in veins, and the rock adjoining the vein is frequently impregnated with it. It occurs in various mines of Saxony and Bohemia; likewise in Hungary, Siberia, Mexico and Peru. It has been met with also in Cornwall, the Hartz, Norway, &c.

Colour blackish lead-grey; streak similar, shining; lustre metallic; opaque.

Massive and crystallized in cubes, regular octahedrons and rhomboidal dodecahedrons. Cleaves parallel to the faces of the cube, which is of course its primary form.

Fracture imperfect small conchoidal; malleable.

Hardness 2·75; specific gravity 7·196.

Fuses easily before the blowpipe and intumesces, but gives a globule of silver, if we continue the blast.

Its constituents, by Klaproth's analysis,[‡] are

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[*] Bournon's Catalogue, p. 209.

[†] Phillips' Mineralogy, p. 289.

[‡] Beitrage, i. 162.

		Atoms.
Silver,	85 . 6·18 .	10
Sulphur,	15 . 7·5 .	12
	100	

These numbers coincide very nearly with
4 atoms sulphuret of silver,
1 atom bisulphuret of silver.

This, if Klaproth's analysis be accurate, must be the constitution of this mineral.

Sp. 7. *Sternbergite.*[*]

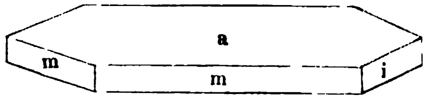
This mineral was first described by Mr. Haidinger.[†] It was found in the mines of Joachimsthal in Bohemia, from which it had been obtained many years ago. Fine specimens of it exist in the museum at Prague, and in the possession of M. Neumann, formerly professor of chemistry. It was from these specimens that Mr. Haidinger drew up his description.

Colour dark pinchbeck-brown, nearly resembling the colour of magnetic pyrites, only inclining a little more to black; streak black; lustre metallic, splendent; opaque.

It is usually crystallized, and the primary form seems to be a right oblique prism.

T on T′ 120° 15′

A common form is a short six-sided prism, produced by two of the opposite edges of the prism being replaced by a plane. Two of the angles of this prism are 119° 30′ and four 120° 15′. All the crystals observed are modifications of this six-sided prism. Sometimes the terminal edges are replaced by planes. This is the case also with several of the angles.



The cleavage is highly perfect parallel to the face a, but no other cleavage can be observed. The faces a are delicately streaked; they retain their original colour, while the other faces acquire a violet-blue tarnish.

Texture foliated; laminæ flexible; very sectile.

Hardness 1 to 1·5; specific gravity 4·215.

When heated in a glass tube it gives out a strong odour of sulphureous acid, loses its lustre and becomes dark grey and friable. Alone on charcoal it burns with a blue flame and

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[*] Named in honour of Count Sternberg.

[†] Edin. Phil. Trans. xi. 1.

sulphureous odour, and melts into a globule generally hollow, with a crystalline surface and covered with metallic silver. The globule acts strongly on the magnetic needle, and before the blowpipe exhibits all the properties of sulphuret of iron. It communicates to fluxes the ordinary colours produced by iron; red while hot, and yellow on cooling in the oxidizing flame; greenish in the reducing flame. Borax readily removes the iron, and leaves a button of metallic silver.

Its constituents, determined by the analysis of professor Zippe* in Prague, are

			Atoms.
Silver,	33·2	2·41	1
Iron,	36·0	10·28	4·26
Sulphur,	30·0	15	6·22
	99·2		

These numbers indicate a compound of

4½ atoms sulphuret of iron,
1 atom bisulphuret of silver.

Probably the sulphuret of iron acts the part of an acid, and the bisulphuret of silver of a base. If this were the case, the mineral would be a sulphur salt.

Sp. 8. *Seleniet of Silver.*

This mineral was first described and analyzed by M. Gustavus Rose.† It occurs at Tilkerode in the eastern Hartz, and specimens of it were observed by Rose in the Royal Museum of Berlin. The gangue is bitterspar, and it is mixed with seleniet of lead, but easily separated.

Colour iron-black; streak unaltered; lustre metallic, splendent; opaque.

Structure foliated. It exhibits three cleavages perpendicular to each other, so that its primary form is the cube.

The thin plates are covered with a brass-yellow metallic substance, which seems to be copper pyrites.

Malleable, but not so much so as sulphuret of silver.

Hardness 2·5; specific gravity 8·00.

When heated in a glass tube it melts, and gives off a small sublimate, consisting partly of selenium and partly of selenic acid. It gives out a strong smell of selenium. Before the blowpipe, on charcoal, it melts silently in the exterior flame,

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* Poggendorf's Annalen, xxvii. 690.

† Ibid. xiv. 471.

with frothing in the interior flame. It glows, on cooling, almost as distinctly as magnetic pyrites. With carbonate of soda on charcoal it is reduced. The globule is shining as long as it is hot, but on cooling becomes covered with a black coating; if borax be added, it retains the metallic lustre after cooling. It is silver-white, very malleable, and behaves like pure silver.

Very soluble in smoking nitric acid, but it dissolves with difficulty in dilute nitric acid.

Its constituents are:

		Atoms.
Silver,	65·56	4·76
Lead,	4·91	0·38
Selenium,	25·93	5·18
	96·40	

The atoms of selenium being equal to those of silver and lead together, it is obvious that the mineral is composed of simple seleniets. If the seleniet of lead is not to be reckoned an accidental impurity, the constitution of the mineral is

12 atoms seleniet of silver,
1 atom seleniet of lead.

Sp. 9. *Chloride of Silver.*

Horn silver.

This mineral is most frequently found in the upper part of veins in clay slate, but it occurs also in beds. Formerly it existed in considerable quantity in the Saxon mining districts of Johangeorgenstadt and Freiberg, and also at Joachimsthal in Bohemia. In small quantities, it has been found in Cornwall and in many other localities.

Colour pearl-grey, passing into blue and into greyish, yellowish and greenish-white, and into various shades of green. Becomes brown when exposed to the light.

Massive or investing other minerals; also crystallized in small cubes and acicular prisms. The cube is considered as the primary form.

Lustre resinous, passing into adamantine.

Translucent, at least on the edges.

Sectile.

Hardness 3·5; specific gravity 5·552.

Melts in the flame of a candle.

On charcoal before the blowpipe it is almost entirely reduced. It is reduced also when rubbed wet upon a surface of iron or zinc.

Soluble in ammonia, but not in nitric acid.

Its constituents are

	*	†
Silver,	76	67·75
Chlorine,	24	27·32
Oxide of iron,	—	6·00
Sulphuric acid,	—	0·50
Alumina,	—	1·75
	100	101·30

The first specimen was pure chloride of silver, composed of
1 atom chlorine,
1 atom silver.

The second specimen was obviously contaminated with foreign matter.

Sp. 10. *Iodide of Silver.*

This mineral exists in Mexico, and was recognised by Vauquelin among some specimens which M. Joseph Tabary brought from that country.[‡]

Colour white, and when the surface was polished it exhibited grains of metallic silver. Its structure was foliated, and the surface of the plates yellowish-green, with some black portions of metallic silver.

Vauquelin subjected it to a chemical examination, and found it to consist of

Silver,
Lead,
Iron,
Iodine,
Sulphur.

But the proportions of each were not determined.

2. *Simple Oxygen Salts of Silver.*

Sp. 1. *Carbonate of Silver.*

This scarce mineral was discovered by Mr. Selb in 1788, in the mine of Winceslas, in Suabia. It is said also to have

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[*] Klaproth, Beitrage, iv. 10. The specimen was from Peru.

[†] Ibid. i. 132.

[‡] Ann. de Chim. et de Phys. xxix. 99.

been observed in veins traversing granite at Altwolfatch, in the Black Forest.

Colour greyish-black; streak bright; lustre metallic; opaque.

Massive; soft; brittle; heavy.

Effervesces with acids; froths when heated with borax.

It has not been analyzed by any modern chemist. Mr. Selb states its constituents to be

Silver, . .	72·5
Oxide of antimony,	15·5
Carbonic acid, .	12·0
	100

But no confidence can be put in this analysis. We may conclude from it, however, that the mineral contains carbonic acid, but whether or not in combination with oxide of silver, remains to be determined.

3. *Sulphur Salts of Silver.*

Sp. 1. *Sulpho-cuprite of Silver.*

Cupreous sulphuret of silver.

This rare mineral has hitherto been found only at Schlangenberge in Siberia, where it occurs mixed with copper pyrites, calcareous spar, &c. It was first examined and recognised as a peculiar species by Stromeyer, from specimens in the museum of Gottingen.*

Colour blackish lead-grey; lustre metallic, splendent; opaque.

Massive; fracture flat conchoidal.

Soft; Bournon describes it as *brittle*, Stromeyer as *sectile*.

Specific gravity 6·258.

Fuses readily before the blowpipe.

Its constituents, as determined by Stromeyer, are

		Atoms.
Sulphur,	15·782 .	7·84
Silver, .	52·272 .	3·80
Copper,	30·478 .	7·62
Iron, .	0·333	
	98·865	

The atoms of copper being twice those of silver, it is obvious that the mineral is composed of

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* Gilbert's Annalen, liv. 114.

1 atom sulphuret of silver,
2 atoms disulphuret of copper.

If the disulphuret of copper acts the part of an acid, and the sulphuret of silver of a base, the mineral is a ***bisulpho-cuprite of silver.***

Sp. 2. *Brittle Silver Glance.*

Trisulpho-antimoniate of silver.

This mineral had been recognised as a subspecies by Werner, but Mohs seems to be the first who accurately described it, under the name of *prismatic melan glance.* It occurs at Schemnitz in Hungary, and in the mines in the neighbourhood of Freiberg.

Colour iron-black; streak unaltered.

Crystals six-sided prisms, terminated by faces perpendicular to the axis. Mohs describes them as four-sided oblique prisms, having the acute edges replaced by faces which render the prism six-sided.

Fracture conchoidal, uneven.

Lustre metallic; opaque; sectile.

Hardness 2·25; specific gravity 6·269.

Before the blowpipe on charcoal it gives a dark coloured metallic bead, which may be reduced either with soda and silica or with saltpetre.

Soluble in dilute nitric acid.

Its constituents, determined by the analysis of Mr. H. Rose,* are

			Atoms.
Sulphur,	16·42	8·21	4·48
Antimony,	14·68	1·83	1
Silver,	68·54	4·98	2·72
Copper,	0·64	0·16	0·09
	100·28		

If we include the copper with the silver, we have nearly three times as many atoms of silver as of antimony. The mineral seems to consist of

1 atom bisulphide of antimony	2 atoms sulphur, 1 atom antimony,
3 atoms sulphuret of silver	3 atoms sulphur, 3 atoms silver.

It is therefore a ***trisulphoantimoniate of silver.***

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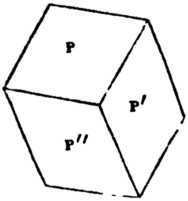
[*] Poggendorf's Annalen, xv. 475.

Sp. 3. *Dark Red Silver Ore.*

Ruby silver, black silver—aerosite, rothgiltigerz—subsesquisulpho-antimoniate of silver.

This beautiful mineral has hitherto been found only in veins. The Saxon and Bohemian mines, and those of Mexico and Peru yield it in considerable quantities, and it has been found in smaller quantities in many other localities.

Colour, by reflected light, varies from lead-grey to iron-black, by transmitted light from brilliant to dark red; streak cochineal and aurora red.



Massive and crystallized in a great variety of forms. Its primary crystal is an obtuse rhomboid.

P on P' 109° 56', according to Brooke,
108° 30', according to Phillips.

It occurs also in six-sided prisms, and with a six-sided prism interposed between the two halves of the rhomboid, which constitute a triangular pyramid at either extremity. Also in triangular dodecahedrons, or with a six-sided prism interposed between the pyramids, and in various other forms which have been figured by Hauy and by Phillips.

Lustre metallic, adamantine.

Translucent to opaque.

Hardness 2·25; specific gravity from 5·8 to 5·9.

Decrepitates before the blowpipe on charcoal, melts and emits fumes of sulphur and antimony, after which a globule of silver remains.

For the first accurate analysis of this ore, we are indebted to Bonsdorf.* He found its constituents

		Atoms.	
Silver, .	58·949	4·28	1·5
Antimony, .	22·846	2·856	1
Sulphur, .	16·609	8·304	2·9
Earthy matter,	0·299		
	98·703		

These numbers obviously agree with

3 atoms sulphur,
$1\frac{1}{2}$ atom silver,
1 atom antimony.

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* Kong. Vet. Acad. Handl., 1821, p. 338.

We may consider the mineral as composed of

$$1 \text{ atom sesquisulphide of antimony, } \left\{ \begin{array}{l} 1\frac{1}{2} \text{ sulphur,} \\ 1 \text{ antimony,} \end{array} \right.$$

$1\frac{1}{2}$ atoms sulphuret of silver.

It is therefore a *subsesquisulpho-antimoniate of silver.*

Sp. 4. *Miargirite.**

Bisulpho-antimoniate of silver.

This mineral was first recognised as a peculiar species by Mohs, who distinguished it by the name of *hemiprismatic ruby blende.* It was formerly considered as a variety of *dark red silver ore.* It is exceedingly scarce, the only known specimens being in possession of M. Von Weissenbach, at Freyberg. It is believed to have been found in the mine called Neue Hoffnung Gottes at Braunsdorf, near Freyberg in Saxony.

Colour iron-black; streak dark cherry-red.

The specimen is in crystals, which have the form of a flat four-sided prism, with one of the angles at each base replaced by a triangular face.

Lustre intermediate between metallic and adamantine.

Opaque, except in thin splinters, when it transmits a deep blood-red colour.

Very sectile.

Hardness 2 to 2·5; specific gravity 5·234.

Before the blowpipe it behaves nearly as dark-red silver ore.

Its constituents, as determined by M. H. Rose,† are

		Atoms.
Sulphur,	21·95	10·97
Antimony,	39·14	4·89
Silver,	36·40	2·64
Copper,	1·06	0·26
Iron,	0·62	0·17
	99·17	

The atoms of sulphur are to those of antimony and silver nearly as $1\frac{1}{2}$ to 1. Hence the metals are in the state of sesquisulphurets. The atoms of silver are to those of antimony

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* From μειων, *less,* and ἀργυρος, *silver,* because it contains less silver than some of the other kindred ores.

† Poggendorf's Annalen, xv. 469.

very nearly as 6 to 11. Hence the constitution of miargirite must be

11 atoms sesquisulphite of antimony,
6 atoms sesquisulphuret of silver.

It is probably a *bisulpho-antimoniate of silver*.

Sp. 5. *Light red Silver Ore.*

Subsesqui-sulphoarseniate of silver.

Dark and light red silver were considered by Werner as two subspecies. Mohs pointed out differences in the specific gravity, which led him to conclude, that in reality they constitute two distinct species. Bonsdorf demonstrated, that dark red silver ore is a compound of sulphide of antimony and sulphuret of silver; and H. Rose showed that light red silver ore is a compound of sulphide of arsenic and sulphuret of silver. This demonstrates that they constitute two distinct species, and confirms an old remark of Proust, that red silver ore contains arsenic as well as antimony.

Light red silver ore is found most abundantly in the Saxon and Bohemian mines, near the top of the mountains; while the dark red is found most abundantly lower down.

Colour cochineal red; streak light cochineal red.

Crystals, so far as observation goes, have the same shape as those of dark red silver ore.

Lustre adamantine.

Translucent on the edges, or even semi-transparent; sectile.

Hardness 2·25; specific gravity 5·552.

Its constituents, determined by Rose,* are

			Atoms.
Sulphur,	19·51	9·75	3·07
Antimony,	0·69	0·09	—
Arsenic,	15·09	3·17	1
Silver,	64·67	4·70	1·48
	99·96		

These numbers obviously correspond with

1 atom sesquisulphide of arsenic, $\left\{\begin{array}{l}1\frac{1}{2}\text{ atom sulphur,}\\ 1\text{ atom arsenic,}\end{array}\right.$

$1\frac{1}{2}$ atom sulphuret of silver, $\left\{\begin{array}{l}1\frac{1}{2}\text{ atom sulphur,}\\ 1\frac{1}{2}\text{ atom silver.}\end{array}\right.$

It is therefore a *subsesqui-sulphoarseniate of silver*.

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* Poggendorf's Annalen, xv. 473.

Sp. 6. *Polybasite.*[*]

This is a new species, formerly confounded with *brittle silver glance*, but first accurately distinguished by M. G. Rose. The specimens hitherto examined, seem to be from Guanaxuato, in Mexico.

Colour iron black; streak unaltered; lustre strongly metallic; opaque.

Usually crystallized; crystals regular six-sided prisms, terminated by bases perpendicular to the axis of the prism; lateral facesstreaked, parallel to the hexahedral periphery of the base. Prisms usually short and tabular.

Fracture uneven; sectile.

Hardness 2·5; specific gravity 6·214.

Polybasite occurs both crystallized and amorphous. It was considered as having the same form as *brittle silver glance*, till Mohs made the remark, that the primary form of this last is an oblique four-sided prism, having the acute edges replaced by triangular faces.

The constituents of polybasite, as determined by H. Rose,[†] are

		Atoms.
Sulphur,	17·04	8·52
Antimony,	5·09	0·64
Arsenic,	3·74	0·78
Silver,	64·29	4·67
Copper,	9·93	2·48
Iron,	0·06	
	100·15	

The atoms of antimony, arsenic, silver and copper, are together equal to those of sulphur. Hence the mineral is composed of simple sulphurets. The atoms of antimony and arsenic together constitute $\frac{1}{5}$th of the atoms of silver and copper. Now the sulphides of antimony and arsenic constitute the acid, and the sulphurets of silver and copper the base.

Hence the constituents are

1 atom sulphides of antimony and arsenic,
5 atoms sulphurets of silver and copper.

In this mineral it is obvious that a portion of the antimony is replaced by arsenic, while a portion of the silver is replaced by copper.

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[*] From πολυς, *many*, and βασις, a *base*. [†] Poggendorf's Annalen, xv. 575.

Polybasite might be called a *pentasulpho-antimonite of silver*, if the name were not too unwieldy.

GENUS XXVI.—URANIUM.

Uranium is rather a scarce metal. Its ores are by no means numerous, and hitherto they consist either of the oxide of the metal mechanically mixed with other bodies, or combined with an acid, and constituting a salt.

Sp. 1. *Pitch Ore of Uranium.*

Pitch blende—pech uran—uran pecherz—uran oxydulé—protoxide of uranium.

The chief localities of this mineral are Johangeorgenstadt, Marienberg, Annaberg and Schneeberg, in Saxony; and Joachimsthal and Fribus, in Bohemia. In Cornwall it has been observed in Tincroft mine and Tollcarn mine.

Colour greyish-black, inclining sometimes to iron black; also greenish and brownish-black.

Massive and pulverulent, but never hitherto observed in crystals.

Fracture conchoidal, uneven.

Lustre imperfect metallic; brittle.

Hardness 3·5; specific gravity 6·468.

Alone it is infusible before the blowpipe, but melts with borax into a grey scoria.

When in the state of powder dissolves slowly, but partially in nitric acid.

This mineral is rather a mechanical mixture than a chemical compound; for not merely the proportions, but even the ingredients differ in different specimens. Klaproth found oxide of uranium, sulphuret of lead, silica and peroxide of iron.*

Arfvedson, besides these constituents, found plenty of arsenic, copper, cobalt and zinc. In three specimens which I examined, I found oxide of uranium, oxide of iron, oxides of copper and lead, besides a notable quantity of earthy matter. Some chemists have considered pitch ore as a silicate of uranium, but the ratio of the silica to the oxide of uranium differs so much in different specimens, that it is impossible to consider them as chemically combined. Selenium has been announced as a

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* Beitrage, ii. 221.

constituent of this ore, but Kersten has shown that this substance does not exist in the pitch ore, but in the copper pyrites which is occasionally mixed with it.*

Sp. 2. *Sulphated Protoxide of Uranium.*

This mineral is said to occur near Joachimsthal, in Bohemia, in Elias mine. It was discovered by John.

Colour beautiful emerald green, sometimes passing into apple green.

Crystallized in flattened prisms from 1 to 3 lines in length, arranged in eccentric druses.

Lustre vitreous.

Commonly transparent or translucent, sometimes opaque.

Soluble in water. Solution precipitated chesnut brown by prussiate of potash, yellowish green by alkalies, and in brown flocks by infusion of nutgalls.†

Sp. 3. *Sulphated Peroxide of Uranium.*

This mineral is found in the same place as the preceding.

It forms a thin botryoidal, intensely sulphur yellow coloured coating over the surface of the mineral on which it is found.

Friable, and soils the fingers.

Digested in water, a portion dissolves; nitric acid dissolves the rest. Both solutions are yellow coloured.‡

Sp. 4. *Uranite.*

Calcareo-phosphate of uranium—uran mica.

This mineral was discovered by M. Champeaux, at St. Symphorien, near Autun, in veins passing through granite. There are other localities (as near Limoges), but I cannot venture to state them, because this and the following species have been generally confounded together by mineralogists.

Colour fine lemon yellow, gold yellow, and yellowish-brown.

It is found crystallized in four-sided prisms, and in four, six, and eight-sided tables, and sometimes, though rarely, in octahedrons, both obtuse and acute.

Structure lamellar, and it yields with great ease by mechanical division a right square prism, which is its primary form.

Lustre pearly on the face of the prism, adamantine on the other faces.

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* Poggendorf's Annalen, xxvi. 492.

† Annals of Philosophy (second series), viii. 390.

‡ Ibid.

Transparent to translucent on the edges; sectile.

Hardness 2·25; specific gravity, as determined by Champeaux, 3·12.

Loses its transparency before the blowpipe. On charcoal melts into a black globule with traces of crystallization on the surface. With borax it yields a yellowish-green bead.

Soluble without effervescence in nitric acid.

Its constituents, as determined by Berzelius,[*] are

		Atoms.	
Barytes,	1·51	0·16	—
Lime,	5·66	1·61	1·5
Magnesia, Manganese,	0·19	—	—
Peroxide of uranium,	59·37	2·12	1·97
Phosphoric acid,	14·63	3·25	3·02
Water,	14·90	13·24	12·21
Stony matter,	2·70		
Fluoric acid, Ammonia,	trace		
	98·96		

These numbers obviously indicate

1[1] atom lime,
2 atoms peroxide of uranium,
3 atoms phosphoric acid,
12 atoms water.

The constitution of the mineral is therefore

2 atoms phosphated peroxide of uranium,
1 atom subsesquiphosphate of lime,
12 atoms water.

Sp. 5. *Chalcolite*.[†]

Cupreo-phosphate of uranium—green uran-mica.

This mineral agrees in its characters with the preceding, with this remarkable exception, that its colour is grass or emerald green.

Fine specimens of it have been found in Gunnis Lake mine, near Callington, and in various other Cornish mines, as Corrarich, Tincroft, Huel Buller, &c.

Its composition was first determined by Mr. R. Phillips.[‡]

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[*] Kong. Vet. Acad. Handl., 1823, p. 170.

[†] From χαλκος, *copper*, and λιθος, *a stone*.

[‡] Annals of Philosophy (second series), v. 57.

Its constituents are as follows:—

	*	†	Mean.	Atoms.	
Phosphoric acid, with arsenic acid,	16	15·56	15·78	3·5	3·01
Peroxide of uranium,	60	60·25	60·125	2·14	1·84
Oxide of copper, .	9	8·44	8·72	1·74	1·5
Water, . . .	14·5	15·05	14·77	13·12	11·31
Stony matter, . .	0·5	0·70	0·60		
	100	100			

These numbers evidently lead to

3 atoms phosphoric acid,
2 atoms peroxide of uranium,
1½ atom oxide of copper,
11 atoms water.

Hence the constitution of the mineral is

2 atoms phosphated peroxide of uranium,
1 atom subsesquiphosphate of copper,
11 atoms water.

Or the same as the preceding species, oxide of copper being substituted for lime.

Probably the water in both species is the same, and the chalcolite might have lost a little of its water by exposure to the atmosphere.

GENUS XXVII.—PALLADIUM.

This rare metal has hitherto been found chiefly in South America. It must occur in considerable quantity in Brazil, as in 1825 pretty large ingots of palladium from that country were exposed for sale in London. It has been discovered in Germany in the state of seleniet, though in no great quantity.

Sp. 1. *Native Palladium.*

It occurs in grains, apparently composed of diverging fibres. In other respects these grains differ little from those of native platinum, among which they are found.

Mr. Sowerby describes them as crystallized occasionally in octahedrons and prisms with a square base.

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* Phillips, Annals of Philosophy (second series), v. 57.

† Berzelius, Kong. Vet. Acad. Handl., 1823, p. 174.

Colour steel-grey, inclining to silver-white.

Lustre metallic; opaque.

Hardness greater than that of wrought iron.

Specific gravity, as determined by Mr. Lowry, 12·14; according to Dr. Wollaston, 11·8.

Infusible per se before the blowpipe, but fuses readily with sulphur. By continuing the heat the sulphur is dissipated, and a globule of palladium obtained.

It consists of palladium, alloyed with a little platinum and iridium.

It was discovered by Dr. Wollaston, mixed with grains of native platinum.*

Sp. 2. *Seleniet of Palladium.*

This mineral was discovered in 1829, in the seleniet of lead which exists in considerable quantity at Tilkerode, in the Duchy of Anhalt-Bernborg, in the Hartz. Attempts were made to separate the selenium from the lead, in order to obtain the gold and the silver with which the seleniet was mixed. These attempts were successful. But after the gold had been thrown down from its solution in *aqua regia*, a considerable quantity of palladium was found in the solution. This led Mr. Zinken to examine the seleniet of lead, to discover the state in which the palladium existed in it.

He found that it existed mixed with native gold in the form of small platinum white plates, crystallized in six-sided tables. These plates have a foliated structure, and cleave in a direction parallel to the axis of a six-sided prism.

When heated strongly it becomes coloured, and it is more brittle than any noble metal in a state of purity.

When heated in a tube it gives out selenium. With borax it forms a transparent glass, and gives a brittle metallic globule which, when cupellated with lead, does not change its nature.

By examining it by solution in acids, M. Zinken showed that it is a compound of selenium, palladium, silver and lead. Hence it is probably a triple seleniet of palladium, silver and lead, in proportions not yet determined.†

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* Phil. Trans. 1809, p. 189.

† Zinken, Ann. de Chim. et de Phys. lxiv. 206.

CLASS III.

NEUTRAL BASES.

This class comprehends three metallic bases, which seem neither capable of forming acids nor alkalies by uniting to oxygen or the other supporters of combustion, and which for that reason are denominated *Neutral*. These are *gold*, *platinum*, and *iridium*.

GENUS I.—GOLD.

So far as is known at present, *gold* always occurs in the metallic state, sometimes nearly pure, very frequently alloyed with silver, and sometimes with other metals.

Sp. 1. *Native Gold.*

This mineral occurs both in veins and beds, and is often so minutely disseminated in rocks that it can only be discovered after pounding and washing. In beds it is met with in primary, transition, and secondary rocks. Almost the whole gold of commerce is found in Peru, Mexico, and Brazil, in alluvial soil. Some is found in the same way in Africa. It occurs also in the rivers of France; Spain; at Wicklow in Ireland; at Leadhills; and in Perthshire, it is said, in Glenturrit and Glencoich.

Colour gold-yellow, brass-yellow, greyish-yellow, and greenish-yellow, depending upon the nature of the metals with which it is alloyed.

It is found in threads, plates, and grains, and crystallized in cubes, regular octahedrons, rhomboidal dodecahedrons, and leucite crystals. Sometimes the angles of the cube or octahedron are replaced by tangent planes. Sometimes the faces of the cube, octahedron, and garnet dodecahedron appear altogether on the same crystal. Sometimes the angles of the octahedron are replaced by no fewer than twenty-one small planes, which makes the crystal very complicated.*

Cleavage none; fracture hackly.

Lustre metallic; opaque; ductile.

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* For the best account which I have seen of the crystalline forms of gold and silver, the reader is referred to M. G. Rose, Poggendorf's Annalen, xxiii. 196.

Hardness 3·25.

The specific gravity varies very much according to the quantity of alloy present. The lightest hitherto observed is the native gold of Marmato, composed of 3 atoms gold and 1 atom silver; or,

Gold,	73·45
Silver,	26·48
	99·93

Its specific gravity is only 12·666.[*] It ought to be, taking the mean of the two constituents, 16·931. The highest specific gravity observed in any specimen of native gold is 19·099. This is that of the native gold of Schabrowski, near Catharinenburg, in Siberia, composed of

Gold,	98·96
Silver,	0·16
Copper,	0·35
Iron,	0·05
	99·52[†]

Or almost pure gold, since it contains 72 atoms of gold and 1 atom of alloy.

There are no fewer than thirteen different proportions, in which gold and silver are found united in nature, constituting as many different species.

1. A specimen, analyzed by Klaproth, and called by him *electrum*,[‡] was composed of

			Atoms.
Gold,	64	5·12	2
Silver,	36	2·61	1
	100		

Boussingault analyzed two specimens of native gold,[§] the first from Santa Rosa de Osos, a province of Antioguia, in South America; the second from Transylvania. The constituents were

Gold,	64·93	64·52
Silver,	35·07	35·84
	100·00	100·36

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[*] Boussingault, Ann. de Chim. et de Phys. xxxiv. 409.

[†] G. Rose, Poggendorf's Annalen, xxiii. 177.

[‡] Beitrage, iv. 1.

[§] Ann. de Chim. et de Phys. xxxiv. 416.

These are obviously equivalent to
2 atoms gold,
1 atom silver.

2. Boussingault analyzed three specimens of native gold. The first from Marmato, near La Vega de Sapio, in the Province of Popayan; the second from Titiribi, in South America; the third from Otra-Mina, near Titiribi.* The constituents were

Gold,	73·45	74	73·4
Silver,	26·48	26	26·6
	99·93	100	100

These numbers are obviously
3 atoms gold,
1 atom silver.

3. M. G. Rose analyzed a specimen of native gold from Titiribi, in Columbia.† Its constituents were

Gold,	76·42
Silver,	23·12
	99·54

This is $3\frac{1}{2}$ atoms gold,
1 atom silver.

4. Boussingault analyzed two specimens of native gold. The first from Trinidad, near Santa Rosa de Osos; the other from Vega de Sucio.‡ Their constituents were

Gold,	82·4	82·1
Silver,	17·6	17·9
	100·0	100·0

This is obviously 5 atoms gold,
1 atom silver.

5. The three following specimens are composed of

	§	‖	‖
Gold,	84·5	83·85	84·89
Silver,	15·5	16·15	14·68
	100	100	99·53

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* Ann. de Chim. et de Phys. xxxiv. 409, 412.

† Poggendorf's Annalen, xxiii. 179.

‡ Ibid.

§ Boussingault. Ibid. p. 415. The specimen from Ojas Anchas.

‖ G. Rose. Ibid. p. 174, 180. The first specimen from Boruschka, near Nischne Tagil, Siberia; the second from St. Barbara, Transylvania.

These are composed of

6 atoms gold,
1 atom silver.

6. M. G. Rose analyzed a specimen of native gold from Petropawlowsk, near Bogoslowsk.* Its constituents were

Gold,	86·81
Silver,	13·19
	100

This approaches

7 atoms gold,
1 atom silver.

7. The specimens composed of 8 atoms gold and 1 atom silver are the most abundant. The following analyses may serve as examples:—

	†	†	†	†	‡	‡	‡	‡	‡	‡
Gold,	88·24	87·94	88·50	88·15	89·35	88·65	87·40	87·31	87·17	87·70
Silver,	11·76	12·06	11·42	11·85	10·65	10·64	12·07	12·12	12·41	12·30
	100	100	100	100	100	99·29	99·47	99·43	99·58	100

These analyses indicate

8 atoms gold
1 atom silver.

8. The following analysis of a native gold from Borowschka is by G. Rose:—

Gold,	90·76
Silver,	9·02
	99·78

It indicates

11 atoms gold,
1 atom silver.

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* Poggendorf's Annalen, xxiii. 175.

† Boussingault. Ann. de Chim. et de Phys. xxxiv. 408. First specimen from Malpasi; the second from Rio Sucio; the third from Slano; the fourth from Baja.

‡ G. Rose, Poggendorf, xxiii. 174. The first specimen from Czarewo Nicolajewsk, near Minsk; the second from Newiansk; the third from Alexander Andrejewsk, near Minsk; the fourth from Gozuschka, near Nischne Tagil; the fifth and sixth from the same place.

9. The following analyses are by the same gentlemen:—

	*	*	†	†	†	†	†	†
Gold, .	91·9	91·9	92·60	92·8	92·01	92·47	91·36	91·88
Silver, .	8·1	8	7·08	9·09	7·52	7·47	8·38	8·08
	100	99·9	99·68	101·89	99·53	99·94	99·74	99·96

These specimens were composed of

12 atoms gold,
1 atom silver.

10. The following analyses of specimens of native gold from Catherinenburg and Beresow, are by G. Rose:

Gold,	93·34 .	93·78
Silver,	6·28 .	5·94
	99·62	99·72

The constitution is

16 atoms gold,
1 atom silver.

11. We have the analysis of another species by G. Rose from Boruschka, in Siberia:

Gold,	94·41
Silver,	5·23
	99·64

The constitution of this specimen is

20 atoms gold,
1 atom silver.

12. Finally, Boussingault found the native gold from Bucoramanga composed of

Gold, .	98
Silver, .	2
	100

That is

56 atoms gold,
1 atom silver.

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* Boussingault, Ann. de Chim. et de Phys. xxxiv. 408. The first from St. Bartholomé, the second from Girar.

† G. Rose, Poggendorf, Ibid. The first from Perroe Powlowlk, the second from Catherinenburg, the third from Bucharei, the fourth from Czarewo Nicolajewsk, near Minsk, the fifth from Boruschka, and the sixth from Beresow.

It may be worth while to exhibit the composition of these twelve species of native gold in a table.

Let Ag be the symbol for silver, and Au for gold, then the composition may be represented as follows:

$\mathrm{Ag\ Au}^{2}$
$\mathrm{Ag\ Au}^{3}$
$\mathrm{Ag\ Au}^{3\frac{1}{2}}$
$\mathrm{Ag\ Au}^{5}$
$\mathrm{Ag\ Au}^{6}$
$\mathrm{Ag\ Au}^{7}$
$\mathrm{Ag\ Au}^{8}$
$\mathrm{Ag\ Au}^{11}$
$\mathrm{Ag\ Au}^{12}$
$\mathrm{Ag\ Au}^{16}$
$\mathrm{Ag\ Au}^{20}$
$\mathrm{Ag\ Au}^{56}$

Sometimes gold is alloyed with a notable quantity of silver and copper at once. I found the constituents of a specimen of African gold dust, having a specific gravity of 14·4567, as follows:

			Atoms.
Gold,	78	6·24	9
Copper,	11·8	2·95	4·27
Silver,	9·48	0·69	1
	99·28		

These numbers agree nearly with

9 atoms gold,
4 atoms copper,
1 atom silver,

Which must have been the constitution of the specimen analyzed.

The greyish-yellow native gold occurring in those small flat grains which are mixed with native platinum, is supposed to contain platinum as a constituent; but I am not aware that this has been verified by direct analysis.

Sp. 2. *White Ore of Tellurium.*

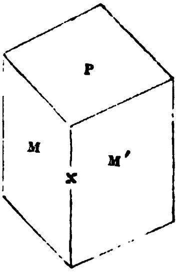
Yellow ore of tellurium.

Hitherto this mineral has been found only at Nagyag in Transylvania.

Colour silver white, much inclining to brass yellow.

Occurs in small but well defined crystals, of which the

primary form is a right rhombic prism,
M on M′ 105° 30′
The edge x is often replaced by a tangent plane, which sometimes is so large as to reduce the faces M, M′ to a very small size, at the same time the terminal edges and angles of the prism are replaced by planes. This converts the crystal into an eight-sided prism, terminated by nine faces.



Traces of cleavage; fracture uneven; lustre metallic; opaque; rather brittle; soft.

Specific gravity, as determined by Muller Von Reichenstein, 10·678.

Before the blowpipe melts into a metallic globule and gives out a pungent smell.

Its constituents, as determined by the analysis of Klaproth,[*] are

		Atoms.	
Tellurium,	44·75	11·19	18·34
Gold,	26·75	2·14	3·5
Silver,	8·50	0·61	1
Lead,	19·50	1·5	2·45
Sulphur,	0·50	0·25	0·4
	100		

Were we to admit the silver to be in the state of disulphuret, the atoms of gold and lead would be one-third of those of tellurium, while the gold is to the lead as 7 to 5. Hence the mineral would seem to be a compound of

7 atoms tertelluret of gold,
5 atoms tertelluret of lead.

Sp. 3. *Graphic Ore of Tellurium.*

Schrifterz—weiss golderz—aurum graphicum.

This mineral has hitherto been found only in the mine Franciscus at Offenbanya, in Transylvania, in very narrow veins that traverse porphyry, accompanied by quartz and rarely by telluret of lead. The crystals of it are so arranged in the gangue, as to give it the appearance of Persepolitan characters. Hence the origin of the name by which it has been distinguished.

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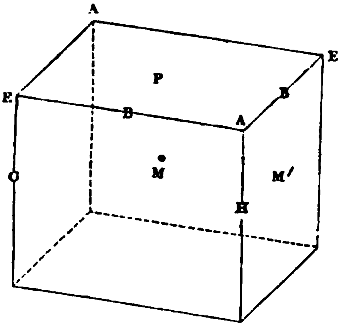
[*] Beitrage, iii. 28.

Colour pure steel-grey; streak unaltered; lustre metallic; opaque.

Structure foliated, though from the smallness of the crystals this can seldom be perceived. Fracture fine-grained, uneven.



The primary form of the crystal, according to Phillips, is a right rhombic prism.

M on M′ about 107° 44′.

Sometimes the edges B are replaced by faces which obliterate the terminal face, and form a four-sided pyramid with scalene faces. Sometimes the edge H is truncated. The crystals are very small, and so entangled in each other, that it is difficult to make them out.

Hardness 1·5 to 2. The specific gravity is stated by Muller von Reichenstein at 5·723. But this must be considerably under the truth.

Before the blowpipe on charcoal, it fuses into a dark grey metallic globule, which finally becomes brilliant and malleable.

Its constituents, by Berzelius's analysis, are

Tellurium, .	52·00
Silver, . .	11·33
Gold, . .	24·00
Lead, . .	1·50
	88·83

The quantity of matter wanting to make up the hundred parts, consisted of copper, iron, antimony, sulphur, and arsenic.*

The atoms of tellurium are nearly four times as numerous as those of the gold, and silver, and lead. If the mineral be a chemical compound, we must consider it as composed of

2 atoms quarto-telluret of gold,
1 atom quarto-telluret of silver.

GENUS II.—PLATINUM.

This metal, like gold, has hitherto been observed only in the metallic state; though always in combination with various metals. Only one species is at present known.

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[*] Jahres-Bericht for 1833, p. 162.

Sp. 1. *Native Platinum.*

This mineral has hitherto been found only in grains, some of which are of a large size. It occurs principally in the provinces of Choca and Barbacoas, in South America. Also at Matto Grosso, in Brazil. It has also been found in St. Domingo. It has been found in considerable quantity at Nischne Tagilsk, and Goroblagodat in Siberia, in the Uralian mountains.

Humboldt brought from America, and deposited in the Berlin museum, a mass of native platinum, weighing 1088 grains. Its specific gravity was 18·94. In the year 1822, a mass of native platinum from Condoto, was deposited in the museum at Madrid, 2 inches and 4 lines in diameter, and weighing 11641 grains. But in the year 1827, a mass of native platinum was found in the Ural, not far from the Demidoff mines, weighing 10$\frac{54}{96}$ Russian pounds, or 9·522 lbs. avoirdupois.[*] Its specific gravity was 16.

Colour perfect steel-grey; streak similar.

In irregular grains, sometimes a little convex on one side.

Lustre metallic, shining; opaque; ductile.

Hardness 2·75; specific gravity never exceeds 17·7, usually about 17·332.

Soluble in nitro-muriatic acid, when the action is assisted by heat.

I am not aware that the native platinum from South America has been subjected to a regular analysis; but we have two analyses by Berzelius of the grains of native platinum from Siberia.[†] They are as follows:

	‡	‡	§
Platinum,	78·94	73·58	86·50
Iridium,	4·97	2·35	—
Rhodium,	0·86	1·15	1·15
Palladium,	0·28	0·30	1·10
Copper,	0·70	5·20	0·45
Iron,	11·04	12·98	8·32
Osmium, Iridium,	1·96	—	1·40
Undissolved,	—	2·30	
	98·75	97·86	98·92

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[*] Humboldt, Poggendorf's Annalen. x. 487.

[†] Kong. Vet. Acad. Handl., 1828, p. 113.

[‡] From Nischne Tagilsk. The first specimen consisted of grains attracted by the magnet, the second of grains not affected by the magnet.

[§] The specimen from Goroblagodat.

We have also an analysis of the platinum grains from the Uralian mountains, by M. Osann, professor of chemistry in Dorpat.* He obtained

		Atoms.
Platinum,	80·87	6·74
Iron,	10·92	3·12
Palladium,	1·301	0·20
Rhodium,	4·44	0·65
Copper,	2·30	0·6
Osmium,	0·081	
Ruthenium,		
Iridium,		
Silica,	0·027	
Iron,		
Platinum,		
Copper,		
Rhodium,		
	99·939	

The constitution of the specimens analyzed by Berzelius is not very evident. That analyzed by Osann (if we join the palladium to the iron,) would seem to be a compound of

2 atoms platinum,
1 atom iron,

together with a little cupret of rhodium.

We might state the constituents

5 atoms biplatinet of iron,
1 atom cupret of rhodium.

But doubtless, grains of native platinum, like those of native gold, will be found to vary very much in their constitution.

GENUS III.—IRIDIUM.

This metal, like the two preceding, is found only alloyed with other metals. In what state it exists in native platinum has not been determined. But one species of iridium ore was discovered by Dr. Wollaston.

Sp. 1. *Native Iridium.*

Found in grains accompanying the native platinum, both of South America and Siberia.

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* Poggendorf's Annalen, xiv. 329.

Colour tin-white, paler than that of native antimony; lustre metallic; opaque; hardness 7.

Usually in small irregular flattened grains. It is sometimes crystallized in six-sided prisms terminated by truncated six-sided pyramids.* Brittle.

Hardness 2·75 to 3; specific gravity, as determined by Dr. Wollaston, 19·5; M. G. Rose found a crystal at 52° to be 19·471, that of a crystal from Nischne Tagil, in Siberia, 21·118.

Three different varieties have been described by Berzelius, all from Siberia.

1. The first variety consists of flat plates, which possess two smooth and shining faces, but have no regular form. They never exceed 1 or 2 lines in diameter, and are often much smaller. They are hard enough to scratch glass, and have a specific gravity of 19·25; when heated they give out a little osmium. Their constituents, as analyzed by Berzelius, are

		Atoms.
Iridium,	46·77	3·81
Rhodium,	3·15	—
Iron,	0·74	—
Osmium,	49·34	3·9
Palladium,	trace	
	100·00	or of an atom of each.

2. The second variety resembles the plates from Brazil, which have been already described. Its specific gravity varies from 18·645 to 19·25.

3. The third variety is very rare. It consists of six-sided plates, two of which are larger than the two others. The specific gravity is 21·118. Two kinds of them were analyzed by Berzelius.

The first composed of

Iridium,	25·1	or 1 atom,
Osmium,	74·9	3 atoms.
	100	

The other of

Iridium,	20	or 1 atom,
Osmium,	80	4 atoms.
	100†	

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* G. Rose, Poggendorf's Annalen, xxix. 452.

† Poggendorf's Annalen, xxxii. 232.

APPENDIX.

I HAVE described, in the systematic arrangement, all the minerals which have been subjected to chemical analysis, or of the constitution of which probable conjectures might be formed; but there is a considerable number noticed by crystallographers, which have been met with only in such minute quantity that it has not been in the power of chemists to subject them to analysis, so that their specific characters depend chiefly upon the crystalline form. It will be proper to give a short account of the most important of these minerals by way of Appendix.

Sp. 1. *Brookite.*

Juriuite of Soret.

This mineral was named by Mr. Levy in honour of Mr. Brooke, whose crystallographical labours have conferred so many benefits on mineralogy. It was first noticed by Mr. Soret among the minerals accompanying titanite from Dauphiny; but much finer crystals, some of them half an inch in diameter, were afterwards found at Snowdon, in Wales. These crystals were examined by Mr. Levy, and the measures of the angles determined with great care.*

Colour hair brown, passing into deep orange yellow, with some tints of red; streak yellowish-white.

Crystallized in six-sided prisms, terminated by pyramidal summits. Mr. Levy has shown that the primary form is a right rhombic prism, with angles of 100° and 80°, and whose height is to its breadth as 11 to 30.

Translucent to opaque; brittle.

Hardness 5·5 to 6; specific gravity unknown.

It contains titanium, but its constitution is unknown.

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* Annals of Philosophy (second series), ix. 140.

Sp. 2. *Bucklandite.*[*]

Diagonal Scotine of Breithaupt.

This name has been given by Mr. Levy to a mineral from Neskiel, near Arendal, in Norway, deposited in Mr. Turner's collection, and having a good deal of resemblance to pyroxene.

Colour dark brown nearly black.

Crystals usually six-sided prisms, terminated by bihedral summits. Mr. Levy derives them from an oblique rhombic prism, the faces of which are inclined to each other at angles of 70° 40′, and the base is inclined to the lateral faces at an angle of 103° 56′.

Opaque; lustre vitreous.

Fracture uneven.

Specific gravity, according to Mr. G. Rose, 3·945.[†] He found it completely soluble in muriatic acid.

In the collection of Mr. Monrad of Copenhagen, there is a crystal of it about an inch and a half in length, and fully five lines in breadth.[†]

Sp. 3. *Chlorophæite.*

This name has been given by Dr. M'Culloch to a mineral which he found in the Western Isles of Scotland.[‡]

Colour pistachio-green, and transparent, or opaque; but soon becoming brown or black on being exposed to the air without losing its lustre.

Massive; in small grains, imbedded in basalt or amygdaloid, and sometimes hollow.

Fracture conchoidal, nearly earthy.

Brittle; scratched by a quill; specific gravity 2·020.

It occurs in Scuirmore Cliff, in the Island of Rum, also in Fifeshire, and in Iceland.

Sp. 4. *Forsterite.*[§]

This mineral was discovered by Mr. Levy accompanying pleonast and olive-green pyroxene from Vesuvius.

Colourless, brilliant, translucent.

Primary form a right rhombic prism with angles of 128° 54′. The length of a side of the base to the height of the prism as 7 to 4. Cleaves readily parallel to the base.

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[*] Annals of Philosophy (second series), vii. 134.

[†] Allan's Manual of Mineralogy, p. 153.

[‡] M'Culloch's Western Isles, i. 504.

[§] Annals of Philosophy (second series), vii. 61.

Hard enough to scratch quartz.

The angles, as given by Levy, agree nearly with those of chrysoberyl; but no cleavage parallel to the base has been discovered in that mineral.

Sp. 5. *Humite.*

This name was given by Bournon* to a mineral from Monte Somma.

Colour various shades of yellow, sometimes almost white, passing into reddish-brown.

In minute very complicated crystals, often macled.

Traces of cleavage parallel to the faces of a six-sided prism.

Lustre vitreous; brittle; transparent to translucent.

Hardness 6·5 to 7.

Before the blowpipe becomes opaque, but does not melt. Gives a clear glass with borax.

Sp. 6. *Sommervillite.*†

This name has been given by Mr. Brooke to a mineral from the ancient scoriæ of Vesuvius.

Colour pale dull yellow.

In crystals. The primary form seems to be a right rectangular prism; but several of the edges and angles are replaced by new planes. A perfect cleavage parallel to the base of the prism, but in no other direction.

Lustre vitreous.

Decrepitates before the blowpipe, fusing per se into a grey coloured globule, and with borax into a transparent ore.

Sp. 7. *Turnerite.*‡

This name has been given by Mr. Levy to a crystallized mineral from Mount Sorel in Dauphiny, which he observed in Mr. Turner's collection.

Colour several shades of yellow, often inclining to brown; streak white, sometimes greyish.

The primary form, according to Levy, is an oblique rhombic prism, the lateral faces of which are inclined at an angle of 96° 10′, and the base to one of the lateral faces at angle of 99° 40′. The ratio between one side of the base and one of the lateral edges, is nearly that of 10 to 7. The only crystal measured by

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* Catalogue, p. 52.

† Quarterly Journal, xvi. 275.

‡ Annals of Philosophy (second series), v. 241.

Levy is a very complicated one, which could not be understood without a figure.

Lustre nearly adamantine.

Transparent to translucent.

Scratches fluor spar very readily, but yields to the knife.

According to the experiments of Children, it consists chiefly of alumina, lime, magnesia and a little iron, but very little silica and no titanium.

Sp. 8. *Monazite.*[*]

Mengite of Brooke.[†]

This name was given by Breithaupt to a mineral brought by Fiedler from the Uralian mountains. It occurs near Slataoust along with a flesh-red felspar, in an immense bed of granite to the south of the Ilmenn mountain range.

Colour brown or smoky-red; streak reddish-white.

Crystallized in oblique rhombic prisms. The edge of the base is to the height as 13 to 18. The inclination of the faces of the prism is 95° 30′; that of the base on one of the sides 100°, as measured by Brooke.

Lustre vitreous, very small.

Hardness 6; specific gravity 4·88 to 4·922.

Before the blowpipe it does not give out water, nor decrepitate, nor alter its colour. In a white heat the edges become rounded, and the colour becomes greenish-yellow. On charcoal, with carbonate of soda and borax it fuses easily with effervescence in the reducing flame, into a light yellow opaque bead. While hot the bead was dark yellow, but on cooling it became pure yellow and by flaming was rendered opaque, indicating the presence of oxide of uranium. With biphosphate of soda in the oxidizing flame it fuses easily. The bead while hot is yellow, but on cooling it becomes yellowish-green and muddy. In the reducing flame the bead while hot is green, on cooling the colour becomes much deeper, and the bead becomes opaque. From these phenomena it is obvious that monazite contains oxide of uranium, mixed with earthy matter. But I am not aware that it has hitherto been subjected to a chemical analysis.

Sp. 9. *Uwarowite.*[‡]

This name has been given by M. Hess in St. Petersburgh to a mineral from Bissersk, which he examined by the blowpipe.

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[*] Breithaupt, p. 239 and 330. Poggendorf, xxv. 332.

[†] Annals of Philosophy (second series) x. 187.

[‡] Poggendorf's Annalen, xxiv. 388.

Colour emerald-green.

Crystallizes in small rhombic dodecahedrons.

Transparent.

Hardness 7·5.

When heated it does not give out water, nor decrepitate, nor is its colour altered. Not altered per se before the blowpipe. With borax it fuses with difficulty into a clear chrome-green glass; with biphosphate of soda it undergoes decomposition only when in powder. The bead when cold has a fine green colour, and is muddy from interspersed silica. With carbonate of soda it fuses with effervescence into a green frit, which cannot be melted into a bead.

This mineral has a strong resemblance to the *garnet*, but is harder, and of more difficult fusion.

Sp. 10. *Herschellite.*[*]

This name has been given by Mr. Levy to a mineral which occurs in the cavities of trap at Aci Reale, near Catania, in Sicily.

Colour white.

Crystallized in triangular dodecahedrons, the summits of which are deeply truncated. Mr. Levy considers the primary form to be a six-sided prism.

Fracture conchoidal.

Translucent or opaque.

Hardness 4·5; specific gravity 2·11.

Its constituents, according to the trials of Dr. Wollaston, are silica, alumina and potash. It is therefore connected with the felspar tribe of minerals, though its crystalline form differs much from all the kindred bodies.

Sp. 11. *Beudantite.*[†]

This name has been given by Mr. Levy to a mineral which has been found at Horhausen, in the district of Nassau, on the Rhine.

Colour black.

Translucent in thin fragments, and of a deep brown colour by transmitted light; streak greenish-grey; lustre resinous.

Crystallizes in a slightly obtuse rhomboid, in which the summits are truncated. The inclination of the contiguous edges of the rhomboid is 92° 30′ and 87° 30′. Cleaves easily in the direction perpendicular to the axis of the rhomboid.

Composed, according to Dr. Wollaston, of the oxides of iron and lead.

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[*] Annals of Philosophy (second series), x. 361.

[†] Ibid. xi. 195.

Sp. 12. *Condurrite.*[*]

This name was given by Mr. W. Phillips to a singular copper ore found in a vein in Cordorrow mine, which is situated in granite, and half a mile south of Dolcoath mine at Redruth, in the county of Cornwall.

Massive; colour brownish-black.

Hard, but not capable of scratching glass.

Brittle; yields to the knife, which leaves a polished metallic-looking surface, nearly of a lead grey colour.

Specific gravity 5·2045.

When ignited it gives out a copious white vapour, leaving on the coal a metallic substance in a semifluid state, of a yellow colour. Its constituents, as determined by the analysis of Mr. Faraday, are as follows:—

		Atoms.
Copper,	60·50	15·12
Sulphur,	3·06	1·53
Arsenic,	1·51	0·31
Arsenious acid,	25·94	4·15
Water,	8·99	8
	100	

There can be little doubt that the arsenious acid had originally existed in this ore in the state of metallic arsenic. The composition was undoubtedly

1 atom sulphuret of copper,
3 atoms arseniet of copper.

The water is no doubt merely mechanical; at first the ore contained a great deal more of it, but by drying it cracked and split into irregular columns like starch.

Sp. 13. *Mohsite.*[†]

This is a name given by Mr. Levy to some crystals upon a group of quartz belonging to Mr. Heuland, and which probably came originally from Dauphiny.

Colour iron-black.

In twin crystals, presenting the aspect of small flat tables nearly circular, with re-entering and salient angles, alternating on their edges. Mr. Levy considers the primary form to be an acute rhomboid of 73° 43′.

Opaque, with a perfect metallic lustre.

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[*] Phil. Mag. (new series), ii. 286.

[†] Ibid. i. 221.

Surface brilliant; fracture conchoidal and shining.

Scratches glass readily.

No visible cleavage; does not affect the magnet; brittle.

It seems to be related to Crichtonite, but has not been subjected to a chemical analysis.

Sp. 14. *Spinellane.*[*]

Nosin, nosiane.

This mineral was discovered by M. Nose on the shores of the lake Loach.

Colour greyish-black, passing into ash-grey and brown.

Crystals rhomboidal dodecahedrons, similar to the form of garnet.

Fracture conchoidal, uneven.

Translucent to opaque.

Hardness 5·5 to 6; specific gravity 2·282.

Before the blowpipe it is infusible, whether alone or with additions.

Its constituents, according to Klaproth, are:

		Atoms.
Silica,	43	26·5
Alumina,	29·5	13·11
Lime,	1·5	0·42
Soda,	19	4·75
Peroxide of iron,	2	0·4
Sulphur,	1	0·5
Water,	2·5	
	98·5	

Or nearly $3AlS^{1\frac{1}{2}}+NS^{1\frac{1}{2}}$.

So that it may be considered as a sesquisilicate of alumina and soda.

Sp. 15. *Okenite.*[†]

This name has been given by Von Kobell to a mineral of which I have only seen a very imperfect description.

Colour yellowish and bluish-white.

Lustre pearly, from shining to glimmering.

Occurs in fibrous masses in amygdaloid.

Hardness stated by Breithaupt from 5 to 8. Specific gravity 2·28.

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[*] Klaproth's Beitrage, vi. 371.

[†] Breithaupt's *Volständige Charakteristik des Mineral Systems*, 127.

Sp. 16. *Breislakite.*[*]

This mineral occurs at Capo di Bove, near Rome, and in the lava of Mount Vesuvius, where it accompanies nepheline, pyroxene, &c.

Occurs in delicate capillary crystals, of a reddish-brown or chesnut-brown colour; bent and grouped like wool, coating the cavities of certain lavas.

It contains silica, alumina, iron and a considerable proportion of copper; affording, when fused with biphosphate of soda, a green globule, which becomes red in the reducing flame.

Sp. 17. *Biotine.*[†]

This mineral was noticed by Monticelli among the volcanic debris of Mount Vesuvius. He named it from M. Biot.

Colour white or yellowish.

Transparent and limpid; refracts doubly.

Lustre brilliant.

Scratches glass.

Specific gravity 3·11.

Is not affected by the blowpipe, and is partially soluble in nitric acid.

Sp. 18. *Tautolite.*[‡]

This mineral is found in the volcanic felspathic rocks in the neighbourhood of the lake Loach in Rhein, Prussia.

Colour velvet-black; streak grey.

Occurs in crystals, and Mohs considers the primary form to be an octahedron with scalene triangles, the three diameters of which are to each other as the numbers 1, 1·9451 and 1·3648. It is usually under the form of a ten-sided prism, with dihedral summits.

Opaque; lustre vitreous; fracture conchoidal.

Hardness 6·5; specific gravity 3·865.

Before the blowpipe upon charcoal it melts into a blackish scoria, which is attracted by the magnet. With borax it melts into a clear green glass.

Tautolite is considered as related to chrysolite, though the degree of relation is not very evident.

Sp. 19. *Tephroite.*[§]

This mineral occurs along with franklinite and red zinc, at Sparta, in the United States of America.

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[*] Allan's Manual of Mineralogy, p. 301.

[†] Ibid, p. 163.

[‡] Phil. Mag. (new series), iii. 398.

[§] Silliman's Jour. xviii. 391.

Colour ash-grey, tarnishing black; streak paler than the mineral.

Massive and compact.

Cleavage perfect in several directions, two of them meeting at right angles.

Fracture imperfect conchoidal, or uneven.

Forms a black slag before the blowpipe.

Sp. 20. *Zurlite.*[*]

This mineral was discovered by Ramondini in 1810, and described by him in the Memoirs of the Academy of Naples. Its only locality is Vesuvius, where it occurs in large distinct crystals generally associated with calcareous spar and other minerals.

Colour asparagus green, inclining to grey.

Crystals rectangular four-sided prisms, having occasionally their lateral edges replaced by tangent planes.

Cleavage indistinct.

Lustre resinous.

Opaque; fracture conchoidal.

Surface of the crystals rough, frequently covered with a white coating.

Hardness about 6; specific gravity 3·27.

Infusible before the blowpipe, but melts with borax into a black glass.

Nitric acid dissolves it partly with effervescence, and the solution is yellow.

Sp. 21. *Hydrous Tris-silicated Peroxide of Iron.*

I have stated in page 476 of this volume, on the authority of a notice from a German mineral dealer, from whom I purchased the specimen, that the mineral on which *cacoxenite* is found at Hrbetk in Bohemia, is a *clay ironstone* occurring in the coal formation. But I have lately procured a specimen of this mineral from Dr. Bondi of Dresden, and have found that it constitutes a new species of iron ore, to which, from its composition, the name of *hydrous tris-silicated peroxide of iron* may be given.

It constitutes an amorphous mass having a brownish red colour, a compact texture, and exhibiting no traces of any tendency to crystallization.

Streak brownish yellow; brittle; opaque.

Fracture uneven.

Hardness 5; specific gravity 3·571.

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[*] Allan's Manual, p. 328.

Before the blowpipe undergoes no change, excepting that the colour becomes dark red.

With carbonate of soda it does not fuse. With borax it fuses readily into a transparent bead, yellow in the oxidizing flame, but becoming almost colourless in the reducing flame. With biphosphate of soda fuses in the oxidizing flame into a transparent bead, yellow while hot but becoming colourless on cooling. The same changes are observable in the reducing flame.

It was subjected to a careful analysis, in my laboratory, by Mr. Richardson, who found its constituents as follows :

			Atoms.
Silica,	10·65	5·32	1
Peroxide of iron,	74·40	14·88	2·80
Lime,	2·25	0·69	0·12
Sesquioxide of mangan.,	0·60	0·12	0·02
Water,	12·00	10·66	2·00
	99·9		

If we unite the lime and sesquioxide of manganese to the peroxide of iron, it is obvious that the constituents are

1 atom silica,
3 atoms peroxide of iron,
2 atoms water.

It is therefore a hydrous *tris-silicated peroxide of iron.* It ought to come in after chloropal in page 463.

Sp. 22. *Rhodizite.*[*]

This mineral was lately observed by M. Gustavus Rose in small crystals on some of the red tourmalins from Siberia.[†]

The crystals observed were small, never exceeding a line in length, and often not so large. They have the form of rhomboidal dodecahedrons, having those angles which consist of three faces replaced by small triangular planes. The faces of the octahedron are also occasionally visible, showing the connexion between the cube, octahedron and rhomboidal dodecahedron.

Colour white; translucent; lustre splendent, vitreous; hard enough to resist the action of the knife; fracture and specific gravity not determined.

Very difficultly fusible before the blowpipe. A small fragment in the platinum forceps, fused on the edges into a white opaque

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[*] Named by M. G. Rose from ῥοδίζειν, *to have the colour of the rose.* Because it tinges flame *red.*

[†] Poggendorf's Annalen, xxxiii. 253.

glass. The colour of the flame is at first green, then the under surface continues green while the upper surface becomes red, and at last the whole flame is tinged red. The red tinge is as deep as that caused by *red* tourmalin, lepidolite, petalite, or spodumen, and is probably induced by the same cause, the existence of *lithia* in the rodizite.

When heated on charcoal its edges are rounded off, it becomes snow-white and opaque, and protuberances make their appearance similar to those which appear when the mineral is exposed to the action of the blowpipe in the platinum forceps.

When heated in a glass tube it gives out no water.

With borax and with biphosphate of soda, it fuses into a transparent glass and appears to contain no silica. With fluor spar it melts into a clear glass. It fuses also completely in silicate of soda without inducing any colour, and therefore contains no sulphuric acid.

With a little carbonate of soda it fuses into a white enamel, which when moistened on a polished silver plate produces no stain. With a greater proportion of the soda it fuses into a clear glass, which does not crystallize on cooling. When the soda glass thus formed is pounded, and dissolved in muriatic acid, and the solution after being evaporated to dryness is digested in alcohol, and the spirit set on fire it burns with as deep a green flame as when *boracite* is treated in the same manner.

Rhodizite dissolves with great difficulty in muriatic acid. A small quantity having been pounded and boiled in muriatic acid left a residue, which would probably have disappeared had the digestion been continued long enough. From the solution ammonia threw down nothing, but oxalate of ammonia occasioned a considerable precipitate. Lithia could not be distinctly recognised in the filtered solution, doubtless from its small quantity.

It is obvious that *rhodizite* has a great resemblance to *boracite*. Its shape, colour, and hardness are analogous, and so are its behaviour before the blowpipe with borax, biphosphate of soda, fluor spar, and silicate of soda. Boracite when heated in the platinum forceps tinges the flame green, and produces a similar precipitate when its muriatic acid solution is treated with oxalate of ammonia. The situation in which rhodizite and boracite are found is different. But a chemical analysis is still wanting to enable us to determine the exact relation in which these two minerals stand to each other.

Sp. 23. *Brevicite.*[*]

This name has been given by Berzelius to a mineral sent him by M. Strom, from Brevig, in Norway, which appears to have filled up an amygdaloidal cavity in a trachyte-looking rock.

It is a white, foliated or radiated mass, which fills the cavity in regular prismatic crystals. It is traversed by dark red and smutty grey red streaks. It was analyzed by M. Sonden in Berzelius's laboratory, who found its constituents to be

		Atoms.	
Silica,	43·88	21·94	33·5
Alumina,	28·39	12·57	19·2
Soda,	10·32	2·58	4
Lime,	6·88	1·96	3
Magnesia,	0·21	0·08	0·12
Water,	9·63	8·56	13·1
	99·31		

These numbers approach

$$19AlS+4NS^2+3CalS^2+13Aq.$$

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[*] From *Brevig*, in Norway, where it was found. See Poggendorf's Annaleu, xxxiii. 112.

TABLE

Exhibiting the Specific Gravity, Hardness, and Crystalline Form of Minerals, as far as these properties have been determined.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
CLASS I.			
ACID BASES.			
GENUS I.—CARBON.			
1. Diamond	3·5295	10	Octahedron.
2. Plumbago	2·25—2·32	1	Six-sided prism.
3. Anthracite	1·4—1·75	2	Regular six-sided prism.
4. Bituminous mineral coal . .			Cube ?
1. Caking coal . . .	1·269		
2. Splint coal . . .	1·29		
3. Cherry coal . . .	1·265		
4. Cannel coal . . .	1·272		
5. Wood coal . . .			
5. Asphalt	1·073—1·205	2	
6. Elastic bitumen	0·9053—1·233		
7. Retinasphaltum	1·135		
8. Scheererite	0·65		Needles.
9. Mineral tallow	0·983		
10. Amber	1·081	2—2·5	
11. Highgate resin	1·046	2·5	

Names.[1]	Specific Gravity.	Hardness.	Primary Crystalline Form.
GENUS II.—BORON.			
1. Boracic acid	1·439		
GENUS III.—SILICON.			
1. Quartz	2·6413—2·69	7	Rhombohedron, P on P′ 94° 15′.
2. Kilpatrick quartz	2·525	7	
3. Calcedony	2·6	7	Rhombohedron as quartz.
4. Flint	2·575—2·594	7—7·25	
5. Opal	2·015—2·21	6·75	
6. Jasper	2·6		
7. Basanite	2·585—2·644	7	
GENUS IV.—PHOSPHORUS.			
GENUS V.—SULPHUR.			
1. Native sulphur	2·033—2·071	2·5	Rhomboidal octahedron.
GENUS VI.—SELENIUM.			
GENUS VII.—TELLURIUM.			
1. Native tellurium	5·7—6·1	2—2·5	Regular six-sided prism.
GENUS VIII.—ARSENIC.			
1. Native arsenic	5·672	5	
2. Arsenious acid	3·720		Regular octahedron.

Name.	Specific Gravity.	Hardness.	Primary Crystalline Form.
3. Arsenic acid			
4. Sulphide of arsenic	3·642	1·5	Oblique rhombic prism.
5. Sesquisulphide of arsenic	3·4—3·48	1·5	Right rhombic prism.
GENUS IX.—ANTIMONY.			
1. Native antimony	6·72	2·5—3	Rhombohedron, P on P′ about 117°
2. Arseniet of antimony	6·13	3·5	
3. Protoxide of antimony	5·566	2·5—3	Rhombic prism, P on P′ 137° 43′
4. Sesquisulphide of antimony	4·516—4·62	2	Right rhombic prism.
5. Red antimony	4·09—4·6	1·—1·5	Right square prism.
GENUS X.—CHROMIUM.			
GENUS XI.—MOLYBDENUM.			
1. Bisulphide of molybdenum	4·569—4·7385	1—1·5	Regular six-sided prism.
GENUS XII.—TUNGSTEN.			
GENUS XIII.—COLUMBIUM.			
GENUS XIV.—TITANIUM.			
1. Native titanium	5·3	7·5	Cube.
2. Protoxide of titanium	3·826—3·857	5·5—6	Octahedron with square base.
3. Titanic acid	4·18—4·249	6·5—7	Right square prism.
GEUNS XV.—VANADIUM.			

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
CLASS II.			
ALKALINE BASES.			
GENUS I.—AMMONIA.			
1. Sal ammoniac	1·528	1·5—2	Regular octahedron.
2. Sulphate of ammonia . . .	2	1·5	Right square prism.
GENUS II.—POTASSIUM.			
1. Nitrate of potash	1·933		Octahedron with rectangular base.
GENUS III.—SODIUM.			
1. Carbonate of soda . . .	1·622		Oblique rhombic prism.
2. Sesquicarbonate of soda . . .	1·98		Oblique four-sided prism.
3. Nitrate of soda	2·069		Oblique four-sided prism.
4. Hydrous sulphate of soda . .	1·349		Oblique rhombic prism.
5. Anhydrous sulphate of soda . .	2·73		Right oblique prism.
6. Borax	1·740		Doubly oblique four-sided prism.
7. Common salt	2·257	2	Cube.
GENUS IV.—LITHIUM.			
GENUS V.—BARIUM.			
1. Carbonate of barytes . . .	4·2985	3·75	Right rhombic prism.

Name.	Specific Gravity.	Hardness.	Primary Crystalline Form.
2. Sulphate of barytes	4·472	3—3·5	Right rhombic prism.
3. Calcareo-sulphate of barytes	4·1907	2·75	Right rhombic prism.
4. Baryto-calcite	3·868	4	
5. Sulphato-carbonate	4·141	3	
			Six-sided prism.
GENUS VI.—STRONTIAN.			
1. Green carbonate of strontian	3·713	3·5	Right rhombic prism.
2. Brown carbonate of strontian	3·651	3—3·5	
3. Sulphate of strontian	3·9626	3—3·5	Right rhombic prism.
4. Baryto-sulphate of strontian	3·921	2·75	
5. Calcareo-sulphate of strontian	3·81	2·75	
6. Stromnite	3·703	3·5	
GENUS VII.—CALCIUM.			
1. Calcareous spar	2·721	3	Obtuse rhombohedron, P on P′ 105° 5′.
2. Arragonite	2·7647—2·9467	3·75	Right oblique prism, M on M′ 116° 10′.
3. Subsesquicarbonate of lime			
4. Hydrous sulphate of lime	2·31—2·3257	2	Right oblique prism.
5. Anhydrous sulphate of lime	2·899—2·957	2·75—3·25	Right rectangular prism.
6. Siliceous sulphate of lime	2·8787	2·75	Right oblique four-sided prism.
7. Subsesquiphosphate of lime	3·0989—3·235	5	Regular six-sided prism.
8. Fluor spar	3·0943—3·1911	4	Regular octahedron.
9. Sesquisilicate of lime		7—7·5	Octahedron with square base.
10. Bisilicate of lime	2·785—2·895	3·—4	Doubly oblique four-sided prism.
11. Wollastonite	2·85—2·876	2·5	

Name.	Specific Gravity.	Hardness.	Primary Crystalline Form.
12. Tersilicate of lime	2·2055	3·5	
13. Dysclasite	2·362	4·25	
14. Sesquihydrous arseniate of lime	2·848	2—2·5	Octahedron with oblique base.
15. Bisesquihydrous arseniate of lime	2·536—2·730	2·5	Right oblique prism.
16. Tungstate of lime	5·959—6·076	6·5	Octahedron with square base.
17. Glauberite	2·73—2·807	2·5—3	Doubly oblique rhomboidal prism.
18. Gaylussite	1·928—1·99	2·5	Doubly oblique prism.
19. Calcareo carbonate of barytes	3·66	4	Oblique rhombic prism.
20. Bicalcareo carbonate of barytes	3·718	2·25	Pyramidal dodecahedron.
21. Baryto fluate of lime	3·75		
22. Xanthite	3·221	2	Doubly oblique prism.
23. Borosilicate of lime	2·98—3·3463	4·25—5	Right rhombic prism.
24. Botryolite	2·885	4	
25. Colophonite	3·871—3·965	6·75	Rhomboidal dodecahedron.
26. Ilvaite	3·825—4·061	4·75—5	Right rhombic prism.
27. Hedenbergite	3·154	3·5	Rhombic prism.
28. Ligurite	3·49	5+	Oblique rhombic prism.
29. Sphene	3·2378—3·510	5—5·5	Oblique rhombic prism.
30. Raphilite	2·85	3·75	Oblique four-sided prism.
31. Polyadelphite	3·767	3·25	
32. Pectolite	2·69	4·5	
GENUS VIII.—MAGNESIUM.			
1. Hydrate of magnesia,	2·35	1	
2. Carbonate of magnesia	2·808—2·95	4·5	

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
3. Hydro-carbonate of magnesia, .			
4. Sulphate of magnesia . . .	1·751	2—2·25	Right rhombic prisms.
5. Reissite			
6. Bloedite			
7. Biborate of magnesia . . .	2·974	4·25	Cube.
8. Hydroboracite	1·9	2	
9. Chrysolite	3·44	6·5—7	Right rectangular prism.
10. Nemalite	2·353—2·44	2	
11. Common serpentine . . .	2·8	3·5	
12. Precious serpentine . . .	2·595	3·5	Oblique four-sided prisms.
13. Picrosmine	2·596—2·66	2·5—3	Octahedron.
14. Schiller spar	2·652	3·75	Rhombic prism.
15. Tersilicate of magnesia . . .	2·555—2·594	3·5—4	Doubly oblique prism.
16. Hydrous tersilicate of magnesia .	2·127	2	
17. Magnesite			
18. Quincite			
19. Ferro-carbonate of magnesia . .	3·001—3·112	4—4·5	Rhombohedron.
20. Calcareo-carbonate of magnesia, .	2·815—2·884	3·5—4	Rhombohedron.
21. Wagnerite	3·13	5—5·5	Right oblique prism.
22. Chondrodite	3·118	4·5	Right oblique prism.
23. Potash bisilicate of magnesia . .	2·87		
24. Venetian talc	2·697	1	
25. White augite	3·2307—3·297	4·75	Doubly oblique four-sided prism.
26. Pyroxene	3·233—3·349	4·75	Doubly oblique four-sided prism.
27. Jeffersonite	3·51—3·55	4·5	Doubly oblique four-sided prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
28. Amphibole	2·957—3·2	4·75	Oblique rhombic prism.
29. Norwegian tremolite	3·2	6	
30. Retinalite	2·493	3·75	
31. Hypersthene	3·338—3·385	4·75	Right oblique prism.
32. Humboldilite	3·104		Right square prism.
33. Hyalosiderite	2·875	5·5	Octahedron with rectangular base.
34. Anthophyllite	2·94—3·1558	5—5·5	Right rhombic prism.
35. Mellilite			Square prism.
36. Mountain cork	2·442		
37. Hydrous Anthophyllite	2·911	2·5	
GENUS IX.—ALUMINUM.			
Section I.			
1. Sapphire	3·9511	9	Acute rhombohedron.
2. Spinell	3·523	8	Regular octahedron.
3. Ceylanite	3·575	8	
4. Automalite	4·261	7·25	Regular octahedron.
5. Sapphirine	3·4282	7·75	
6. Candite	3·617	8	
7. Dysluite	4·551	4·5	Regular octahedron.
Section II.			
1. Gibbsite	2·091	2·75	
2. Bihydrate of alumina		3·25	

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
3. Diaspore	3·4324		Doubly oblique prism.
4. Mellate of alumina	1·55—1·597	2·75	Octahedron with square base.
5. Aluminite	1·7054	2	
6. Sulphate of alumina	1·666		
7. Fluellite			Right rhombic prism.
8. Turquoise	2·696—3·25	6·75	
9. Andaluzite	3·314	4·25	Right rhombic prism.
10. Hydrous trisilicate of alumina			
11. Bucholzite	3·193	6	
12. Scarbroite	1·48	3·5	
13. Gilbertite	2·648	2·75	
14. Hydrous bucholzite	2·855	3	
15. Halloylite			
16. Pholerite			
17. Worthite	3·+	7·25	
18. Cyanite	3·618—3·675	6	Doubly oblique four-sided prism.
19. Allophane	1·852—1·889	3	
20. Tuesite	2·558	2·5	
21. Nacrite	2·788—2·793	2·75	Four-sided prism.
22. Fuller's earth	2·4448	1	
23. Davidsonite	2·3629	6·5	Four-sided oblique prism.
24. Lenzenite	1·8—2·1		
25. Quatersilicate of alumina	2·688	3	
Section III.			
1. Cryolite	2·949	2·25	Right rectangular prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
2. Topaz	3·449—3·641	8	Right rhombic prism.
3. Pycnite	3·503—3·53	7·5	Six-sided prism.
4. Ambligonite	3·—3·04	6	Rhombic prism.
5. Fibrolite	3·214	7·25	Right rhombic prism.
6. Nepheline	3·27	2·5	Regular six-sided prism.
7. Sodalite	2·295—2·378	5·75	Rhomboidal dodecahedron.
8. Idocrase	3·349—3·599	6	Right square prism.
9. Grossularite	3·372—3·64	6·75	Rhombic dodecahedron.
10. Melanite	3·157—3·73	6·75	Rhombic dodecahedron.
11. Garnet		6·75	Rhombic dodecahedron.
12. Essonite	3·631	6·5	
13. Brown manganese garnet	3·829	6·75	Four-sided oblique prism.
14. Pyrope	3·78	7·5	Cube.
15. Amphodelite	2·763	4·5	Doubly oblique prism.
16. Zoisite	3·32—3·32707	6·25	Oblique rhombic prism.
17. Meionite or Scapolite	2·612—2·749	4·25	Right square prism.
18. Prehnite	2·9—2·953	5	Right rhombic prism.
19. Anhydrous Scolezite		6	
20. Iolite	2·5969—2·6643	7	Regular six-sided prism.
21. Hydrous Iolite		3·75	Irregular six-sided prism.
22. Staurotide	3·693	6·75	Right rhombic prism.
23. Gehlenite	2·9166—3·029	6·5	Right square prism.
24. Weissite	2·808		
25. Fahlunite	2·62—2·79		
26. Anhydrous Fahlunite	2·632		

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
27. Leucite	2·49	7	Cube.
28. Pipestone	2·606—2·608	1·5	
29. Murchisonite	2·5091	6	Four-sided prism.
30. Gabronite	3		Rectangular prism.
31. Icespar	2·4365		Right oblique four-sided prism.
32. Felspar	2·394—2·581	6	Doubly oblique prism.
33. Glassy felspar	2·576—2·582	6	Doubly oblique prism.
34. Albite	2·608—2·619	6	Doubly oblique prism.
35. Anorthite	2·656—2·762	6	Doubly oblique prism.
36. Labradorite	2·691—2·75	6	Doubly oblique prism.
37. Kaolin	2·484		
38. Leelite	2·606	6·25	
39. Spodumene	3·188	6·5	Oblique four-sided prism.
40. Petalite	2·42—2·45	6·5	Oblique four-sided prism.
Section IV.			
1. Ammonia-alum	1·56		Regular octahedron.
2. Potash-alum	1·753	2·75	Regular octahedron.
3. Soda-alum	1·88	3	Regular octahedron.
Section V.			
1. Alumstone	2·7517	3·5	Rhombohedron.
2. Wavellite	2·253—2·337	3·25	Right rhombic prism.
3. Lazulite	3·057	5—55	Right rhombic prism.
4. Blue spar	3·024	5·5—6	Right oblique prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
Section VI.			
1. Stellite	2·612	3·25	Four-sided prism.
2. Thomsonite	2·29—2·36966	4·75	Right rectangular prism with square base.
3. Natrolite	2·139—2·2302	4·5	Right rhombic prism.
4. Mesolite	2·125—2·333		Right rhombic prism
5. Scolezite	2·214—2·27		
6. Zeuxite	3·051	4·25	
7. Ittnerite	2·3854	7	Rhomboidal dodecahedron.
8. Plinthite	2·342	2·75	
9. Bonsdorfite		3·5	Regular six-sided prism.
10. Chalilite	2·252	4·5	
11. Karpholite	2.923—2·9365	2·5	Needles.
12. Antrimolite	2·0964	3·75	
13. Glottalite	2·181	3·5	Regular octahedron ?
14. Harringtonite	2·217	5·25	
15. Soapstone	2·396—2·411		
16. Killinite	2·711	3·5	Rectangular four-sided prism.
17. Lomonite	2·3	3·5	Oblique rhombic prism.
18. Chabasite	2·088—2·7176	3·75	Obtuse rhombohedron.
19. Leveyine	2·161	4	Obtuse rhombohedron.
20. Analcime	2·278	6·25	Cube.
21. Lehuntite	1·953	3·75	
22. Cluthalite	2·166	3·5	Right rectangular prism.
23. Hydrolite	2·054	4	

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
24. Erinite	2·04	1·75	
25. Pyrophyllite			
26. Agalmatolite	2·895	2	
27. Stilbite	2·133—2·161	3·5	Right rhombic prism ?
28. Heulandite	2·195—2·2	3·5	Right oblique prism.
29. Brewsterite	2·432	4·25	Right oblique prism.
30. Harmotome	2·400	4·25	Right rectangular prism.
31. Philipsite		4·25	Right rectangular prism.
32. Morvenite	2·448	4·25	Right rectangular prism.
33. Apophyllite	2·335—2·359	62·5	Right square prism.
34. Rhodalite	2·000	2	
35. Neurolite	2·476	4·25	
36. Comptonite	2·427	5	Right rectangular prism.
37. Hexagonal talc	2·772	1·75	Regular six-sided prism.
38. Chlorite	2·823	1·5	
39. Brown chlorite			
Section VII.			
1. Mica	2·824—3·08	2·5	Oblique rhomboidal prism.
2. Elœolite	2·546—2·618	6	Right rhombic prism.
3. Epidote	3·425—3·46	6	Right oblique prism.
4. Axinite	3·271	7	Doubly oblique prism.
5. Tourmaline	3·076	8	Obtuse rhombohedron.
6. Bytownite	2·801	6	
7. Vermiculite	2·5252	1	

Name.	Specific Gravity.	Hardness.	Primary Crystalline Form.
8. Lithomarge	2·457	2·5	
9. Latrobite	2·8		Doubly oblique prism.
10. Withamite	3·137	6	
11. Isopyre			
12. Kirwanite	2·941	2	
13. Scorilite	1·708	2	
14. Sordawalite	2·58		
15. Cauzeranite	2·69		Oblique rhomboidal prism.
Section VIII.			
1. Gieseckite	2·832		
2. Nutallite	2·748—2·758	3·5	Regular six-sided prism.
3. Phyllite	2·889	7	Right square prism.
4. Huronite	2·8625	5·75	
5. Erlanite	3—3·1	3·25	
6. Pinite	2·7575—2·782	6·25—7	Regular six-sided prism.
7. Glauconite	2·598—2·632		
8. Glaucolite	2·72—2·9	5	Rhombic prism.
9. Mountain leather . . .	1·334		
10. Pearl stone	2·342	6	
11. Saussurite	2·801	7	
12. Pitchstone	2·338—2·8604	6·5	
13. Obsidian	2·363—2·372	6·5	
GENUS X.—GLUCINUM.			
1. Phenakite	2·969	7·25	Rhombohedron.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
2. Euclase	2·907—3·098	7·5	Right oblique prism.
3. Emerald	2·58—2·732	7·5—8	Regular six-sided prism.
4. Chrysoberyl	3·508—3·754	8·5	Right rectangular prism.
GENUS XI.—YTTRIUM.			
1. Phosphate of yttria	4·5577	4·25	Octahedron with square base.
2. Yttrotantalite			
1. Black	5·395	5·5	
2. Yellow	5·882		
3. Brownish-black . .			
3. Fergusonite	5·8—5·838	5·75	Octahedron.
4. Gadolinite	4·1493—4·1795	8	Oblique rhombic prism.
5. Orthite	3·288	7	
6. Pyrorthite	2·19	2·75	Four-sided prism.
GENUS XII.—CERIUM.			
1. Carbonate of cerium			
2. Cerite	4·912	5·5	
3. Thulite	3·1055	5.5	Oblique prism.
4. Fluate of cerium	4·7	4	Regular six-sided prism.
5. Subsesquisilicate of cerium . .		5	Rhomboidal dodecahedron.
6. Yttrocerite	3·447	5	Right rhombic prism.
7. Allanite	4·001	6	Right oblique four-sided prism.
8. Pyrochlore	4·206—4·216	5	Regular octahedron.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
GENUS XIII.—ZIRCONIUM.			
1. Zircon	4·681	6·5	Octahedron with square base.
2. Sillimanite	3·1636—3·41	6	Oblique four-sided prism.
3. Aeschynite			
4. Eudyalite	2·9036	6	Rhombohedron.
5. Polymignite	4·806	7 ?	Rhomboidal octahedron.
GENUS XIV.—THORIUM.			
1. Thorite	4·63		
GENUS XV.—IRON.			
Section I.			
1. Native iron	5·95—6·72	4·5	
2. Meteoric iron	7·3		
3. Magnetic iron ore	5·092	5·5—6·5	Regular octahedron.
4. Specular iron ore	5·251	5·5—6·5	Slightly acute rhomboid.
5. Crucite	3·579	3	Oblique four-sided prism.
6. Manganesian iron ore	5·079	7	Octahedron.
7. Franklinite	5·069	6—6·5	Octahedron.
8. Dihydrous peroxide of iron	4·375	4·5	Right rhombic prism.
9. Hydrous peroxide of iron	3·922—4·04	4·5—5	
10. Magnetic pyrites	4·631	5—6	Regular six-sided prism.
11. Bisulphuret of iron	4·83—5·031	6·5	Cube.
12. Radiated pyrites	4·678—4·847	6	Right rhombic prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
13. Sesquiarseniet of iron	7·228	5—5·5	Octahedron with scalene faces.
Section II.			
1. *Simple Oxygen Salts.*			
1. Carbonate of iron	3·7317—3·829	3—4·5	Obtuse rhombohedron.
2. Junkerite	3·815	3·5	Right oblique prism.
3. Bisulphated peroxide of iron			Regular six-sided prism.
4. Sulphated peroxide of iron			Six-sided prism.
5. Mullicite	1·787	1	
6. Subsesquiphosphate of iron			
7. Vivianite	2·661	1·5—2	Right oblique prism.
8. Diarseniate of iron			
9. Subsesquiarseniate of iron	3	2·5	Cube.
10. Arseniate of iron			
11. Hydrous disilicate of iron	3	2·5	Tetrahedron.
12. Chamoisite	3—3·4		
13. Anhydrous silicate of iron	3·8846	4	Four-sided prism.
14. Cronstedtite	3·348	2·5	Regular six-sided prism.
15. Hedenbergite	3·154	3·5	
16. Chloropal	1·727—2·105	3·5	
17. Titaniate of iron	4·427		
18. Iserine	4·491—4·65		
19. Subsesquititaniate of iron			
20. Crichtonite	3	4·25	Acute rhombohedron.
21. Nigrin	4.445		

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
22. Oxalate of iron?	2·489	2	
2. *Double Oxygen Salts.*			
1. Hydrous carbonate of iron . .	3·404	3·25	
2. Magnesia carbonate of iron . .			Rhomboid.
3. Manganeso diphosphate of iron .	3·439—3·562	5—5·5	Right rectangular prism.
4. Alumina sulphate of iron . .		1	
5. Hetopizite	3·524		Rhomboidal prism.
6. Carbono-phosphate of iron . .	3·71		
7. Scorodite	3·162—3·4	3·5—4	Right rhombic prism.
8. Cacoxenite			
9. Sulpharseniate of iron . . .	2·4		
10. Thraulite			
11. Achmite	3·398	4	Right oblique prism.
12. Krokidolite	3·2	4	
13. Chrome iron ore	4·321	5·5	Regular octahedron.
14. Arfvedsonite	3·369	4·5	Oblique four-sided prism.
15. Knebelite	3·714		
16. Columbite	7·236—7·963	5·25	Right rectangular prism.
17. Wolfram	7·155	5	Right oblique prism.
18. Ilmenite	4·766—4·808	5·75	Rhombohedron.
19. Titaniferous iron ore . . .	4·488—4·789	5—5·5	Rhombohedron.
3. *Triple Oxygen Salts.*			
1. Ankerite	3·080	3·5—4	Rhombohedron.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
2. Pyrosmalite	3·081	4·5	Regular six-sided prism.
3. Commingtonite	3·2014	2·75	
4. Nontronite		1·75	
5. Volkonskoite			
6. Polylite	3·231	6·25	
Section III.			
1. Arsenical pyrites	6·127	4·75	Right rhombic prism.
2. Berthierite			
GENUS XVI.—MANGANESE.			
Section I.			
1. Haussmannite	4·722	4·5—5	Octahedron with square base.
2. Braunite	4·818	6—6·5	Octahedron with square base.
3. Manganite	4·312—4·328	4—4·25	Right rhombic prism.
4. Pyrolusite	4·97	2—2·5	Four-sided prism.
5. Hydrous binoxide of manganese			
6. Hydrous sesquibinoxide of manganese	3·31245	4·25	
7. Varvacite	4·283—4·531	2·5	
8. Psilomelanite	4·145	5—6	
9. Newkirkite	3·824	3—3·5	Rectangular prism.
10. Sulphuret of manganese	3·95—4·014	3·5—4	Cube.
11. Arseniet of manganese	5·55		

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
Section II.			
1. *Simple Oxygen Salts.*			
1. Carbonate of manganese	3·592	3·5	Obtuse rhombohedron.
2 Disilicate of manganese			Octahedron.
3. Silicate of manganese	4·078	6·25	Right oblique prism.
4. Sesquisilicate of manganese	3·586	6·25	Doubly oblique four-sided prism.
5. Bisilicate of manganese	3·538	7	
2. *Double Oxygen Salts.*			
1. Huraulite	2·27		Right oblique prism.
2. Bustamite	3·12—3·25	6·5	
3. Ferruginous silicate of manganese	3·014—3·034	2·5	Obtuse rhombohedron ?
4. Carbo-silicate of manganese	3·1—3·89		
5. Babingtonite			Doubly oblique prism.
3. *Triple Oxygen Salts.*			
1. Helvine	3·166	6·5	Acute rhombohedron.
GENUS XVII.—NICKEL.			
Section I.			
1. Sulphuret of nickel			
2. Arseniet of nickel	7·655	5·5	Six-sided prism.
3. Subsesquiarseniet of nickel			

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
4. Binarseniet of nickel			
5. Antimoniet of nickel			Regular six-sided prism.
Section II.			
1. Diarseniate of nickel			
Section III.			
1. Sulphoarsenite of nickel	6·129	5	
2. Sulphoantimonite of nickel	6·097	5·5	Cube.
GENUS XVIII.—COBALT.			
Section I.			
1. Sesquisulphuret of cobalt			
2. Sesquiarseniet of cobalt			
3. Binarseniet of cobalt	6·466	5·5	Cube.
4. Terarseniet of cobalt	6—6·7	5·5	
5. Cobalt ochre	2·2		
Section II.			
1. Diarseniate of cobalt	2·948		Right oblique prism.
2. Disulphate of cobalt			
Section III.			
1. Sulpho-arsenite of cobalt	6·298	5·5	Cube.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
GENUS XIX.—ZINC.			
Section I.			
1. Blende	4·049	3·75	Rhombic dodecahedron.
2. Voltzine	3·66	4·5	
3. Seleniet of zinc	5·56		
4. Red zinc	5·432	4	Regular six-sided prism.
Section II.			
1. Anhydrous carbonate of zinc . .	4·334—4·442	5	Obtuse rhombohedron.
2. Hydrous dicarbonate of zinc . .	3·584—3·598	2—2·5	
3. Anhydrous silicate of zinc . .	3·935	5	
4. Hydrous silicate of zinc . . .	3·379—3·434	5	Right rhombic prism.
5. Sulphate of zinc	2·036	2—2·5	
6. Hopeite	2·76	2·5	Right oblique prism.
Section III.			
1. Marmatite			
GENUS XX.—LEAD.			
Section I.			
1. Native lead			
2. Protoxide of lead	8·00		Rhombohedron.
3. Sesquioxide of lead . . .			Right oblique prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
4. Sulphuret of lead	7·532—7·652	3	Cube.
5. Supersulphuret of lead	6·713	3	
6. Seleniet of lead	7·187	3	
7. Bitelluret of lead	7·087	1—1·5	Right square prism.
Section II.			
1. Carbonate of lead	6·1465—6·48	3·25	Right rhombic prism.
2. Sulphate of lead	6·259—6·298	2·75	Right rhombic prism.
3. Chromate of lead	6	2·75	Oblique rhombic prism.
4. Melanochroite	5·75		Rhombic prism.
5. Tungstate of lead	8	3	Octahedron with square base.
6. Molybdate of lead	5·706—676	2·75	Octahedron with square base.
7. Trismolybdate of lead	6		
8. Chloride of lead	1·897	2	Acicular crystals.
9. Dichloride of lead	7·0—7·1	2·5—3	Oblique prism.
Section III.			
1. Oxydo-chloride of lead			
2. Cupreo-sulphate of lead	5·3	3	Right oblique prism.
3. Sulphato-carbonate of lead	6·8—7	2—2·5	Doubly oblique four-sided prism.
4. Sulphato-tricarbonate of lead	6·3—6·5	2·5	Acute rhombohedron.
5. Chloro-carbonate of lead	6·056	2·75	Rectangular square prism.
6. Phosphate of lead	6·5781—6·915	2·75	Regular six-sided prism.
7. Vanadiate of lead	6·663	2·75	Regular six-sided prism.
8. Arseniate of lead	6·41	2·75	Regular six-sided prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
9. Cupro-chromate of lead . . .			Rhombohedron.
10. Sex-aluminate of lead . . .		4·5	
Section IV.			
1. Cupreous sulphato-carbonate of lead	6·4	2·5—3	Right rhombic prism.
2. Hediphan		3·5	
Section V.			
1. Zinkinite	5·303	3—3·5	Six-sided prism.
2. Plagionite	5·4	2·5	Octahedron.
3. Jamesonite	5·564	2—2·5	Oblique four-sided prism.
4. Feather ore of lead . . .			
5. Nagyag tellurium ore . . .	6·84		
GENUS XXI.—TIN.			
1. Peroxide of tin	6·55—6·945	6·5	Octahedron with square base.
2. Cupreous sulphuret of tin .	4·35	3·25	Cube.
GENUS XXII.—BISMUTH.			
Section I.			
1. Native bismuth	9·737	3·25	Regular octahedron.
2. Sulphuret of bismuth . .	6·549	2·75	Rhombic prism.
3. Ferruginous arseniate of bismuth .	3·694	5·5	
4. Arsenic glance . .			

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
5. Telluret of bismuth . . .			
6. Oxide of bismuth	4·3611		
Section II.			
1. Carbonate of bismuth . . .			
2. Silicate of bismuth . . .	5·912—6·006	5·5—6	Rhomboidal dodecahedron.
Section III.			
1. Needle ore of bismuth . . .	6·125	5·25	—
GENUS XXIII.—COPPER.			
Section I.			
1. Native copper	8·5844	2·75	Cube.
2. Red oxide of copper . . .	5·992	3·5	Regular octahedron.
3. Black oxide of copper . . .			
4. Disulphuret of copper . . .	5·7022	2·75	Acute rhombohedron.
5. Seleniet of copper			
6. Arseniet of copper . . .	4·5		
Section II.			
1. Anhydrous dicarbonate of copper .	2·62	4·25	
2. Hydrous dicarbonate of copper .	4·008	4	Oblique rhombic prism.
3. Sulphate of copper . . .	2·213	2·25	Doubly oblique prism.
4. Brochantite			

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
5. Tetrasulphate of copper . .			
6. Hydrous diphosphate of copper .	3·6—3·8	4	Right rhombic prism.
7. Pelokonite	2·567	3	
8. Hydrous sub-bisesquiphosphate of copper	4·2	4·75	Oblique rhombic prism.
9. Hydrous sesquisilicate of copper .	5·278	5	Obtuse rhombohedron.
10. Bisilicate of copper . . .	2·159		
11. Hydrous subsesquiarseniate of copper	4·043	4·75	Rectangular four-sided prism.
12. Diarseniate of copper . . .	3·389	3·75	Four-sided prism.
13. Prismatic oliven ore . . .	4·2809	3	Right rhombic prism.
14. Acicular oliven ore . . .	4·192	2·75	Rhombic prism.
15. Copper mica	2·5488	2	Acute rhombohedron.
16. Octahedral arseniate of copper .	2·882—2·926	2·25	Octahedron with rectangular base
17. Copper schaum	3·098	1·25	Octahedron.
Section III.			
1. Hydro-carbonate of copper . .	3·831	4·25	Oblique rhombic prism.
2. Silico-carbonate of copper . .	2·238	3	
Section IV.			
1. Hex-muriate of copper . . .	4·43	2·5	Right rhombic prism.
Section V.			
1. Variegated copper ore . . .	5·003	2·5	Regular octahedron.
2. Copper pyrites	4·159—4·16	2·75	Octahedron with square base.
3. Bournonite	5·766	2·75	Right rectangular prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
4. Grey copper ore	4·798—5·104	2·75	Tetrahedron.
5. Tennantite	4·375	3	Regular octahedron or tetrahedron.
Section VI.			
1. Eukairite			
GENUS XXIV.—MERCURY.			
1. Native mercury	13·568		
2. Native amalgam	13·755	3·25	Rhombic dodecahedron.
3. Sulphuret of mercury	8·098	1—4·25	Acute rhombohedron.
4. Dichloride of mercury	6·482	1·5	Right square prism.
5. Chloride of mercury			
GENUS XXV.—SILVER.			
1. Native silver	10·338	4·25	Cube.
2. Antimoniet of silver	9·4406	3·5	Six-sided prism.
3. Arseniet of silver			
4. Bitelluret of silver	8·412—8·565	2·25	
5. Flexible sulphuret of silver			Right oblique-angled prism.
6. Sulphuret of silver	7·196	2·75	Cube.
7. Sternbergite	4·215	1—1·5	Right oblique prism.
8. Seleniet of silver	8	2·5	Cube.
9. Chloride of silver	5·552	3·5	Cube.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
10. Iodide of silver			
Section II.			
1. Carbonate of silver . . .			
Section III.			
1. Sulpho-cuprate of silver . .	6·255		
2. Brittle silver glance . . .	6·269	2·25	Six-sided prism.
3. Dark red silver ore . . .	5·8—5·9	2·25	Obtuse rhombohedron.
4. Miargirite	5·234	2—2·5	Four-sided prism.
5. Light red silver ore . . .	5·552	2·25	Four-sided prism.
6. Polybasite	6·214	2·5	Regular six-sided prism.
GENUS XXVI.—URANIUM.			
1. Pitch ore of uranium . . .	6·468	3·5	
2. Sulphated protoxide of uranium .			
3. Sulphated peroxide of uranium .			
4. Uranite	3·12	2·25	Right square prism.
5. Chalcolite			
GENUS XXVII.—PALLADIUM.			
1. Native palladium	11·8—12·14		
2. Seleniet of palladium . . .			Six-sided prism.

Names.	Specific Gravity.	Hardness.	Primary Crystalline Form.
CLASS III.			
NEUTRAL BASES.			
GENUS I.—GOLD.			
1. Native gold	12·666—19·099	3·25	Cube.
2. White ore of tellurium . . .	10·678		Right rhombic prism.
3. Graphic ore of tellurium . .	5·723	1·5—2	Right rhombic prism.
GENUS II.—PLATINUM.			
1. Native platinum	17·332	2·75	
GENUS III.—IRIDIUM.			
1. Native iridium	19·5	2·75—3	Regular six-sided prism.

TABLE

Exhibiting the Specific Gravity of Minerals.

Specific Gravity.	Names.
0·65	Scheererite.
0·9053—1·233	Elastic bitumen.
0·983	Mineral tallow.
1·46	Highgate resin.
1·073—1·208	Asphalt.
1·081	Amber.
1·135	Retinasphaltum.
1·265	Cherry coal.
1·269	Caking coal.
1·272	Cannel coal.
1·29	Splint coal.
1·334	Mountain leather.
1·349	Hydrous sulphate of soda.
1·4—1·75	Anthracite.
1·439	Boracic acid.
1·48	Scarbroite.
1·528	Sal ammoniac.
1·55—1·597	Mellate of alumina.
1·56	Ammonia-alum.
1·623	Carbonate of soda.
1·666	Sulphate of alumina.
1·7054	Aluminite.
1·708	Scorilite.
1·727—2·105	Chloropal.
1·740	Borax.
1·751	Sulphate of magnesia.
1·753	Potash-alum.
1·787	Mullicite.
1·8—2·1	Lenzinite.
1·852—1·889	Allophane.
1·88	Soda-alum.
1·897	Chloride of lead.
1·9	Hydroboracite.
1·928—1·99	Gaylussite.
1·933	Nitrate of potash.
1·953	Lehuntite.
1·98	Sesquicarbonate of soda.
2	Sulphate of ammonia.
2	Rhodalite.
2·015—2·21	Opal.
2·033—2·071	Sulphur.
2·036	Sulphate of zinc.
2·04	Erinite.
2·054	Hydrolite.

Specific Gravity.	Names.
2·069	Nitrate of soda.
2·088	Chabasite.
2·091	Gibbsite.
2·0964	Antrimolite.
2·125—2·333	Mesolite.
2·127	Hydrous tersilicate of magnesia.
2·133—2·161	Stilbite.
2·139—2·2303	Natrolite.
2·159	Bisilicate of copper.
2·161	Levyine.
2·166	Cluthalite.
2·181	Glottalite.
2·19	Pyrorthite.
2·195—2·2	Heulandite.
2·2	Cobalt ochre.
2·2055	Tersilicate of lime.
2·213	Sulphate of copper.
2·214—2·27	Scolezite.
2·217	Harringtonite.
2·22	Huraulite.
2·238	Silico-carbonate of copper.
2·25—2·32	Plumbago.
2·252	Chalilite.
2·253—2·337	Wavellite.
2·257	Common salt.
2·278	Analcime.
2·29—2·36966	Thomsonite.
2·295—2·378	Sodalite.
2·3	Lomonite.
2·31	Hydrate of magnesia.
2·31—2·3257	Hydrous sulphate of lime.
2·335—2·359	Apophyllite.
2·338—2·3604	Pitchstone.
2·342	Plinthite.
2·342	Pearlstone.
2·353	Nemalite.
2·362	Dysclasite.
2·363—2·372	Obsidian.
2·3629	Davidsonite.
2·385	Ittnerite.
2·394—2·581	Felspar.
2·396—2·411	Soapstone.
2·4	Harmotome.
2·4	Sulpharseniate of iron.
2·42—2·48	Petalite.
2·427	Comptonite.
2·432	Brewsterite.
2·4365	Icespar.
2·442	Mountain cork.
2·4448	Fuller's earth.

Specific Gravity.	Names.
2·448	Morvenite.
2·457	Lithomarge.
2·476	Neurolite.
2·484	Kaolin.
2·489	Oxalate of iron.
2·49	Leucite.
2·493	Retinalite.
2·5091	Murchisonite.
2·525	Kilpatrick quartz.
2·528	Vermiculite.
2·536—2·730	Bisesquihydrous arseniate of lime.
2·546—2·618	Elœolite.
2·5488	Copper mica.
2·558—2·594	Tersilicate of magnesia.
2·558	Tuesite.
2·567	Pelokonite.
2·575—2·594	Flint.
2·57—2·582	Glassy felspar.
2·58	Sordawalite.
2·58—2·732	Emerald.
2·585—2·644	Basanite.
2·595	Precious serpentine.
2·596	Picrosmine.
2·5969—2·6643	Iolite.
2·598—2·632	Glauconite.
2·6	Calcedony.
2·6	Jasper.
2·606—2·608	Pipestone.
2·606	Leelite.
2·608—2·619	Albite.
2·612—2·749	Meconite or scapolite.
2·612	Stellite.
2·62—2·79	Fahlunite.
2·62	Anhydrous dicarbonate of copper.
2·632	Anhydrous fahlunite.
2·6413—2·69	Quartz.
2·648	Gilbertite.
2·652	Schiller spar.
2·656—2·762	Anorthite.
2·661	Vivianite.
2·688	Quatersilicate of alumina.
2·69	Cauzeranite.
2·69	Pectolite.
2·691—2·75	Labradorite.
2·696—3·25	Turquoise.
2·697	Talc.
2·711	Killinite.
2·72—2·9	Glaucolite.
2·721	Calcareous spar.
2·73	Anhydrous sulphate of soda.

Specific Gravity.	Names.
2·73—2·807	Glauberite.
2·748—2·758	Nutallite.
2·7517	Alumstone.
2·7575—2·782	Pinite.
2·76	Hopeite.
2·772	Hexagonal talc.
2·785—2·895	Bisilicate of lime.
2·788—2·793	Nacrite.
2·8	Latrobite.
2·801	Bytownite.
2·801	Saussurite.
2·808	Weissite.
2·808—2·95	Carbonate of magnesia.
2·815—2·884	Calcareo-carbonate of magnesia.
2·823	Chlorite.
2·824—3·08	Mica.
2·832	Gieseckite.
2·848	Sesquihydrous arseniate of lime.
2·85	Raphilite.
2·85—2·876	Wollastonite.
2·855	Hydrous bucholzite.
2·8628	Huronite.
2·87	Potash-bisilicate of magnesia.
2·875	Hyalosiderite.
2·8787	Siliceous sulphate of lime.
2·882—2·926	Octahedral arseniate of copper.
2·885	Botryolite.
2·889	Phyllite.
2·895	Agalmatolite.
2·899—2·957	Anhydrous sulphate of lime.
2·9—2·953	Prehnite.
2·9036	Eudyalite.
2·9076—3·098	Euclase.
2·911	Hydrous anthophyllite.
2·9166—3·029	Gehlenite.
2·923—2·9365	Karpholite.
2·94—3·1558	Anthophyllite.
2·941	Kirwanite.
2·9467	Arragonite.
2·948	Diarseniate of cobalt.
2·949	Cryolite.
2·957—3·2	Amphibole.
2·969	Phenakite.
2·974	Biborate of magnesia.
2·98—3·3463	Borosilicate of lime.
3	Gabronite.
3	Crichtonite.
3	Subsesquiarseniate of iron.
3	Hydrous disilicate of iron.
3—3·04	Ambligonite.

Specific Gravity.	Names.
3—3·4	Chamoisite.
3—3·1	Erlanite.
3·014—3·034	Ferruginous silicate of manganese.
3·001—3·112	Ferro-carbonate of magnesia.
3·024	Blue spar.
3·051	Zeuxite.
3·057	Lazulite.
3·076	Tourmalin.
3·080	Ankerite.
3·081	Pyrosmalite.
3·098	Copper schaum.
3·0943—3·191	Fluor spar.
3·0989—3·235	Subsesquiphosphate of lime.
3·1—3·89	Carbo-silicate of manganese.
3·104	Humboldilite.
3·118	Chondrodite.
3·12	Uranite.
3·12—3·25	Bustamite.
3·13	Magnesite.
3·137	Withamite.
3·154	Hedenbergite.
3·1636—3·41?	Sillimanite.
3·166	Helvine.
3·175—3·73	Melanite.
3·188	Spodumene.
3·193	Bucholzite.
3·2	Norwegian tremolite.
3·2	Krokidolite.
3·2014	Commingtonite.
3·214	Fibrolite.
3·221	Xanthite.
3·2307—3·297	White augite.
3·231	Polylite.
3·233—3·349	Pyroxene.
3·2378—3·510	Sphene.
3·27	Nepheline.
3·271	Axinite.
3·288	Orthite.
3·31245	Anhydrous sesquibinoxide of manganese.
3·314	Andaluzite.
3·32—3·32707	Zoisite.
3·338—3·385	Hypersthene.
3·349—3·599	Idocrase.
3·369	Arfvedsonite.
3·379—3·434	Hydrous silicate of zinc.
3·372—3·64	Grossularite.
3·389	Diarseniate of copper.
3·398	Achmite.
3·4	Worthite.
3·4—3·48	Sesquisulphide of arsenic.

Specific Gravity.	Names.
3·404	Hydrous carbonate of iron.
3·425—3·46	Epidote.
3·4282	Sapphirine.
3·4324	Diaspore.
3·439—3·562	Manganeso-diphosphate of iron.
3·44	Chrysolite.
3·447	Yttrocerite.
3·49	Ligurite.
3·449—3·641	Topaz.
3·503—3·53	Pycnite.
3·508—3·754	Chrysoberyl.
3·51—3·55	Jeffersonite.
3·523	Spinell.
3·524	Hetopizite.
3·5295	Diamond.
3·575	Ceylanite.
3·579	Crucite.
3·584—3·598	Hydrous carbonate of zinc.
3·586	Sesquisilicate of manganese.
3·592	Carbonate of manganese.
3·6—3·8	Hydrous diphosphate of copper.
3·617	Candite.
3·618—3·675	Cyanite.
3·631	Essonite.
3·642	Sulphide of arsenic.
3·651	Brown carbonate of strontian.
3·66	Calcareo-carbonate of barytes.
3·66	Voltzine.
3·693	Staurotide.
3·694	Ferruginous arseniet of bismuth.
3·703	Stromnite.
3·71	Carbono-phosphate of iron.
3·713	Green carbonate of strontian.
3·714	Knebelite.
3·718	Bicalcareo-carbonate of barytes.
3·729	Arsenious acid.
3·7317—3·829	Carbonate of iron.
3·75	Baryto-fluate of lime.
3·767	Polyadelphite.
3·78	Pyrope.
3·81	Calcareo-sulphate of strontian.
3·815	Junkerite.
3·824	Newkirkite.
3·825—4·061	Ilvaite.
3·826—3·857	Anatase.
3·829	Brown manganesian garnet.
3·831	Hydro-carbonate of copper.
3·868	Baryto-calcite.
3·871—3·965	Colophonite.
3·8846	Cronstedtite.

Specific Gravity.	Names.
3·921	Baryto-sulphate of strontian.
3·922—4·04	Hydrous peroxide of iron.
3·935	Anhydrous silicate of zinc.
3·95—4·014	Sulphuret of manganese.
3·9511	Sapphire.
3·9626	Sulphate of strontian.
4·001	Allanite.
4·008	Hydrous dicarbonate of copper.
4·043	Hydrous sub-bisesquiarseniate of copper.
4·049	Blende.
4·078	Silicate of manganese.
4·09—4·6	Red antimony.
4·141	Sulphato-carbonate of barytes.
4·145	Psilomelanite.
4·1493—4·1795	Gadolinite.
4·159—4·16	Copper pyrites.
4·18—4·249	Titanite.
4·1907	Calcareo-sulphate of barytes.
4·192	Acicular oliven ore.
4·2	Sub-bisesquiphosphate of copper.
4·206—4·216	Pyrochlore.
4·215	Sternbergite.
4·261	Automolite.
4·209	Prismatic oliven ore.
4·283—4·831	Varvacite.
4·2985	Carbonate of barytes.
4·312—4·328	Manganite.
4·321	Chromiron ore.
4·334—4·442	Anhydrous carbonate of zinc.
4·35	Cupreous sulphuret of tin.
4·3611	Oxide of bismuth.
4·375	Tennantite.
4·375	Dihydrous peroxide of iron.
4·427	Titaniate of iron.
4·43	Hexmuriate of copper.
4·445	Nigrin.
4·472	Sulphate of barytes.
4·488—4·789	Titaniferous iron ore.
4·491—4·65	Iserine.
4·5	Arseniet of copper.
4·516—4·62	Sesquioxide of antimony.
4·551	Dysluite.
4·5577	Phosphate of yttria.
4·569—4·7385	Bisulphide of molybdenum.
4·63	Thorite.
4·631	Magnetic pyrites.
4·678—4·847	Radiated pyrites.
4·681	Zircon.
4·7	Fluate of cerium.
4·722	Haussmanite.

Specific Gravity.	Names.
4·766—4·808	Ilmenite.
4·795—5·104	Grey copper ore.
4·806	Polymignite.
4·818	Braunite.
4·83	Bisulphuret of iron.
4·912	Cerite.
4·97	Pyrolusite.
5·003	Variegated copper ore.
5·069	Franklinite.
5·079	Manganesian iron ore.
5·092	Magnetic iron ore.
5·234	Miargerite.
5·251	Specular iron ore.
5·278	Hydrous sesquisilicate of copper.
5·3	Cupreous sulphate of lead.
5·3	Native titanium.
5·303	Zinkenite.
5·395	Black yttrotantalite.
5·4	Plagionite.
5·432	Red zinc.
5·55	Arseniet of manganese.
5·552	Chloride of silver.
5·552	Light red silver ore.
5·56	Seleniet of zinc.
5·564	Jamesonite.
5·566	Protoxide of antimony.
5·672	Native arsenic.
5·7—6·1	Native tellurium.
5·7022	Disulphuret of copper.
5·706—6·760 ?	Molybdate of lead.
5·723	Graphic ore of tellurium.
5·75	Melanochroite.
5·766	Bournonite.
5·8—5·838	Fergusonite.
5·8—5·9	Dark red silver ore.
5·882	Yellow yttrotantalite.
5·912—6·006	Silicate of bismuth.
5·95—6·72	Native iron.
5·959—6·076	Tungstate of lime.
5·992	Red oxide of copper.
6	Chromate of lead.
6	Trismolybdate of lead.
6—6·7	Terarseniet of cobalt.
6·056	Chloro-carbonate of lead.
6·097	Sulpho-antimonite of nickel.
6·125	Needle ore of bismuth.
6·127	Arsenical pyrites.
6·129	Sulpho-arsenite of nickel.
6·214	Polybasite.
6·255	Sulpho-cuprite of silver.

Specific Gravity.	Names.
6·259—6·298	Sulphate of lead.
6·269	Brittle silver glance.
6·298	Sulpho-arsenite of cobalt.
6·3—6·5	Sulphato-tricarbonate of lead.
6·4	Cupreous sulphato-carbonate of lead.
6·41	Arseniate of lead.
6·465—6·48	Carbonate of lead.
6·466	Binarseniate of cobalt.
6·468	Pitch ore of uranium.
6·482	Dichloride of mercury.
6·549	Sulphuret of bismuth.
6·55—6·945	Peroxide of tin.
6·5781—6·915	Phosphate of lead.
6·663	Vanadiate of lead.
6·713	Supersulphuret of lead.
6·72	Native antimony.
6·8—7	Sulphato-carbonate of lead.
6·84	Nagyag tellurium ore.
7·0—7·1	Dichloride of lead.
7·087	Bitelluret of lead.
7·155	Wolfram.
7·187	Seleniet of lead.
7·196	Sulphuret of silver.
7·228	Sesquiarseniate of iron.
7·2366—7·903	Columbite.
7·3	Meteoric iron.
7·532—7·652	Sulphuret of lead.
7·655	Arseniet of nickel.
9·446	Antimoniet of silver.
9·737	Native bismuth.
10·338	Native silver.
10·678	White ore of tellurium.
11·8—12·14	Native palladium.
12·666—19·099	Native gold.
13·568	Native mercury.
13·755	Native amalgam.
17·332	Native platinum.
19·5	Native iridium.

TABLE

Of the Hardness of Minerals, arranged according to the degree of hardness.

		Hardness.
1.	Plumbago	1
2.	Hydrate of magnesia	1
3.	Venetian talc	1
4.	Fuller's earth	1
5.	Vermiculite	1
6.	Mullicite	1
7.	Red antimony	1—1·5
8.	Bisulphide of molybdenum	1—1·5
9.	Bitelluret of lead	1—1·5
10.	Sternbergite	1—1·5
11.	Sulphuret of mercury	1—4·25
12.	Copper schaum	1·25
13.	Sulphide of arsenic	1·5
14.	Sesquisulphide of arsenic	1·5
15.	Pipestone	1·5
16.	Chlorite	1·5
17.	Dichloride of mercury	1·5
18.	Sal ammoniac	1·5—2
19.	Vivianite	1·5—2
20.	Diarseniate of cobalt	1·5—2
21.	Graphic ore of tellurium	1·5—2
22.	Erinite	1·75
23.	Hexagonal talc	1·75
24.	Nontronite	1·75
25.	Anthracite	2
26.	Asphalt	2
27.	Common salt	2
28.	Sesquisulphide of antimony	2
29.	Hydrous sulphate of lime	2
30.	Xanthite	2
31.	Hydroboracite	2
32.	Nemalite	2
33.	Hydrous tersilicate of magnesia	2
34.	Aluminite	2
35.	Agalmatolite	2
36.	Kirwanite	2
37.	Scorilite	2
38.	Copper mica	2
39.	Sulphate of magnesia	2—2·25
40.	Amber	2—2·5
41.	Native tellurium	2—2·5
42.	Sesquihydrous arseniate of lime	2—2·5

		Hardness.
43.	Pyrolusite	2—2·5
44.	Hydrous dicarbonate of zinc	2—2·5
45.	Sulphate of zinc	2—2·5
46.	Sulphato-carbonate of lead	2—2·5
47.	Jamesonite	2—2·5
48.	Margerite	2—2·5
49.	Cryolite	2·25
50.	Pinite	2·25
51.	Sulphate of copper	2·25
52.	Octahedral arseniate of copper	2·25
53.	Bitelluret of silver	2·25
54.	Brittle silver glance	2·25
55.	Dark red silver ore	2·25
56.	Light red silver ore	2·25
57.	Calcareo phosphate of uranium	2·25
58.	Highgate resin	2·5
59.	Native sulphur	2·5
60.	Wollastonite	2·5
61.	Bisesquihydrous arseniate of lime	2·5
62.	Hydrous anthophyllite	2·5
63.	Tuesite	2·5
64.	Nepheline	2·5
65.	Karpholite	2·5
66.	Mica	2·5
67.	Subsesquiarseniate of iron	2·5
68.	Hydrous disilicate of iron	2·5
69.	Hydrous silicate of iron	2·5
70.	Varvasite	2·5
71.	Ferruginous silicate of manganese	2·5
72.	Hopeite	2·5
73.	Sulphato tricarbonate of lead	2·5
74.	Plagionite	2·5
75.	Muriate of copper	2·5
76.	Variegated copper ore	5·5
77.	Seleniet of silver	2·5
78.	Polybasite	2·5
79.	Native antimony	2·5—3
80.	Protoxide of antimony	2·5—3
81.	Glauberite	2·5—3
82.	Picrosmine	2·5—3
83.	Cupreous sulphato carbonate of lead	2·5—3
84.	Calcareo sulphate of barytes	2·75
85.	Baryto sulphate of strontian	2·75
86.	Calcareo sulphate of strontian	2·75
87.	Siliceous sulphate of lime	2·75
88.	Gibbsite	2·75
89.	Mellate of alumina	2·75
90.	Gilbertite	2·75
91.	Nacrite	2·75
92.	Potash alum	2·75

		Hardness.
93.	Plinthite	2·75
94.	Pyrorthite	2·75
95.	Commingtonite	2·75
96.	Sulphate of lead	2·75
97.	Chromate of lead	2·75
98.	Molybdate of lead	2·75
99.	Chloro-carbonate of lead	2·75
100.	Phosphate of lead	2·75
101.	Vanadiate of lead	2·75
102.	Arseniate of lead	2·75
103.	Sulphuret of bismuth	2·75
104.	Native copper	2·75
105.	Disulphuret of copper	2·75
106.	Acicular oliven ore	2·75
107.	Copper pyrites	2·75
108.	Bournonite	2·75
109.	Grey copper ore	2·75
110.	Sulphuret of silver	2·75
111.	Native platinum	2·75
112.	Native iridium	2·75—3
113.	Anhydrous sulphate of lime	2·75—3·25
114.	Calcareous spar	3
115.	Hydrous bucholzite	3
116.	Allophane	3
117.	Quatersilicate of alumina	3
118.	Soda alum	3
119.	Sulphuret of lead	3
120.	Supersulphuret of lead	3
121.	Seleniet of lead	3
122.	Tungstate of lead	3
123.	Cupreous sulphate of lead	3
124.	Pelokonite	3
125.	Prismatic oliven ore	3
126.	Silico-carbonate of copper	3
127.	Tennantite	3
128.	Sulphate of barytes	3—3·5
129.	Brown carbonate of strontian	3—3·5
130.	Sulphate of strontian	3—3·5
131.	Newkirkite	3—3·5
132.	Zinckinite	3—3·5
133.	Bisilicate of lime	3—4
134.	Carbonate of iron	3—4·5
135.	Polyadelphite	3·25
136.	Bihydrate of alumina	3·25
137.	Wavellite	3·25
138.	Stellite	3·25
139.	Huronite	3·25
140.	Hydrous carbonate of iron	3·25
141.	Carbonate of lead	3·25
142.	Cupreous sulphuret of tin	3·25
143.	Native bismuth	3·25

		Hardness.
144.	Native amalgam	3·25
145.	Native gold	3·25
146.	Arseniet of antimony	3·5
147.	Green carbonate of strontian	3·5
148.	Stromnite	3·5
149.	Tersilicate of lime	3·5
150.	Hedenbergite	3·5
151.	Nephrite	3·5
152.	Precious serpentine	3·5
153.	Alumstone	3·5
154.	Bonsdorfite	3·5
155.	Glottalite	3·5
156.	Killinite	3·5
157.	Lomonite	3·5
158.	Cluthalite	3·5
159.	Stilbite	3·5
160.	Heulandite	3·5
161.	Gieseckite	3·5
162.	Chloropal	3·5
163.	Carbonate of manganese	3·5
164.	Hedyphan	3·5
165.	Red oxide of copper	3·5
166.	Antimoniet of silver	3·5
167.	Chloride of silver	3·5
168.	Pitch ore of uranium	3·5
169.	Ferro-carbonate of lime	3·5—4
170.	Tersilicate of magnesia	3·5—4
171.	Calcareo-carbonate of magnesia	3·5—4
172.	Scorodite	3·5—4
173.	Sulphuret of manganese	3·5—4
174.	Carbonate of barytes	3·75
175.	Arragonite	3·75
176.	Raphilite	3·75
177.	Schiller spar	3·75
178.	Retinalite	3·75
179.	Hydrous iolite	3·75
180.	Antrimolite	3·75
181.	Chabasite	3·75
182.	Lehuntite	3·75
183.	Blende	3·75
184.	Diarseniate of copper	3·75
185.	Sulphate of barytes and lime	4
186.	Fluor spar	4
187.	Baryto-carbonate of lime	4
188.	Botryolite	4
189.	Levyine	4
190.	Hydrolite	4
191.	Fluate of cerium	4
192.	Anhydrous silicate of iron	4
193.	Achmite	4
194.	Krokidolite	4

		Hardness.
195.	Red zinc	4
196.	Hydrous diphospate of copper	4
197.	Hydrous dicarbonate of copper	4
198.	Manganite	4—4·25
199.	Ferro-carbonate of magnesia	4—4·5
200.	Dysclasite	4·25
201.	Biborate of magnesia	4·25
202.	Andalusite	4·25
203.	Meionite	4·25
204.	Zeuxite	4·25
205.	Brewsterite	4·25
206.	Harmotome	4·25
207.	Neurolite	4·25
208.	Phosphate of yttria	4·25
209.	Crichtonite	4·25
210.	Hydrous sesquibinoxide of manganese	4·25
211.	Anhydrous dicarbonate of copper	4·25
212.	Hydro-carbonate of copper	4·25
213.	Native silver	4·25
214.	Borosilicate of lime	4·25
215.	Carbonate of magnesia	4·5
216.	Chondrodite	4·5
217.	Jeffersonite	4·5
218.	Dysluite	4·5
219.	Natrolite	4·5
220.	Chalilite	4·5
221.	Native iron	4·5
222.	Dihydrous peroxide of iron	4·5
223.	Arfvedsonite	4·5
224.	Pyrosmalite	4·5
225.	Voltzine	4·5
226.	Sexaluminate of lead	4.5
227.	Hydrous peroxide of iron	4·5—5
228.	Hausmannite	4·5—5
229.	White augite	4·75
230.	Pyroxene	4·75
231.	Amphibole	4·75
232.	Hypersthene	4·75
233.	Thomsonite	4·75
234.	Arsenical pyrites	4·75
235.	Hydrous subbisesquiphosphate of copper	4·75
236.	Hydrous subbisesquiarseniate of copper	4·75
237.	Ilvaite	4·75—5
238.	Native arsenic	5
239.	Subsesquiphosphate of lime	5
240.	Ligurite	5
241.	Prehnite	5
242.	Subsesquifluate of cerium	5
243.	Yttro cerite	5
244.	Pyrochlore	5
245.	Wolfram	5

	Hardness
246. Sulpho-arsenide of nickel	5
247. Anhydrous carbonate of zinc	5
248. Anhydrous silicate of zinc	5
249. Hydrous silicate of zinc	5
250. Hydrous sesquisilicate of copper	5
251. Harringtonite	5·25
252. Columbite	5·25
253. Needle ore of bismuth	5·25
254. Sphene	5—5·5
255. Wagnerite	5—5·5
256. Anthophyllite	5—5·5
257. Lazulite	5—5·5
258. Sesquiarseniate of iron	5—5·5
259. Manganeso diphosphate of iron	5—5·5
260. Titaniferous iron ore	5—5·5
261. Hyalosiderite	5·5
262. Black yttrotantalite,	5·5
263. Cerite	5·5
264. Chrome iron ore	5·5
265. Arseniet of nickel	5·5
266. Sulpho-antimonide of nickel	5·5
267. Sesquiarseniet of cobalt	5·5
268. Binarseniet of cobalt	5·5
269. Sulpho-arsenide of cobalt	5·5
270. Ferruginous arseniet of bismuth	5·5
271. Sodalite	5·75
272. Phyllite	5·75
273. Fergusonite	5·75
274. Ilmenite	5·75
275. Magnetic pyrites	5—6
276. Psilomelanite	5—6
277. Protoxide of titanium	5·5—6
278. Silicate of bismuth	5·5—6
279. Magnetic iron ore	5·5—6·5
280. Specular iron ore	5·5—6·5
281. Norwegian tremolite	6
282. Bucholzite	6
283. Cyanite	6
284. Amblygonite	6
285. Idocrase	6
286. Anhydrous scolezite	6
287. Murchisonite	6
288. Felspar	6
289. Glassy felspar	6
290. Albite	6
291. Anorthite	6
292. Labradorite	6
293. Elœolite	6
294. Epidote	6
295. Bytownite	6
296. Withamite	6

	Hardness.
297. Pearlstone	6
298. Allanite	6
299. Sillimanite	6
300. Eudyalite	6
301. Radiated pyrites	6
302. Franklinite	6—6·5
303. Brownite	6—6·5
304. Zoisite	6·25
305. Leelite	6·25
306. Analcime	6·25
307. Apophyllite	6·25
308. Polylite	6·25
309. Silicate of manganese	6·25
310. Sesquisilicate of manganese	6·25
311. Tungstate of lime	6·5
312. Davidsonite	6·5
313. Essonite	6·5
314. Gehlenite	6·5
315. Spodumene	6·5
316. Petalite	6·5
317. Pitchstone	6·5
318. Obsidian	6·5
319. Zircon	6·5
320. Bisulphuret of iron	6·5
321. Bustamite	6·5
322. Helvine	6·5
323. Peroxide of tin	6·5
324. Opal	6·75
325. Colophonite	6·75
326. Turquoise	6·75
327. Grossularite	6·75
328. Melanite	6·75
329. Brown manganese garnet	6·75
330. Staurotide	6·75
331. Erlanite	6·25—7
332. Titanic acid	6·5—7
333. Quartz	7
334. Kilpatrick quartz	7
335. Chalcedony	7
336. Basanite	7
337. Iolite	7
338. Leucite	7
339. Ittnerite	7
340. Axinite	7
341. Nutallite	7
342. Saussurite	7
343. Orthite	7
344. Polymignite	7?
345. Manganesian iron ore	7
346. Bisilicate of manganese	7
347. Flint	7—7·25

	Hardness.
348. Sesquisilicate of lime	7—7·5
349. Automalite	7·25
350. Worthite	7·25
351. Fibrolite	7·25
352. Phenakite	7·25
353. Native titanium	7·5
354. Pycnite	7·5
355. Pyrope	7·5
356. Euclase	7·5
357. Sapphirine	7·75
358. Emerald	7·5—8
359. Spinell	8
360. Candite	8
361. Topaz	8
362. Tourmaline	8
363. Gadolinite	8
364. Chrysoberyl	8·5
365 Sapphire	9
366. Diamond	10

ERRATA.

Page 24, line 5 from bottom, for " Arsenious acid $\dot{\mathrm{A}}\mathrm{s}$" read " Arsenious acid $\bar{\mathrm{A}}\mathrm{s}$."

Page 24, line 4 from bottom, for "Arsenic acid $\bar{\mathrm{A}}\mathrm{s}$" read " Arsenic acid $\dot{\mathrm{A}}\mathrm{s}$."

The dot in the table of symbols denotes the acid containing the most oxygen, while the line ($\bar{\mathrm{A}}\mathrm{s}$) denotes the acid containing least oxygen united to the same base.

Page 27, line 15, for " $\mathrm{Cal}\dot{\mathrm{S}}+1\frac{1}{2}\mathrm{Br}\dot{\mathrm{S}}$" read " $4\frac{1}{2}\mathrm{Cal}\dot{\mathrm{S}}+\mathrm{Br}\dot{\mathrm{S}}$."

Page 28, line 11 from bottom, for " Hemolite" read " Nemalite."

Page 30, line 2 from bottom, for " Trollite" read " Weissite."

Page 40, line 9, for " Nagyag of tellurium ore" read " Nagyag tellurium ore."

Page 125, bottom line, for " 13·21" read " 3·211."

Page 210, delete the lines 9, 10, 11.

Page 333, line 7, for " Box d'Antic" read " Bosc d'Antic."

Page 452, bottom line, for " Fouveroy" read " Fourcroy."

Page 483, line 4 from bottom, for " chromium ore" read " chromiron ore."

END OF VOLUME FIRST.

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Cat.

OUTLINES

J C Branner

OF

MINERALOGY, GEOLOGY,

AND

MINERAL ANALYSIS.

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CONTENTS.

VOL. II.

PART II.

OF GEOLOGY.

INTRODUCTION.

The *Earth* is one of eleven bodies called planets, which revolve round the sun. Its mean distance from that luminary is 93,595,000 English miles; its mean diameter is 7,912 miles; and its mean circumference 24,856 miles. It completes its diurnal revolution in 24 hours; and its annual revolution in 365 days, 5 hours, 48 minutes, and 51 seconds. One satellite or attendant body, the *Moon*, 2,180 miles in diameter, revolves round the earth in 29 days, 12 hours, and 44 minutes, at a mean distance of 475,000 English miles. The moon, like the earth, exhibits a surface of mountains and valleys. But it can have no atmosphere, or at least the density of its atmosphere can only be $\frac{1}{3000}$th of that of the earth; so that it can only support a column of mercury 0·006 inch in height, which is considerably beyond the highest vacuum that can be produced in our best constructed air pumps.

The earth is not a perfect sphere but an oblate spheroid, or sphere flattened at the poles. The amount of the compression is such, that the *equatorial* diameter exceeds the *polar* diameter or *axis* by about 25 miles; or the one is to the other very nearly as 312 to 311.

The centrifugal force arising from the revolution of the earth round its axis, which obviously tends to dilate the equatorial parts, led Newton to infer the oblate or compressed figure of the earth, before it had been ascertained by actual measurement. He calculated the ellipticity from theory at

$\frac{1}{230}$th of the axis, which is almost $\frac{1}{3}$d greater than the truth. A homogeneous fluid body of the mean density of the earth, and making its diurnal revolution in the same time, would in fact have the proportions which Newton supposed, and the ellipticity in that case would be a *maximum*.

But if the earth, instead of being homogeneous, increase in density as we approach the centre, the compression in that case is not so great. Mathematicians have shown, that if the density were to increase so as to be infinitely great at the centre, the ellipticity in that case would be a *minimum*, and would amount only to $\frac{1}{578}$.

From the observations made at Schechallian by Dr. Maskelyne, it has been shown by Dr. Hutton, that the mean specific gravity of the earth is not under 4·75. Now, the mean density of the external surface of the earth (to which alone we have access) is not so high as 2·75; so that the mean density is nearly twice as great as that of the surface. Hence it is obvious that the specific gravity must increase as we advance from the surface towards the centre. If we suppose the specific gravity of the centre about 12, and that the specific gravity increases nearly regularly from the surface to the centre, we would obtain a mean specific gravity nearly equal to that of the earth. If this supposition be well founded, the figure of the earth is a spheroid of equilibrium. The ellipticity of such a spheroid would be intermediate between that of a homogeneous globe and that of a globe having an infinitely high specific gravity in the centre. Now, as this accords with fact, we are entitled to infer that the earth approaches very nearly to a spheroid of equilibrium, if it does not, as is more probable, coincide with it entirely.

It is evident, that whatever causes gave this oblate figure to the globe, have acted upon the *solid* as well as the fluid *parts*. The land, in a general point of view, is as much elevated at the equator as towards the poles. But, since the equatorial regions are 12 miles farther from the centre than the parts at the pole, it is obvious, that if the solid nucleus of the globe were a true sphere, the sea would be accumulated by the centrifugal force in the equatorial regions, which would have been completely submerged while the polar regions would have been left dry and elevated many miles above the level of the waters. The ocean would have formed a broad and deep zone round the equator, separating the two *continents encircling* the poles.

The figure of the earth shows that the whole globe was originally fluid. At the time of its consolidation, it must have had the same axis that it has at present. Hence those geologists, who, about the middle of the 18th century, accounted for the fossil remains of animals and plants belonging to the torrid zone in Siberia and other frozen regions of the globe, by supposing that the axis of the earth may have changed its position, have started an hypothesis inconsistent with the mathematical constitution of the globe, and therefore erroneous.

Laplace was of opinion, that the precession of the equinoxes and the nutation of the earth's axis, indicate a gradual increase of specific gravity from the surface to the centre. This is the way that the materials would have arranged themselves, on the supposition of their having existed in a state of liquidity. The heaviest would occupy the centre, and the rest would arrange themselves in the order of their specific gravity. Now, the only bodies known to us as possessing a specific gravity equal to 12, or that of the central nucleus, are certain metallic bodies. Does this circumstance warrant the conjecture that the central parts of the earth are composed of metallic bodies, and give probability to the opinion of Becher, that the veins of metallic ores found near the surface, are minute offsets from these central proportions?

CHAP. I.

OF THE TEMPERATURE OF THE EARTH.

THE mean temperature of the air, overland, nearly on a level with the sea at the equator, is reckoned by Humboldt 81°·5.[*] The mean temperature of latitude 45° in Europe is 56°. At the pole, judging from the observations of Parry, the mean temperature cannot exceed —13°.[†]

The mean temperatures of places in Western Europe, differ very considerably from those on the Eastern side of America and of Asia. This will appear evident by inspecting the following table :—

---

[*] It would appear that the temperature of places in the torrid zone, differs a little according to situation. The following table of Boussingault, drawn up partly from his own observations and partly from those of Humboldt and Captain Hall, shows this :—

Ports.	Latitude.	Mean Temperature.
Cumana, .	10° 27′ N.	81°·5
La Guayra, .	10 37	81 ·5
Rio Hacha, .	11 40	82 ·58
Sta Marta, .	11 15	83 ·48
Barranquilla, .	11 0	82 ·22
Carthagena, .	10 25	81 ·5
Panama, .	8 58	80 ·96
Tumaco, .	1 40	78 ·98
Esmeraldas, .	0 55	79 ·52
Guayaquil, .	2 11 S.	78 ·80
Payta, . .	5 5 S.	80 ·78

See Ann. de Chim. et de Phys. liii. 235.

Boussingault found, that in the torrid zone, the earth, a foot below the surface, possessed the mean temperature of the year.

[†] The following mean temperatures have been deduced from the observations of Parry and Franklin :—

	Latitude.	Mean Temperature.	
Melville Island, .	74°¾	—1°½	Parry.
Port Bowen, . .	73 ¼	+4	Do.
Igloolik, . .	69 ⅓	+7	Do.
Winter Island, . .	66 ¼	+9 ½	Do.
Fort Enterprize, .	64 ½	+15½	Franklin.

Places.	Situation.	Latitude.	Mean Temperature.
Enontekis and Uleo,	Lapland,	66° to 68°	32°
Table Bay,	Labrador,	54°	
Stockholm,	Sweden,	60°	41
St. George's Bay,	Newfoundland,	48°	
Belgium,	Europe,	51°	50
Boston,	America,	42° 30′	
Rome and Florence,	Italy,	43°	59
Raleigh,	Carolina,	36°	
Pekin,	Asia,	39° 54′	55 ½

In the torrid zone the mean temperature of the surface of the sea is higher than that of the atmosphere.

Perrings found it		82°·76
Quevedo,	.	83 ·48
Chornea,	.	83 ·66
Rodman,	.	83 ·84
Humboldt,	.	84 ·74
Mean,	.	83 ·7

Or, about two degrees higher than that of the air.*

In the immense valley of the Mississippi to the west of the Allegany mountains, the mean temperatures are nearly the same as in the corresponding latitudes on the Atlantic; but the winters are not so cold nor the summers so hot. The mean temperatures of the west coast of America appear to correspond with the mean temperatures of the western parts of Europe.

The following table, drawn up by Humboldt, exhibits the mean temperature of winter and summer in places having the same mean annual temperature; it shows the great diversity which exists in this respect in different parts of the earth:—

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* At great depths even in the torrid zone the temperature of the water is low. Thus, Captain Foster found the temperature of the Atlantic near the equator 80° at the surface, and 44° at the depth of 400 fathoms. (Webster's Narrative, Vol. i. p. 27.) Off Cape Horn, on the 2d January, 1829, the temperature of the surface of the sea was 39°, and at the depth of 900 fathoms 34°. (Ibid. p. 134.)

Mean Temper.	Latitude N.	Longitude.	Situation.	Mean Temper.	
				Winter.	Sum.
68°	29° 30′	84° 20′·5 W.	Florida	53°·6	80°·6
	32 37	19 6½ W.	Madeira	63 ·5	72 ·28
	36 48	49 23 E.	Africa	59	80 ·6
63 ·5	32 30	92 9 23″ W.	Mississippi	46 ·4	77
	40 50	12 0 23 E.	Italy	50	77
59	35 30	86 21 W.	Ohio Basin	39 ·2	77 ·9
	43 30	1 to 2 E.	France	44 ·6	75 ·2
54 ·5	38 30	86 51 W.	America West	34 ·7	75 ·2
	40	76 21 W.	America East	32 ·54	77
	47 10	3 43 W.	France	41	68
	45 30	7 9 E.	Lombardy	34 ·7	73 ·4
	40	113 51 E.	Asia East	21 ·46	88 ·4
50	41 20	86 31 W.	America West	31 ·1	61 ·6
	42 30	73 21 W.	America East	30 ·2	73 ·4
	52 30	9 9 W.	Ireland	39 ·2	59 ·54
	53 30	3 9 W.	England	37 ·8	62 ·6
	51	0 9 E.	Belgium	36 ·5	63 ·5
	40	113 51 E.	Asia East	21 ·46	88 ·4
45 ·5	44 42	73 29 W.	America West	23 ·9	61 ·6
	57	4 39 W.	Scotland	36 ·14	56 ·48
	55 40	10 24 E.	Denmark	30 ·74	62 ·6
	53 5	19 9 E.	Poland	28 ·04	66 ·2
41	47	73 21 W.	Canada	14	68
	62 45	7 9 E.	Norway	24 ·8	62 ·6
	60 30	15 9 E.	Sweden	24 ·8	60 ·8
	60	22 9 E.	Finland	21 ·46	63 ·5
	58 30	34 9 E.	Russia	13 ·1	68
36 ·5	50	73 51 W.	Canada	6 ·8	60 ·8
	62 30	15 54 E.	G. of Bothnia	17 ·6	57 ·2
	62 5	20 9 E.	G. of Bothnia	16 ·7	59
32	53	59 51 W.	Labrador	3 ·2	51 ·8
	65	17 39 E.	Sweden	11 ·3	53 ·6
	71	23 9 E.	Norway	23 ·9	44 ·7

The temperature of the southern hemisphere is nearly the same as that of the northern, from the equator to the latitude of 40°.* Beyond that the mean temperature perhaps does not differ much from that of the corresponding northern latitude. But the summers are much colder, while the winters are as much milder. This is owing to the great preponderance of sea over land in the southern hemisphere.

The preceding remarks apply only to the temperature of those parts of the earth that are nearly as low as the surface of the sea; but as we ascend into the atmosphere the temperature constantly diminishes, so that even in the torrid zone, at a certain elevation, we come to the region of perpetual congelation. The cause of this diminution of temperature is the expansion of the air in proportion to its elevation, which occasions an increase in its capacity for heat and a consequent lowering of its temperature. This diminution is partly counteracted by large masses of earth, which communicate heat to the air. Hence in extensive table-lands the temperature is not quite so low as it would be if the air were at a distance from the surface of the earth. This is probably the reason why the temperature in Mexico and in Peru diminishes according to the observations of Humboldt only one degree of Fahrenheit for every 495 feet of elevation; while in this country, according to the observations of Dr. Hutton of Edinburgh, the diminution amounts to 1° for about 268 feet of elevation. He kept a thermometer on the top of Arthur's Seat and another at Leith, near the level of the sea, for three years. The mean difference between the two was about 3°, and the height of Arthur's Seat, above the level of the sea, is very nearly 803 feet.

How far the temperature of the earth has remained permanent, or whether it has undergone any alteration since the commencement of history, is a question which cannot easily be determined. From the account of the climate near the Black Sea, given by Ovid in his Tristia, and from various passages in the ancient Roman writers, it has been inferred by some that the climate is milder now, at least in Europe, than it was about 2000 years ago. Others have drawn a

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* The mean temperature at Paramatta, in New South Wales, as determined by Sir Thomas Brisbane, is 61°·½. That of the Cape of Good Hope is 67°. The mean summer temperature is 76°, and the mean winter temperature 60.†

† Webster's Narrative of Foster's Voyage, Vol. i. p. 316.

contrary conclusion from observations, which, however, are far from conclusive. A fortunate accident has demonstrated that the climate of Italy has undergone no sensible alteration during the course of the last two centuries. The Academy del Cimento, which may be said to have terminated its scientific labours about the year 1667, contrived a thermometer, which was reduced to Fahrenheit's scale by Dr. Martine.* In the year 1829, Signor Libri of Florence found a considerable number of these original alcoholic thermometers of the Academy, and was thus enabled to verify the reductions of Dr. Martine.† By a fortunate accident some registers of the weather kept by Raineri, a pupil of Galileo for 16 years, were discovered. By the discussion of these, with a knowledge of the true scale, Signor Libri has been able to show that no sensible change has taken place upon the climate of Florence between that period and the present, though the contrary had been suspected.‡

M. Arrago has demonstrated that during the last 2000 years the temperature of the earth cannot have varied so much as $\frac{1}{5}$th of a degree, otherwise the length of the day would have altered, which is not the case.

When we dig to a certain depth below the surface of the ground, we come at last to a situation in which if the bulb of the thermometer be put, it remains unaltered during the whole year. The heat at this depth is considered as representing the mean heat of the place at the surface of the ground. The bottom of the cavern under the Observatory of Paris is about 90 feet below the surface of the ground. A thermometer placed in it varies only about $\frac{1}{55}$th of a degree during the whole year from 52°, which is the mean temperature of Paris.

Lambert, in his Pyrometry, published in 1779, gives a set of observations made by M. Ott, in a garden near Zurich, in Switzerland. The observations were made with seven thermometers, the bulbs of which were sunk respectively 0·266 foot, 0·5325 foot, 1·065 foot, 2·13 feet, 3·195 feet, 4·26 feet, and 6·39 feet under the surface of the ground. The following table exhibits the result of these observations, which were continued for four years:—§

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* Martine's Essays, p. 38. † Ann. de Chim. et de Phys. xlv. 354.

‡ Forbes' Report on Meteorology, p. 209.

§ Ann. de Chim. et de Phys. viii. 214.

Depth of Bulbs.	Mean height of Thermo.	Minimum height.	Maximum height.	Variation.
Feet.				
0·266	50°·72	30°·92 Feb.	67°·1 July.	36°·18
0·5325	48 ·74	32 ·36 Feb.	63 ·86 July.	31 ·5
1·065	48 ·92	34 ·7 Feb.	63 ·7 July.	29 ·0
2·13	48 ·92	36 ·14 Feb.	60 ·98 July & Aug.	24 ·84
3·195	49 ·46	37 ·04 Feb.	61 ·34 August.	24 ·3
4·26	50 ·18	39 ·92 Feb.	60 ·98 August.	21 ·06
6·39	50 ·90	41 ·9 Feb. & Mar.	59 ·36 Aug. & Sep.	17 ·46

It is obvious that the mean temperature in these observations slowly increases as the bulb of the thermometer is sunk farther under the surface of the earth, and that the annual variation diminishes so much that at 6·39 feet under the surface it does not amount to half of what it is at 0·266 foot under the surface.

A set of similar observations was made in the garden of Mr. Ferguson of Raith, near Kirkaldy, in Scotland, in North latitude 56° 10′, during the years 1815, 1816 and 1817. Four thermometers were employed, the bulbs of which were respectively 1 foot, 2 feet, 4 feet, and 8 feet below the surface of the ground. The following table shows the results:—*

Depth of Bulbs.	Mean height.	Minimum.	When reached.	Maximum	When reached.	Variation.
1 foot	45°·5	33°	30th Dec.	58°	13th July.	25°
2 feet	46 ·5	36	4th Feb.	56	24th July.	20
4 feet	46 ·5	39	11th Feb.	54	2d Aug.	15
8 feet	46 ·75	42	16th Feb.	51½	12th Sept.	9½

The years of observation happened to be colder than usual. Hence the mean was below that of the atmosphere at Kirkaldy, which is 47°·7. The variation diminishes as the thermometers are sunk deeper, and the time of the minimum and maximum is farther distant from the winter and summer solstices according to the depths.

A set of observations on this subject has been lately made by M. Gerhard in Prussia, between North latitude 50° and 51°½. He took advantage of the shafts to coal and other mines in that country, and placed the bulbs of his thermometers at some little distance from these shafts (when possible),

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[*] Leslie, article *Climate*, in Supplement to Encyclopædia Britannica, 6th edition. Vol. iii. 179.

and covered with earth to exclude, as far as could be done, the action of the air. The following table exhibits the results:*—

Names of Places.	Height of do. above the sea in feet.	Depth of Therm. under surface in feet.	Mean temperature	Annual variation.	
Robeshaft, near Tornowitz, in Dalomate.	1062	34	46°·08	2°·25	1
Annashaft, coal mine by Czernitz.	914·8	47·8	46 ·19	10 ·125	2
Coal mine near Bielschowitz.	1026·75	29·3	46 ·37	2 ·8	3
Catherineshaft, coal mine by Ruda.	930·9	35·5	47 ·04	6 ·75	4
Frahlicheranblick, copper mine.	1519·7	67·5	44 ·46	2 ·25	5
Gotthillshaft, Löbejüne, coal mine.	3026·7	58·15	48 ·72	6 ·19	6
Shaft T, copper slate, near Eisleben.	507	34	47 ·93	1 ·8	7
Gopelshaft coal mine, Trappe.	694·7	28·2	47 ·23	0 ·83	8
Josinashaft coal mine, near Wetter.	264·97	30·78	48 ·31	12 ·6	9
Kniggelweger, sparry ironstone.	1414·32	34	45 ·14	5 ·29	10
Luftshaft coal mine, Herzogenrath.	319·8	27·37	47· 91	3 ·371	11

The great difference in the height of the localities in this table above the sea, prevents us from seeing whether the temperature increases as we descend, as it does in the observations at Raith. The great inequality of the annual variation, from 0·83° to 12°·6, shows that the thermometers were not completely excluded from the action of the air, as they were at Raith; had they been so the variation at the depth of 67·5 feet would have been almost nothing. The variation of the thermometer (No. 8,) at 28·2 feet below the surface was only 0·83°, while that of No. 9 at 30·78 feet was 12°·6. The

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* *Poggendorf's* Annalen, xxii. 497.

former must have been much more completely screened from the action of the air than the latter.

It is obvious from the preceding observations that at a certain depth below the surface, which does not seem much to exceed thirty feet, the thermometer remains unaltered during the whole year, and exhibits the mean temperature of the air at the surface of the ground in that locality. Hence the mean temperature of a place may be determined by that of springs flowing from a certain depth (not less than thirty feet) under ground. The wells at New York vary from 32 to 40 feet in depth, and, according to Dr. Nooth, the mean annual variation of their temperature is 2°, namely, from 54° to 56°;[*] this would make the mean temperature of New York 55°. Dr. J. Hunter informs us that the temperature of the wells at Brighton vary from 50° to 52°;[†] this would make the mean temperature of the air in that part of England 51°. Now, the mineral spring at Tunbridge wells, at no great distance from Brighton, is always of the temperature of 50°, at least I have observed it at that temperature both in winter and in summer. The great *Brennerei* spring at Upsala has an annual variation of 0·34°, and its mean temperature is 44°·07, which is the temperature of the air in that part of Sweden.[‡] The temperature of a spring at Mehedi on the river Dal in N. lat. 60°½ is constant at 42°·26,[§] which must be the mean temperature of the place. That of a spring at Medelsped in N. lat. 62°·5 is 39°·2, indicating the mean temperature of that place.[||] At Umeo in N. lat. 64° the constant temperature of a spring was 37°·22.[¶]

The following table exhibits the mean temperature at various heights in the Carpathian mountains, determined by Wáhlenberg[**] from the heat of springs:—

Height in feet above the sea.	Mean temperature.
1781	45°·23
3617	40 ·19

Thus it appears that at a certain depth below the surface of the earth a thermometer indicates the mean temperature of the air on the surface. It would seem that this depth is not much more than 30 feet, and probably no great increase of temperature is observed at the depth of 60 feet, or even a little more. But when we penetrate to a greater depth below

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[*] As quoted by Hunter; Phil. Trans. 1788, p. 53.

[†] Ibid.

[‡] Annals of Philosophy, iv. 23.

[§] Ibid. p. 102.

[||] Ibid. p. 105.

[¶] Ibid. p. 107.

[**] Ibid. vol. ix. p. 140.

the surface the temperature becomes higher than the mean of the place, and the elevation of the thermometer increases as the depth augments. This remarkable rise has been observed in all mines in which observations have been made.

Mines are generally situated in veins which usually dip down in one direction while they rise to the surface in another. In following such a vein the mine necessarily gets deeper and deeper. Mines 1000 feet below the surface are not uncommon; indeed, several of the Cornish mines are sunk to a depth of not less than 1500 feet. In such mines a constant rise of temperature is observed as we descend. Thus, at the bottom of Dalcoath mine, near Redruth, at a depth of 238 fathoms, the constant temperature is 84°, while the mean temperature of that part of Cornwall does not exceed 51°. A similar elevation of temperature has been observed by Mr. Fox in many other Cornish mines. Mr. Bald has made a similar observation with respect to the coal mines at Newcastle, most of which exceed 100 fathoms in depth. We are informed by Daubuisson that the same rule holds good in the mines of Freyberg in Saxony and of Brittany in France. Humboldt found the mines of South America in precisely the same predicament. Cordier made similar observations respecting the coal mines in the south of France, and Gerhard of those in Prussia.

I. The following tables exhibit the observations made on the Cornish mines by Mr. R. W. Fox:—*

1. *Huel Abraham—December*, 1815.

Depth in Feet.		Temp. of Air and Water.
0		50°
16		52
121		57
239		61
269		62
298		63
361		63½
479		64
590	Air,	66
	Water,	64
667	Air,	68
	Water,	66

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* *Ann.* de Chim. et de Phys. xiii. 200.

Depth in Feet.	Temp. of Air and Water.	
744½	Air,	70
	Water,	68
769	Air,	71½
	Water,	73½
961	Air,	70
	Water,	74
1079	Air,	74
	Water,	74
1141½	Air,	74
	Water,	74
1200½	Air,	78
	Water,	78

Here the temperature (with some remarkable irregularities) augments by a descent of 1200 feet 28°, which is 1° for every 43 feet.

2. *United Mines—May*, 1819.

Depth in Feet.	Temperature.	
0	Air,	58°½
272¼	Air,	56
392	Air,	70
810	Air,	70
961	Air,	68
990½	Air,	73
	Water,	74

Here in a depth of 990½ feet the temperature augmented 15°½, or 1° for every 64 feet of depth. The anomalies are striking. The temperature at 272¼ feet deep is less by 2° than at the surface; while in the next 120 feet it augments by 12°. In the next 418 feet there is only an augmentation of 2°, and in the next 150 feet there is a diminution of 2°; the temperature at 392 feet being 2° higher than at 961 feet.

3. *Dolcoath Mine—October*, 1815.

Depth in Feet.		Temper. of Air.
0		62°
420		62½
951		70
1020		71
1079		71·5
1171		74
1230		74
1381	Air,	80
	Water	82

Here in a depth of 1381 feet the temperature increases 18°, or 1° for every 77 of descent. The same anomalies are observable as in the last mine. For the first 420 feet there is only an increase of temperature amounting to half a degree; while for the next 531 feet there is an increase of 9°½.

4. *Tincroft Mine—May*, 1819.

Depth in Feet.		Temperature of Air.
167¼		53°
331¼		52
439½		54
553½		56
659¼		62
767½	Air,	62
	Water,	59

Here a descent of 600 feet occasioned an augmentation of 9° of temperature, or 1° for every 66⅔ feet. The same kind of anomalies are perceptible. But this mine had been recently overflowed with water.

5. *Cook's Kitchen—May*, 1819.

Depth in Feet.		Temperature of Air.
167½		50°
298½		55
420		57
553½		57
639½		62
767½		63½
882⅓		64
1020		69
1121¾	Air,	69
	Water,	68

Here a depth of 954 feet occasioned an augmentation of the temperature amounting to 19°, or 1° for every 50 feet of descent. Similar irregularities occur here as in the other Cornish mines. This mine also had been recently inundated.

II. Mr. Bald made a similar set of observations on various coal mines in the north of England. The following tables exhibit the results which he obtained:*—

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* Edin. Phil. Jour. i. 134.

1. *Whitehaven Coal Mine, Cumberland.*

	Temperature.
Air at the surface, . . .	55°
A spring at the surface, . .	49
Water at the depth of 480 feet, .	60
Air at same depth, . . .	63
Air at depth of 600 feet, . .	66

Here at a depth of 480 feet the temperature augments 11°, or 1° for 43 feet of descent.

2. *Workington Coal Mine, Cumberland.*

Air at surface, ...	56°
Spring at surface, . . .	48
Water at depth of 180 feet, .	50
Ditto at 504 feet depth, . .	60

Here the augmentation of temperature in a descent of 504 feet is 12°, or 1° for 42 feet.

3. *Teen Colliery, Durham.*

Air at pit bottom 444 feet deep in a country little elevated above the sea,	68°
Water at same depth, . .	61
Water at surface, . . .	49

Here the depth of 444 feet produced an increase of temperature amounting to 12°, or 1° for every 37 feet of descent.

4. *Percy Main Colliery, Northumberland.*

Air at surface, ...	42°
Water about 900 feet below the bed of the sea, under the Tyne, . .	68
Air at same depth, ...	70
Water at surface, ...	49

Here a depth of 900 feet occasioned an augmentation of temperature of 19°, or 1° per every 47 feet of descent.

5. *Jarrow Colliery, Durham.*

Air at surface, . . .	49°½
Water 882 feet below the surface,	68
Air at same depth, . . .	70
Water at surface, . . .	49

Here the elevation of temperature for a descent of 882 feet was 19°, or 1° for every 46 feet.

6. *Killingworth Colliery, Northumberland.*

	Temperature.
Air at surface, ...	48°
Air at pit bottom, 790 feet deep, . .	51
Air at depth of 900 feet, after having traversed 1¼ mile from the bottom to the downcast pit,	70
Water at depth of 1200 feet, ...	74
Air at same depth, ...	77
Water at surface, ...	49

Here the elevation of temperature for a descent of 1200 feet is 25°, or 1° for every 48 feet. This is the deepest coal mine in Great Britain.

7. *Princes-end Pit, Tipton, Staffordshire.*

Water at bottom of engine, pit above 400 feet deep,	47°½
Air in the mine, ...	60

8. A very satisfactory set of experiments was made on this subject at Sunderland, by Mr. John Phillips, in the month of November, 1834. Mr. Pemberton was engaged in sinking a pit at Monk-Wearmouth to reach the coal beds that lie under the magnesian limestone. It had been sunk to the depth of 1500 feet, and had passed through a bed of coal six feet thick. No attempt had been made to work this coal. The pit had been tubbed in various parts to stop the water, which nevertheless drops, but not in great quantity, down the sides. This water fills several yards below the coal bed in which the observations were made, to the bottom of the pit, which is to be carried considerably deeper to a lower bed of coal. The temperature of the air at the surface was 49°; that of the coal bed at the depth of 250 fathoms varying from 70°·1 to 72°·6.[*]

III. M. Humboldt, while in America, made some observations on the temperatures of mines in Mexico and Peru, the most important of which are exhibited in the following tables:[†]

1. *Mines of Mexico.*

Guanaxuato, lat. 21° 0′ 15″; height of the table-land above the sea, 7,034 feet; mean temperature of the air, 61°. The mine of Valenciana is so hot that in the deepest parts the

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[*] Phil. Mag. (third series), v. 446.

[†] Ann. de *Chim. et de Phys.* xiii. 207.

miners are constantly exposed to a temperature of 91°½. In the month of September the external air was 66°¾.

Between Despacho del tiro nuevo, and Bovedo de San Pablo, between 124½ and 249 feet deep, the temperature is 74°⅔ to 81°⅔.

In the plains of San Bernardo, at the depth of 747 feet, 92°⅘.

The temperature of the water at that depth, 98°¼.

Mine of Royas, not far from that of Valenciana, temperature of external air, 69°½.

At the depth of 286 feet, 92°⅔.

In the mines of Villapando, three leagues to the north of Guanaxuato, on a table-land 8,505 feet high, the temperature of the external air was 72°⅓.

At the depth of 199 feet, 85.

There are hot springs in the neighbourhood issuing from a basaltic conglomerata. Those of Comagillas have a temperature of 205°.

Mine of Cabrera, lat. 20° 10′ 4″ at a height of 1,512 feet. The temperature of the air was from 50° to 53°¼ (mean temperature of the place nearly 61°). In the gallery of Conde de Regla, at 74·7 feet in transition porphyry, the temperature was 70°.

Water at the same depth, 62°¾.

2. *Peru.*

Hualgayac, 6° 43′ 38″ South latitude, is a mine situated in an isolated mountain 13,429 feet above the level of the sea.

The thermometer stood in the air at	42°
In the gallery of the mine, . .	57 ¾
Water of the mine, . . .	52

In the mine del Purgatorio, which is exceedingly dry, the air is 67°¼.

IV. The following observations were made by Daubuisson in some of the Saxon mines during the year 1802:—*

1. *Mine of Beschertgluch, 2 leagues north of Freyberg.*

Depth in feet.	Temperature of air.
590 . .	52°⅓
853 . .	59

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* Jour. des Mines, xi. 517.

Here a depth of 263 feet occasioned an elevation of temperature amounting to 6°·8, or 1° for 38½ feet.

2. *Alte Hoffnung Gottes, near the same place.*

Depth in feet.		Temperature of air.
239½	. .	48°
557½	. .	55
885½	. .	59
1246½	. .	65 ⅔

Here a descent of 1007 feet occasioned an elevation of 17°⅔, or 1° for every 57 feet. The anomalies are of the same kind as in the Cornish mines. A descent from 239 to 557 feet, or 318 feet occasioned a rise of 7°; while for the next 328 feet the rise was only 4°; and for the last 361 feet the rise was 6°⅔, or nearly corresponding with the first 318 feet.

V. To the same observer we are indebted, in 1806, for the following facts respecting the temperature of some mines in Bretagne :—*

1. *Poullaouen, N. lat.* 48° 17′ 49″. *About* 853 *feet above the surface of the sea. Mean temperature* 52°·7—*September,* 1806.

Temperature of the external air, 66°.

Depth in feet.		Temperature.	
52½	. .	Water,	55°½
128	. .	Do.	53 ½
246	. .	Do.	53 ½
462½	. .		59
492	. .	Water,	56 ⅓
		Air,	58

Here a descent from 128 to 492, or 364 feet, occasioned a rise of 2°⅔, or 1° for every 157 feet of descent.

2. *Huelgoat, lat.* 48° 18′ 11″. 567½ *feet above the surface of the sea. Mean temperature* 52—*5th September*, 1806.

Depth in feet.		Temperature of water.
49	. .	52°
229½	. .	54
262½	. .	59
459	. .	62 ½
754½	. .	67 ½

* Jour. des Mines, xxi. 218.

Here a depth of 754½ feet occasioned an elevation of temperature amounting to 15°½, or 1° for every 48 feet.

VI. The following observations on the temperature of certain coal mines in the south of France, were made by M. Cordier:—*

1. *Carmeaux, departmemt of Tarn.*

Depth in feet.	Temperature.
20⅛	55°⅕
37·75	55 ⅖
596·66	62 ·75
629·75	67

Here a depth of 609 feet occasioned an elevation of 12°, or 1° for every 50 feet of descent.

2. *Littry department of Calvados.*

Temperature of external air,	52°
Do. of mine at 324·75 feet deep,	61

3. *Decises, department of Nievre.*

Depth in feet.	Temperature.
28·9	52 ·5
55⅕	53
351	64
551	70

VII. The following observations were made by M. Gerhard in 1829, on the temperatures of the bottoms of a variety of mines in Prussia, between N. latitude 50° and 51°½. The observations were continued for more than a year. The table exhibits the depth of the mine in feet, the mean height of the thermometer, and the variation observed in that height. The numbers in the first column refer to the table in page 11, where the names of the mines are given and the mean height of the thermometer, at from 27 to 67 feet below the surface. Most of these mines are at an elevation of from 500 to 3000 feet above the level of the sea, which accounts for the lowness of the temperatures observed:—†

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* Ann. des Mines (2d series), ii. 62.

† Poggendorf's Annalen, xxii. 497.

	Depth of mine in feet.	Mean height of thermom.	Variation of do.
1	164·54	46°·85	0
2	342·93	51 ·89	2°·25
3	169·37	49 ·7	0
4	154·64	50 ·47	1 ·125
5	394·37	48 ·81	0 ·56
6	478·72	56 ·75	0
7	400	49 ·66	2 ·25
8	480·1	50 ·43	1 ·125
9	230·13	50 ·58	2 ·25
10	376·05	47 ·59	0 ·28
11	280·41	48 ·13	1 ·128
	533·35	49 ·86	0
	786·4	58 ·1	2 ·25

When we compare this table with that in page 11, we perceive that the temperature, in every case, is higher at the bottom of the mine than near the top; though the same anomalies occur as in the observations of preceding geologists. The last which gives the mean height of the thermometer at three different depths in the coal mine near Herzogenrath, shows an elevation of 10° in a descent of 759 feet, or 1° of elevation for every 76 feet of deepening.

VIII. The following observations were made by Kupfer,[*] in the copper mine of Bagoslowsk, Eastern Russia, in North latitude 60°, and East longitude 60° 9′ 20″:—

Depth in feet.	Temperature of water.
183·7	38°
213·3	39 ·2
363·5	43 ·25

Here, a depth of 179·8 feet occasioned an increase of temperature of 5°·25, or 1 for every 34 feet of depth.

IX. At Charlieshope, New Jersey, Mr. Griffith observed the temperature of a spring 250 feet below the surface of the earth, to be 52°, and that of another 294 feet below the surface, to be 54°.[†]

X. The following observations by M. Spasky, show the temperature of the Artesian wells at Vienna, at different depths:—

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[*] *Poggendorf's Annalen, xv. 170.* [†] Ann. des Mines (2d series), vi. 443

Depth in Vienna feet.	Temperature of well.	Depth in Vienna feet.	Temperature of well.
138	53°·15	150	55°·6
150	54 ·5	90	52 ·7
240	57 ·2	166	53 ·37
78	52 ·9	48	54 ·5
234	56 ·75	63	54 ·5
90	52 ·25	60	54 ·3
108	52 ·9	96	55 ·2
108	52 ·9	60	54 ·3
108	52 ·25	144	52 ·9
90	55 ·6	108	52 ·9
102	52 ·9	189	55 ·2
114	52 ·7	102	54 ·95
90	52 ·25	60	54 ·95
		162	54 ·5

The mean temperature of the air at Vienna is 50°·45. M. Spasky has calculated from the preceding observations, joined with the quantity of water given out by each well, that there is a mean augmentation of 1° of temperature for every 37·77 Vienna feet of depression below the surface.*

XI. The following observations were made by Erman, Magnus, and Schmidt, in a shaft which has been sunk in a limestone rock at Rüdersdorf, about twenty miles north-west from Berlin, to a depth of 880 German feet. The observations were made chiefly with a thermometer contrived by M. Magnus for the purpose, during the years 1831, 1832, and 1833:†

Depth in German feet.	Temperature.
80	55°·4
200	56 ·4
225	60 ·375
280	63 ·5
330	63 ·725
380	64 ·4
430	64 ·625
480	65 ·75
530	67 ·325
580	68
630	68 ·45
680	69 ·35
736	71 ·8
830	72 ·5
880	74 ·3

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* *Poggendorf's Annalen,* xxxi. 365. † Ibid. xxii. 136; and xxviii. 233.

The preceding tables contain all the observations on the temperature of mines hitherto published, or at least which have come to my knowledge. With a few insignificant exceptions which can be easily accounted for, they show that the temperature rises as we sink deeper into the earth. But there is a very great difference in the rate of this increase in different mines. It may be worth while to collect this rate as deduced from the different mines observed.

1. Huel Abraham .	1° for	43 feet
2. United mines .	1	64
3. Dolcoath . .	1	77
4. Tincroft . .	1	$66\frac{2}{5}$
5. Cook's Kitchen .	1	50
6. Whitehaven . .	1	43
7. Workington . .	1	42
8. Teen . . .	1	37
9. Percy main . .	1	47
10. Jarrow . . .	1	46
11. Killingworth . .	1	48
12. Beschertgluch .	1	38·5
13. Hoffnung Gottes .	1	57
14. Poullaouen . .	1	157
15. Huel goat . .	1	48
16. Carmeaux . .	1	50
17. Littry . . .	1	36
18. Decises . . .	1	30
19. Herzogenrath . .	1	76
20. Bagoslowsk . .	1	34
21. Charlieshope . .	1	22

The difference is enormous. In the mine of Decises there is an elevation of 1° for every 30 feet of descent; while in Poullaouen an elevation of 1° requires a descent of 157 feet, or more than 5 times as great. If we were to leave out Poullaouen and Charlieshope as deviating too much from the rest, and take the mean of all the others, we would obtain nearly an increase of 1° for every 50 feet of descent.

Can this augmentation of temperature in mines be accounted for by any accidental causes, such as the burning of candles, the blasting of gunpowder, or the number of workmen employed in the mine? Dr. Forbes has given us the requisite data to determine these points in the mine of Dolcoath.*

In the year 1819 the number of men employed in that mine was 800, of whom a third part or 266 were always in the mine. The candles burnt amounted to 200 lbs. every day. The gunpowder employed in blasting the rock in which the mine is situated amounted to 86$\frac{2}{3}$ lbs. per day.

Now, the quantity of water pumped daily out of Dolcoath mine was 535,173 gallons, or nearly 4$\frac{1}{2}$ millions of pounds; and this water had the temperature of 84°, or was 33° higher than the mean temperature of Redruth, where the mine is situated: thus the heat carried off daily, in the water pumped out of the mine, would have heated 824,000 lbs. of water from the freezing to the boiling point.

From the facts ascertained respecting animal heat we have reason to conclude that the heat given out daily by 266 men would be sufficient to raise the temperature of the whole water from the mine one degree.

200 lbs. of candles, according to the best experiments on the heat evolved during the burning of tallow would be only sufficient to raise the temperature of the water of the mine 0·7 of a degree.

The heat from the explosion of 86$\frac{2}{3}$ lbs. of gunpowder would not raise the temperature of the water so much as $\frac{1}{10}$th of a degree.

Thus it is clear that all the heat from these adventitious causes does not amount to so much as $\frac{1}{13}$th of the 33 degrees of heat which the water contains above the mean temperature of Redruth, which must be very nearly 51°.

The simplest explanation of this curious fact, and the one which seems at present almost universally adopted, is, that the temperature of the central parts, of the globe is much higher than that of the surface; so high indeed as to be in a state of intense ignition. From this central ignited nucleus, the temperature gradually diminishes as we approach the circumference, where it is of course lowest: hence the obvious reason why the temperature so constantly increases as the depth of a mine increases. This explanation was advanced by Buffon and by other geologists many years ago. It was strenuously supported by Dr. James Hutton in his *Theory of the Earth*, first published in the *Edinburgh Transac-*

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* Transactions of the Geological Society of Cornwall, vol. ii.

tions about the year 1790, and afterwards in a separate form in 1795. The publication of this theory occasioned a violent controversy, which at last subsided, and many of the opinions of Hutton have been generally adopted by modern geologists.

If we admit the truth of this hypothesis, and consider the mean temperature at the surface to be 56°, since the temperature augments 1° for every 50 feet it is obvious that the temperature of the centre of the globe must be almost 418,000°.

This hypothesis would enable us to account in a very simple way for the hot springs which issue in such abundance in different parts of the globe. The temperature of a spring must depend upon the depth from which it rises. Were a spring to rise from the bottom of Dolcoath mine, which is 1,381 feet deep, to the surface, its temperature would be 84°, or 33° higher than the mean temperature of the place. Now, this happens to be the temperature of Buxton hot well in Derbyshire. We have only to suppose that the water fills a cavity 1,381 feet below the surface, and that from this cavity it rises in a natural pipe to the surface, to be able to account for the temperature.

The temperature of the hottest of the Bath springs is 117°, while that of the air is 50°; so that the Bath spring is 67° higher than the mean heat of the place. If we allow an increase of 1° for every 50 feet of descent, it is obvious that Bath water must form an accumulation in a cavity situated 3,350 feet below the surface of the earth. This amounts to 558 fathoms, which is much deeper than any mine, at least in Great Britain.

But though this supposition of a central fire be so simple and satisfactory that it has been generally adopted, it must not be concealed that there are several circumstances which rather militate against it.

1. It is sufficiently obvious, and has been already noticed, that the temperature of a place, *ceteris paribus*, is regulated by the latitude. The mean temperature of the equator is 81°·5; that of latitude 45° is 56°; that of Stockholm in N. lat. 60° is 41°; and that of Lapland in N. lat. 67° is 32°. In the temperate and frigid zones the mean temperature of summer is much higher than that of winter. This will be evident from the following table taken from that given in page 7:—

Places.	Latitude.	Mean Winter Temp.	Mean Sum. Temp.
Madeira, . .	32° 37′	63°·5	72°·28
Italy, . . .	40 50	50	77
France, . .	43 30	44 ·6	75 ·2
France, . .	47 10	41	68
England, . .	53 30	37 ·8	62 ·6
Scotland, . .	57	36 ·14	56 ·48
Sweden, . .	60 30	24 ·8	60 ·8
Gulf of Bothnia, .	62 5	16 ·7	59
Norway, . .	71	23 ·9	44 ·7

It is obvious from this table that in all these places the higher the sun is elevated above the horizon, and the longer it continues above the horizon, the higher is the temperature; and that in winter, when his altitude is low, and the days short, the temperature is much lower. From all this it cannot be doubted that the temperature is regulated entirely by the sun. Now, how could this be the case if there existed a central fire which makes its influence be felt so much as to raise the temperature 33° at a depth of 200 fathoms under the surface? It has been said, indeed, that the heat lost by radiation is just equal to that transmitted from the centre, so that the surface cannot be heated by the central fire, but only by the sun. But whatever effect may be ascribed to radiation, surely it must act equably on every part of the surface of the earth. But the poles are 12 miles nearer the centre than the equator is. Now, if every 50 feet of descent occasion an increase of 1°, 12 miles should occasion an increase of 1291°; so that allowing the heat dissipated from the surface by radiation to be equal at the poles and equator, still there ought to be an increase of more than 1200° of heat at the pole, derived from the central fire; so that the temperature at the pole, instead of —13°, ought to be enormously high. The low temperature of the pole, owing to the long absence of the sun, and probably also the absence of land, seems to me totally irreconcileable with the existence of a central fire in the globe, or at least with the notion that this central fire transmits heat to the surface in such quantity as to affect the thermometer.

2. The observations of Mr. Moyle, which were made during a series of years in Cornwall, seem to show that the high temperature of the mines in that county continues only while they are working.* When these mines are abandoned they

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* *Annals of Philosophy* (second series), iii. 308, 415.

get filled with water, which of course remains stagnant, and the temperature gradually sinks till it approaches that of the mean temperature of the place. The Oatfield engine shaft, at the depth of 182 fathoms, had a temperature of 77° while the mine was working. Mr. Moyle examined the temperature at that depth a few months after the mine had been abandoned and found it reduced to 66°. He tried it again many months after, and found the temperature reduced to 54°. Thus the temperature at the bottom of this mine had sunk after it was abandoned no less than 23°. It is obvious that if the original high temperature had been derived from the central fire, the mere abandonment of the mine could not have reduced it.

Mr. Moyle found the temperature in the abandoned mines of Herland and Huel Alfred, that of the former 54°, and of the latter 56°, and this at all depths. The working of these two mines being resumed, the water was drawn off, and Mr. Moyle examined it during the operation to the depth of 100 fathoms without finding any increase of temperature.

Huel Trenoweth is another example which Mr. Moyle has brought forward. It is 100 fathoms east of Crenver and Oatfield mines, on the same *load*. This mine was discontinued working for more than 12 months, at least as far as regards the presence of miners; but the engine was still kept working to relieve the other two mines. The adit at which the water is discharged is 32 fathoms from the surface. Here its temperature was 54°; and it gradually increased from this place to the mouth of the pump, where it was 56°. 15 fathoms deeper the walls of the shaft were 54°. A gallery at this level, 40 fathoms east of the shaft, was only 53°. 5 fathoms deeper, or 52 from the surface, where there is a second cistern of water, the water was 57°; the walls in the same place were 54°½. At the bottom, in 66 fathoms, the water that ran through a small crevice, as well as the walls of the shaft, were still 54°. The temperature of the air before going down was 68°, after returning 64°. Here it is obvious that there was no increase of temperature for 34 fathoms, being precisely the same at the bottom as at the adit shaft.

The following table exhibits the whole of Mr. Moyle's observations.* They show in the clearest point of view that the elevation of temperature is chiefly confined to mines at work, and disappears when they are abandoned:—

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* *Annals of Philosophy* (second series), v. 34.

Feet.		MINES AT WORK.												ABANDONED MINES.													
		Huel Unity.		Creeg-brawn.		Huel Trumpet.		Oatfield.		Cronver.		Huel Abraham.		Huel Tre-noweth.		Huel Pool.	Huel Rose.	Relis-tian.	Herland shaft.			Huel Alfred.	Huel Ann.	Treven-nan.		Huel Fanchise.	Huel Nancy.
		Air.	Wat	Air.	Wat.	Air.	Wat.	Air.	Wat.	Air.	Wat.	Air.	Wat.	Air.	Wat.				1	2	3			Air.	Wat		
60 to	120	—	Not working spots.	55°	51°	—	56°	—	—	All not at	spots work.	—	—	—	—	53	53½	—	—	—	—	56	52	—	—	—	—
120	150	54		60	—	—	Not working spots.	—	—			—	—	—	—	53	53½	55	—	—	—	56	52	53½	52	51	51
150	200	—		—	—	—		61°	—	—	—	—	—	54°	—	—	—	55	54	56	52	56	—	—	—	51	51
200	250	—	—	—	—	—		—	—	—	—	—	—	54	53°	—	53½	55	54	56	52	—	—	—	—	—	—
250	300	—	—	62	—	58°	54	—	—	55°	—	—	—	54	—	—	—	55	—	—	—	56	52	—	—	—	—
300	350	62	54°	—	—	—	—	—	—	56	—	—	—	—	—	—	53	55	54	56	52	—	52	—	—	—	—
350	400	—	—	—	—	—	—	—	—	60	60°	—	—	54	—	—	—	—	54	—	—	—	—	—	—	—	—
400	450	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
450	500	—	—	—	—	—	52	—	—	61	61	—	—	—	—	—	—	—	—	—	—	—	52	—	—	—	—
500	550	—	—	—	—	67	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	56	—	—	—	—	—
550	600	—	—	—	—	68	53	—	—	62	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
600	650	71	69	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	54	56	52	—	—	—	—	—	—
650	700	—	—	—	—	—	—	—	—	64	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
700	750	—	—	—	—	—	—	—	—	64	60	—	—	—	—	—	—	—	—	—	—	56	52	—	—	—	—
750	800	—	—	—	—	—	—	—	—	63	61	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
800	850	—	—	—	—	—	—	—	—	64	62	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
850	900	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
900	950	74	65	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
950	1000	—	—	—	—	—	—	—	—	—	—	—	—	58	—	—	—	—	—	—	—	—	—	—	—	—	—
1000	1150	—	—	—	—	—	—	—	—	—	—	—	—	58	—	—	—	—	54	—	—	—	—	—	—	—	—
1150	1250	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1250	1300	—	—	—	—	—	—	78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1300	1350	—	—	—	—	—	—	81	78°	—	—	85°	84°	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1350	1400	—	—	—	—	—	—	80	—	—	—	90	86	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1400	1450	—	—	—	—	—	—	85	—	—	—	84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

These facts seem to me to leave no doubt that the increase of temperature observed in mines as we descend, cannot be owing to the heat communicated from the central parts of the earth; for, if it were so derived it could not disappear when the workmen left it, or when stagnant water was allowed to accumulate in it.

If it were merely the air in the mine, or even the surface of its walls which augmented in temperature, there would be little difficulty in accounting for the phenomenon. The number of miners usually present in the mine at one time (often amounting to 400), together with the heat from the candles and gunpowder exploded, might easily be supposed to increase the temperature very considerably, and this temperature would naturally increase somewhat as the mine deepened, in consequence of the greater density of the air; but we have seen that these causes are utterly inadequate to account for the augmented temperature of the vast quantity of water which is daily pumped out of these mines.

But to whatever cause we are to ascribe this augmented temperature, the facts above stated are incompatible with the notion that it is owing to a central fire.

3. That an intense state of ignition exists within the bowels of the earth, or at least at very considerable depths below the surface, is evident from the numerous volcanoes, more than 200 of which, in a state of activity, are known to exist on the globe. If we consider the evident connexion which many of these volcanoes have with each other, we shall be satisfied that the igneous energy to which they are owing is of the most extensive kind. The Andes extend from the island of Terra del Fuego to the table-land of Mexico, about 77° of latitude, or more than 5000 miles; or, if we exclude Terra del Fuego and Patagonia, as the existence of volcanoes in these districts rests upon uncertain evidence, the volcanic chain of the Andes extends over a space not less in length than 4700 miles, or 68° of latitude. Over the whole of this long space it is rare to find a degree of latitude in which there does not exist an active volcano. The internal fire, of which these craters constitute the vents, must be enormous in point of magnitude, and must exist at a very considerable depth below the surface of the earth, even without reckoning the Andes, which have been probably originally elevated by the expansive force of this internal fire.

A *volcanic band, of very* great extent, exists also in the

Indian Archipelago. It begins to the north of the Philippines in about 20° N. latitude, and extends south to Timor, in about S. latitude 10°; then proceeds west and north to the extremity of Sumatra, from East longitude 130° to 95°.

In Europe volcanoes exist in the Grecian islands, in Italy and Sicily, and in Iceland. Whether these volcanoes have any connexion with each other at a great depth is uncertain, no evidence of any such connexion being known. But if earthquakes and volcanoes both owe their existence to the same internal fires, then there is evidence that such an internal fire must exist at an enormous depth, and that it must extend over a very large space; for the earthquake which destroyed Lisbon in November, 1755, extended over a space which was not less than 4000 miles in length, and as much in breadth. It was felt in Pennsylvania and New York, at Antigua, in Madeira, in Barbary, in the North of Scotland, at Hamburg, and in many other places, though the centre of action seems to have been situated below the Atlantic, and north-west from Lisbon. Now, if an extensive volcanic fire exists under Europe, as is not unlikely from the facts just stated, it is possible that the temperature of some of the mines specified in the preceding pages may have been affected by this internal fire, which may very well be conceived to be nearer the surface of the earth in one place than in others: hence, perhaps, the reason why in some places it breaks out into active volcanoes, while in others it produces only earthquakes. Even if the temperature of mines should not be admitted to be affected by these internal volcanic fires, there can be little doubt that the hot springs which issue so abundantly in many parts of the earth owe their temperature to this cause.

CHAP. II.

OF THE SURFACE OF THE EARTH.

It is known to every person that the surface of the globe is partly *dry land* and partly water, and that nearly two-thirds of the whole is covered by the ocean. The proportion of land upon the north side of the equator is about 13 times as great as upon the south side. Hence the reason why in high *southern latitudes* the summers are colder and the winters milder than in the corresponding latitudes in the northern hemisphere.

The land is usually divided into five great continents; three of these exist in the eastern hemisphere, namely, Europe, Asia and Africa. A fourth, America, constitutes a great belt crossing the western hemisphere, from 68° North latitude to 56° South latitude, or above 8,500 miles in length. The fifth, denominated Polynesia, consists of New Holland and the neighbouring islands. The relative extent of these continents in square miles, may be stated as follows:—

	Square miles.
Europe, with its islands,	2,243,000
Africa, with Madagascar,	7,464,000
Asia,	11,039,000
America,	10,000,000
Polynesia,	2,745,000
	33,491,000

If we reckon the ocean at double the extent of the land, the whole surface of the globe will constitute about 100,000,000 square miles.

America constitutes two continents, North and South, the relative sizes of which are:—

	Square miles.
North America, Greenland, &c.,	5,803,000
South America,	4,196,000

The dry land consists of *high* country, that is mountains and hills with elevated valleys between them; and of *low* country, or the extensive plains which lie at the foot of the mountains. The sea has also its plains, mountains, and valleys. Alpine country sometimes descends to the sea by a succession of valleys below one another, sometimes by one large plain. Elevated and extensive plains with opposite declivities do not terminate in one another, but are almost always divided by land of a mountainous character.

Single detached mountains are generally volcanic, or at least composed of *trap* rocks, which have exactly the aspect of lava. At Edinburgh there occur four such mountains, namely, Arthur's Seat, Salisbury Craigs, the Castle Hill, and the Calton. All of these are precipitous to the west, and slope gently towards the east. They are composed of greenstone, claystone porphyry, traptuff, &c. Near Stirling there are three exactly similar hills; *namely*, the Abbey Craig, the Castle

Hill, and Craigforth, besides some smaller ones of the same kind in the King's Park.

Mountains are generally found in elevated bands, consisting either of one central chain with branches running at right angles, or of several chains or ridges running parallel to each other. And in both cases frequently accompanied by subordinate or dependent chains of smaller elevation. The Alps, for example, consist of a great central chain extending in breadth between fifty and sixty miles. On each side of this chain there is a valley, and beyond these valleys a lower chain, which runs on each side parallel to the great central one. The Grampians exhibit a similar arrangement at least on the south-east side.

Mountain chains in general have a great length compared to their breadth. This is well exemplified in the Andes, which traverse South America from the isthmus of Darien to the Straits of Magellan, constituting a length of upwards of 4000 miles, while the breadth in general is under 100 miles.

If we consider the old continent attentively we shall find that its general form, the declivity of its surface, and the course of its rivers are determined by a great zone, which traverses it from one extremity to the other at a mean latitude of 40°. Mount Atlas, which bounds Barbary on the south, and traverses the north of Africa, between North latitude 30° and 32°, may be considered as part of this great mountain zone. The different mountain tracts in Spain, running in the same direction belong to the same zone. Under the name of the Pyrennees it separates France from Spain. A little farther east it assumes the name of the Alps. Mount Hemus connects the Alps with the great Asiatic chain, which under the names Taurus, Caucasus, Elbourz, is continued eastwards to the 70th degree of longitude. Here it divides into two branches; one of which, the Himalaya range, takes a south-easterly direction, and terminates about 500 miles to the north of the gulf of Bengal. The other branch called the Altai and Yablounoi, passes north-eastwards till it reaches the Pacific Ocean, in North latitude 55°. The entire length of this mountain zone, from west to east, is about 8000 miles, and its breadth varies from 500 to 2000 miles. The Sierras of Spain, the high ridge of Corsica and Sardinia, the Appenines continued through Italy and Sicily, and the *mountains* of Southern Greece, form so many transverse branches connecting together the great northern and southern chains of the band. The Carpathians in Hungary, and the Erzegebirge in Germany, may be considered as dependent chains of the Alps.

It is along this great zone that the highest eminences of the old continent occur. The Peak of Teneriffe is 11,022 feet above the level of the sea. Mont Perdu, long reckoned the highest of the Pyrenees, is 11,172 feet, by the measurement of M. Reboul; that of the other principal summits of the Pyrenees, by the measurement of the same gentleman, are as follows:—

Pic du Midi,	9,560½	feet.
Canigou,	8,544	
Maladetta,	11,427¾	the highest of the Pyrenees.
Posets, .	11,280¾	

Mount Etna, which constitutes the most magnificent object in Sicily, is 10,955 feet above the surface of the Mediterranean, while Vesuvius, near Naples, is only 3,938 feet high. Mont Blanc, the highest of the Alps, and the loftiest of European mountains, is 15,665 feet above the level of the sea; and Mont Rosa, its rival in size and celebrity, is only 125 feet lower.

The highest mountain in France, Mount Pelvoux, is the summit of the mountains of L'Oisans,* in Dauphiné. It is 13,468 feet above the level of the sea, according to the measurement of Durand and Leclerc.* The Dole, constituting the highest peak of Mount Jura, is 5,577 feet above the level of the sea. Mount Meyen, in the Velay, is 5,900 feet high. The following table shows the height of the highest mountains in Auvergne, as determined by M. Ramond:—†

Puy de Dome, . .	4,846	feet
Petit Puy de Dome, .	4,189	
Puy de Pariou, . .	4,012½	
Puy de Vache, . .	3,894	
Grand Sarcouy, . .	3,793	

The Carpathian mountains, which separate Poland and Hungary, may be considered as a kind of continuation of the Alps, though there is a valley interposed between them. The great Lomnitzerspitze, the highest of these mountains, is 8,464 feet above the level of the sea, which is not much more

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* These mountains are composed of granite. An interesting Geological account of them, by M. Elie de Beaumond, will be found in the Annales des Mines (*third series*), *v. iii.*

† Jour. des Mines, xxiv. 241.

than half the elevation of Mont Blanc. The most westerly of these mountains is called Fatra. It runs north and south, and is divided into two by the river Waag. The following are the heights of its principal peaks, as determined by Wahlenberg:*

Coch,	5,196 English feet.
Krivan,	5,648
Klukberg,	4,442
Czerny-kamen,	4,583

To the eastern part of the Carpathian mountains the inhabitants give the name of Trata *(hideous)*, from its singular and dreary aspect. The following is the height of its principal peaks, as determined by Wahlenberg:—†

Krivan,	8,034 English feet.
Nod Pavlova,	5,942
Nochstein,	4,984
Viszoka,	8,313
The lake Hinzka,	6,219
Csabi,	8,313
Gerlsdorfkessel,	7,780
Great Lomnitzerspitze,	8,464
Hunsdorferspitze,	8,313
Rotheseethurm,	7,673
Hintere Leithen,	6,591
Stirnberg,	6,287

The height of Mount Hemus, or the Balkan, which constitutes the chain to the north of European Turkey, is not so well ascertained, though there are reasons for believing that it rises, in some places at least, to a height not inferior to that of the highest of the Carpathians.

Mount Athos, at the extremity of a peninsula in Macedonia, is one of the highest mountains in Greece. Its height, as measured by Captain Gauttier, is 6,778 feet. The following table exhibits the height of different mountains in the Grecian Archipelago, as determined by the same observer:—‡

Mount Kerki, isle of Samos,	4,793 feet.
Mount Jupiter, isle of Naxos,	3,328
Mount Olympus, Meteline,	3,241
Mount Christo, Stancho,	2,828
Mount Cochila, Skiros,	2,588
——— St. Elias, Milo,	2,559
——— St. Elias, Paros,	2,516

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* Annals of Philosophy, ix. 141.

† Ibid. p. 142.

‡ *Ann. de* Chim. et de Phys., xviii. 433.

The height of Kasibeck in the Caucasus, according to Sir Robert Ker Porter, is 14,400; that of Elborus, in the same chain, is 16,414 feet;[*] while that of Mount Ararat, according to M. Parrot of Dorfat, who ascended it in 1829, is $17,266\frac{1}{5}$ feet. The limit of perpetual snow on that mountain is at the height of 12,790 feet. Thus both Ararat and Elborus considerably exceed the height of Mont Blanc.

But this mountain zone reaches by far the greatest elevation towards its eastern extremity, in the extensive table-land of Thibet and the Himalaya mountains, which constitute the northern boundary of Hindostan. The Dologer, the highest of these mountains, rises to the enormous height of 27,677 feet, or $5\frac{1}{4}$ miles above the level of the sea; Javahir, the second in height, is 25,745; and Yamunatri, the third, 25,000 above the sea level.

The Altai chain has been partly examined by Humboldt, but he has not yet laid the result of his measurements before the public. Its height above the surrounding country is not very great, but it stands upon a very elevated base, and the extreme rigour of the climate shows that the absolute elevation above the level of the sea must be very considerable. The height of the little Altai above the level of the sea is, according to Laxman, 6,988 feet.[†]

Many very high mountains occur in the Asiatic Archipelago. Thus, in Sumatra we have

Gunong-Dempo,	12,000 feet.
Berapi, . .	13,003

and in the Phillippines, Ternate, 4,093 feet above the level of the sea.

Besides this central system of mountains there are two other ranges in the Old Continent upon the north side, and nearly at right angles to the central chain. These are the Uralian mountains between Europe and Asia, and long celebrated for the numerous mines that are wrought in them by the Russians, and the Doffrines which separate Sweden from Norway.

The Uralian mountains extend from about North latitude 54° to 66°, and run north and south not far from East longitude 60°. They constitute three parallel chains with valleys between them, the westernmost of which is the most

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[*] As determined by the late Russian Survey, by M. Zenz. See Ann. de *Chim. et de Phys., xlii. 105.*

[†] Ann. de Chim. et de Phys., iii. 309.

elevated. The highest mountain in that chain is Jeremel, which rises beyond the limit of perpetual snow, which in that latitude is about 5,500 feet above the level of the sea. Taganai, the next highest mountain in that chain, is, by Kupffer's measurement, 3,480 feet high. Slatoust, in the same range, is 1,193 feet, and Nasimskisch 2,216 feet. The second chain, called Ural, is lower; the height of it when passed on the way to Slatoust, is 2,059 feet; while Miask is 995·4 feet above the level of the sea. The farthest east chain is the lowest of all.[*]

The Doffrines extend in length at least 1000 miles. Indeed, if we were to consider the Grampians in Scotland, and the Irish mountains as a continuation of the Doffrines, their length would exceed 2,000 miles. The highest of these mountains is Sneehaetta, which, by the measurement of Esmark, is 8,120 feet above the level of the sea. The summit of this mountain was considered as inaccessible till it was reached by Esmark, and his journey is still celebrated in Norway as a most wonderful and dangerous exploit. Syllfjells, in latitude 63°, which Hisinger measured, is 5,819 feet above the level of the sea. Tronfjels, the next in elevation, is 5,611 feet. The snow line at the latitude of these mountains is 5,275 feet above the level of the sea, yet Hisinger found no snow upon the top of either of them in the month of August; this he ascribes to their pointed form, which prevents the snow from lying. It is to this form probably that the want of glaciers in these mountains is owing.

Beerenberg, in the isle of Mayen, near Greenland, is, by Scoreby's measurement, 6,840 feet above the level of the sea. It appears from his observations that the mountain is volcanic. The following table exhibits the heights of some of the principal mountains of Iceland:—

	English feet.
Hecla,	5,110[†]
Eyafiäll,	5,679[†]
Oeräsa Jockal,	5,927[‡]

The mountains in Scotland are less elevated than those of Norway. The Grampian mountains rise low a few miles to the south of Aberdeen, and proceeding in a south-west direction terminate in the table-land constituting the Mull of Kin-

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[*] Kupffer, Poggendorf's Annalen, xvii. 497.

[†] As measured by M. M. Ohlsen and Vetlesen.

[‡] *As measured by* M. Paulson. See Poggendorf's Annalen, x. 19.

tyre. By far the highest tract of mountainous country in Scotland is that part of the Grampians called Brae Mar, at the west end of Aberdeenshire, whence the river Dee takes its rise. The highest mountain of that district is Beni Macdui, which, by the measurement of Dr. Skene Keith, is 4,300 feet; but by the measurement of the gentlemen who conducted the Trigonometrical Survey of Great Britain, 4,400 feet above the level of the sea. There are seven or eight mountains within a short distance of Beni Macdui not much inferior to it in height. Bennevis, in Inverness-shire, near the western extremity of the Caledonian canal, has an elevation of 4,370 feet, and has usually passed for the highest mountain in Great Britain.

Ben Lawers, in Perthshire, rising from the north side of Loch Tay, and the summit of which is almost a ridge, is 4,051 feet above the level of the sea. Benlomond, though so conspicuous from its situation at the western extremity of the flat district constituting the valley of the Forth, is only 3,262 feet high. The highest mountain in the south of Scotland is Hartfell, near Moffat, which, according to Dr. Walker's measurement, is 3,304 feet above the level of the sea. Helvellyn, in Cumberland, is about the same height. The highest mountain in England is Crossfell, in Cumberland, which is 3,390 feet above the level of the sea. Its eastern acclivity is so gentle that you may easily ride to its summit, but its western side, overlooking the Vale of Westmoreland, is very steep. Snowden, in Caernarvonshire, the highest mountain in Wales, is 3,568 feet high. Cader Idris, in Merionethshire, is only 18 feet lower.

Upon the north side of the great central chain, which may be considered as the spine of the ancient continent, there is an enormous plain, extending, with but little interruption, from the Atlantic to the Pacific Ocean. It occupies the space between the fiftieth and seventieth degrees of North latitude, having an average breadth of about 1,400 and a length of about 6000 miles. It embraces the north of France, England Holland and Belgium; the north of Germany, Denmark, Sweden and Russia.

On the south side, if we consider the Atlas range as connected with the great central chain, we have an immense zone of sandy deserts, 900 miles broad and 4,500 miles long, extending between the parallels of 18° and 31° north, and between the west coast of Africa and the mouth of the Persian Gulf, including Northern Africa, Arabia, Persia and the country to the north-west of Hindostan. This tract contains many mountains and some fertile valleys, but is characterized by vast desert plains, formed of very light moveable sands which assume the form of waves—by burning and pestilential winds—by an extraordinary aridity and want of rivers, and by an abundant formation of salt, sometimes deposited like a crust on the surface, sometimes mixed with the inferior soil.

The city of Gondar, in Abyssinia, in North latitude about 11°, and to the south of this sandy zone, is 8,440 feet above the level of the sea.

The heights of the mountains in the vicinity of the Cape of Good Hope, are as follows:—

Table mountain, . .	3,600 feet.
Devil's mount, . .	3,360
Lion's head, . . .	2,200
Lion's rump, . . .	1,100*

The new world forms two great continents united by a neck of high land. South America consists of one vast expanse of surface of small elevation, everywhere protected on the west by the great ramparts of the Andes. These mountains which run from south to north, at the distance of from 50 to 150 miles from the sea, constitute from 14° to 20° South latitude, two parallel chains divided by an elevated valley. Mr. Pentland in his geological tour in South America, measured some of the highest peaks of the Andes. The following are some of the most remarkable of these:—†

1. *In the Oriental Range.*

Nevado de Sorata, . .	25,250 English feet.

This is the highest peak probably of the Andes, and little inferior to Javahir, which is 25,745.

Nevado de Illimani, .	24,000 English feet.
Cerro de Potosi, . .	16,037

2. *In the Western Range.*

Tacora, or Chipicani, .	18,808
Pichu-Pichu, . .	18,603
Volcano of Arequipa, .	18,373
Inchocajo, . . .	17,192

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* Webster's Narrative, vol. i. p. 293.

† *See Ann. de Chim.* et de Phys. xlii. 435.

3. *Passages of the two Ranges.*

Altos de los Huessos,	13,573 English feet.
Tolapalca,	14,075
Gualillas,	14,830
Paquani,	15,227
Chullunguani,	15,610
Altos de Toledo,	15,692

4. *Cities in Peru and Bolivia.*

Lima,	512
Arequipa,	7,799
Cochabamba,	8,448
Chuquisacaor la Plata,	9,331
Tupisa,	10,003
La Paz,	12,195
Oruro,	12,441
Puno,	12,832
Chucuito,	13,025
Potosi,	13,668

The height of Chimborazo, erroneously considered the highest of the Andes, is by the old measurements 21,440 feet above the level of the sea.

The highest mountain in Hermit island at Cape Horn, is 2,156 feet above the level of the sea.[*]

South Shetland appears to be volcanic. The highest mountains observed in it are in Trinity land, between South latitude 63° and 64°. They are between 6000 and 7000 feet above the level of the sea.[†]

There are three transition ridges proceeding eastward, and spreading out into a range of table-land as they approach the eastern coast. The northernmost of these is in Caraccas, at the latitude of 8° or 9° north. The second divides Guiana from the basin of the Amazons. The third proceeds from the Cordilleras, in South latitude 18°, and is the one which chiefly spreads out into a table-land. The low region of this continent is divided into three great plains, which form the basins of the three principal rivers, the Orinoco, the Amazons, and the Plata. In the basin of the Orinoco, the eye is fatigued by the unvaried aspect of a boundless level, uniform as the surface of the ocean; without a plant or any other object, much above a foot in height, to break its monotony. Except

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[*] *Webster's Narrative*, vol. i. p. 186.

[†] Ibid. p. 185.

on the borders of the rivers, these plains are destitute of trees. After the annual rains they are clothed with a luxuriant herbage, which disappears during the dry season. The Pampas of La Plata, which extend from 18° to 40° South latitude, are plains of the same description.

But the zone which divides the open plains and forms the basin of the Amazons, extending from 6° North to 18° South latitude, is one vast and continued forest. This middle region is the highest; but so low are all the three, that if the sea were to rise 50 fathoms at the mouth of the Oronoco and Plata, and 200 fathoms at the mouth of the Amazons, it would wash the foot of the Andes and submerge more than half of South America. The Llanas and Pampas are steppes, like those of Southern Russia. There are no real deserts in South America, except a narrow tract of rock and quicksands on the coast of Peru, between Coquimbo and Lima, on which no rain ever falls.

The Cordilleras do not traverse the isthmus of Darien. That isthmus, as we learn from the description of Mr. Lloyd, is hilly, the mountains generally running from north-east to south-west near Panama, and in other parts bearing a relation to, though not always parallel to, the line of coast. Their altitude was determined by Captain Foster, who found the highest of them to be rather under 2000 feet.*

The North American continent, like the South, is distinguished by one great chain of mountains, which traverse it from south to north nearly through its whole extent, leaving a large open level region to the east, and presenting a steeper and narrower declivity to the west. Mexico constitutes a high table-land from 7000 to 8000 feet above the level of the sea, and its mountains, which are chiefly volcanic, rise, some of them, to the height of 17,720 feet, or 3½ miles above the level of the sea. This is the case with Pocatepetle, the highest of the Mexican mountains. The chain of the Rocky mountains ascends considerably above the level of perpetual snow. In latitude 46°, it seems to have an elevation of about 9000 feet. The highest mountain in that chain and the most elevated in North America, is Mount Elias, situated near the Pacific Ocean, in North latitude 60°. It is 18,090 feet above the level of the sea.

From the centre of Avatcha Bay in Behring's Straits,

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* Webster's Narrative, ii. 148.

(which divide Asia from America) five immense mountains are visible which rise insulated and steep above some lower eminences. Korazka, one of these mountains, is 11,468 feet above the level of the sea. It constantly emits columns of smoke from the northern side. Avatcharkaja, another of them, is an active volcano. Kluschefskaja, or Kamschatskaja, which is also a volcano, is 16,542 feet above the level of the sea.*

The Sandwich islands may be considered as a part of North America, at least they are much nearer that continent than the coast of Asia. They are nearly in the latitude of the tropic of Cancer, and about 15 degrees, or 955 miles west from the coast of California. They consist of a cluster of about a dozen of islands, some of which, particularly Owhyee, the largest of them, contain a number of very high mountains, all obviously volcanic. Merinoroa, the most elevated of these, is, according to Kotzebue's measurement, 15,874 feet above the level of the sea. Merinokoak, in the same island, rises to an elevation of 13,936 feet. Merinowororoi is 10,788 feet high; while the highest peak in Mowee, another of these islands, has an elevation of 10,683 feet.

These islands form a striking contrast with the numerous groups situated nearly south from the Sandwich islands and near the tropic of Capricorn, most of which seem to be nothing else than coral reefs, which at a comparatively recent period have emerged above the surface of the sea.

St. Helena is a volcanic island, situated nearly half way between Africa and America, and in about 16° South latitude. It is almost all high land, its mean height being 1,400 feet. The following table exhibits the height of its most remarkable mountains above the level of the sea:—†

Diana's peak, . .	2,697 feet.
Cuckold point, . .	2,677
Halley's mount, . .	2,460
Flagstaff hill, . .	2,272
Sandybay ridge, . .	2,200
Longwood, . .	1,730
Lot, . . .	1,444
Lot's wife, . . .	1,423
Ladderhill, . . .	600

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* Russian Voyage of Discovery, Annual Register, vol. lxxi. p. 544.

† *Webster's Narrative, vol. i. p.* 344.

Ascension island lies to the north-west of St. Helena in about 8° South latitude. Green Mount, the highest part of it is elevated 2,818 feet above the level of the sea.*

In a general point of view, the North American mountains determine the declivities of the soil and the course of the rivers, over nearly the whole continent. On the west side of the chain the slope is rapid, and the rivers, so far as they are known, flow directly to the Pacific Ocean, passing through a high broken interrupted chain which skirts the coast. On the east side they bend their course to the nearest sea, over a surface little inclined, flowing to the north-east and north in the northern parts, and to the south-east and south in the southern parts. On looking attentively at the rivers in the map of North America, it will be perceived that the chain of lakes above lake Erie, the upper Mississippi, the Missouri, the Arkansas, and the Red River, all point in one direction—to the south-east. But in consequence of the Alleganies, a chain of mountains which run north and south through the states of the Union, the St. Lawrence and the Mississippi after running nearly parallel, till within 500 miles of the coast, are suddenly deflected from their south-east course and proceed to the sea in directions almost exactly opposite.

The whole region east of the rocky mountains, from the 50th parallel to the Arctic Sea, is generally low, abounds in lakes, and is scantily wooded as far north as the 60th degree of latitude, beyond which trees cease to grow. From the Gulf of Mexico to the mouth of the copper mine river in latitude 67°, the country may be considered as one great plain, the summit of which, about the 50th parallel, is not probably more than 1,000 feet above the level of the sea. According to Humboldt, the mean height of the great basin of the Missouri is not more than between 500 and 800 feet.

The interior of the country between Mackenzie's River and Behring's Straits, and between Hudson's Bay and the coast of Labrador, is mostly unknown, except by Franklin's journey, who confined himself to the seacoast. The former is probably fertile and tolerably wooded, as the whole of the region west of the rocky mountains has a wild and humid climate. The discoveries of Parry and Franklin have shown that the northern limits of the American continent run generally between the 67th and the 68th parallel, and that the space between this

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* Webster's Narrative, vol. i. p. 388.

and latitude 78° or 80° is occupied by a group of islands, of which Greenland may be considered as a part.

The following table shows the height of some of the principal inhabited places of the globe, above the sea :—[*]

	English feet.		English feet.
Micuipam pa (Peru),	11,870	Clermont,	1,348
Quito,	9,341	Geneva,	1,220
Santa Fe de Bogota,	8,730	Freyberg,	1,220
Cuença (Prov. of Quito),	8,639	Ulm,	1,211
Mexico,	7,471	Ratisbonne,	1,188
Hospital of St. Gothard,	6,807	Moscow,	984
St. Veran (Marit. Alps),	6,693	Gotha,	935
Village of Breuil (Alps),	6,564	Turin,	755
Village of Heas (Pyrenees)	4,816	Dijon,	712
Gavarnie (Pyrenees),	4,738	Lanark,	660
Briançon,	4,267	Prague,	587
Barege,	4,232	Moffat,	582
St. Ildefonso (Spain),	3,789	Cassel,	518
Pontarlier,	2,693	Vienna,	512
Madrid,	1,971	Lyons,	508
Inspruck,	1,857	Milan,	420
Munich,	1,765	Bologna,	397
Berne,	1,758	Parma,	305
Lausanne,	1,663	Dresden,	295
Mine master's house at		Paris (Observatory),	239
Leadhills,	1,564	Dalkeith,	200
Augsburg,	1,558	Rome (Capital),	151
Saltzburg,	1,483	Wirtemberg,	144
Neufchatel,	1,437	Holyroodhouse,	135
Plombiers,	1,381	Berlin,	131

As all the parts of the ocean have a free communication with each other, and as it is a well known property of water to find its level when left to the free action of its own gravity, it is natural to expect that the mean surface of the ocean will in every part of the world be of the same level. But this apparently reasonable supposition has not been verified by observation. It was suspected by the ancients that the level of the Red Sea was higher than that of the Mediterranean. While the French army, under Bonaparte, was in Egypt, a committee of engineers, under the direction of M. le Pere,

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[*] *Jour. de Mines*, xxxviii. 202.

was appointed to measure the exact height of each, by levelling across the isthmus of Suez, which separates these two seas from each other. The result was, that the surface of the Mediterranean is 26·63 feet lower than the low water surface of the Red Sea.

In like manner it has been ascertained by Mr. Lloyd, who levelled across the isthmus of Darien, that the mean height of the Pacific Ocean at Panama, on the west coast of America, is 3·52 feet higher than that of the Atlantic at Chagres, on the east coast.* But, on the other hand, it has been inferred from the trigonometrical surveys made in France, that the surfaces of the Mediterranean and Atlantic are almost exactly on a level.

From the levels of the canals, which have been made from the west to the east coast of England, or at least from the Severn to the Thames,† it has been shown that the level of the Irish Sea and St. George's Channel, on the west coast of England, is higher than that of the German Ocean by no less than 74 feet.‡ Even in Scotland it is obvious from the Forth and Clyde Canal, that the level of the mouth of the Clyde at Bowling Bay is somewhat higher than the mouth of the Forth at Grangemouth; for, from the summit level to Bowling Bay, on the west side, there are 18 locks, while to the east end of the Canal the number of locks are 19. This makes the surface of the water at the mouth of the Clyde about 10 feet higher than at Grangemouth.

The difference between the level of the Black and Caspian Seas is still more remarkable. It had been suspected that the surface of the Caspian Sea is about 300 feet lower than that of the Black Sea. Messrs. Engelhardt and Parrot levelled the whole space between the two seas no less than three times successively. The result was that the surface of the Caspian is 324·72 feet lower than that of the Black Sea, which is nearly on a level with the Mediterranean. It is obvious from this that Astracan, and the plains both of Russia and Persia bordering on the Caspian, are at a considerably lower level than the ocean.

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* Phil. Trans. 1830, p. 59. The summit level of the isthmus of Darien is 633·32 feet above the sea.

† From the observations of Mr. Lloyd, it appears that the mean level of the Thames, at the London docks, is 2·0359 feet above the mean level of the sea. Phil. Trans. 1831, p. 189.

‡ *Galton, Annals of Philosophy*, ix. 177.

The Caspian is much less salt than the Mediterranean; indeed, it contains only $\frac{1}{4}$th of the usual saline contents of sea water. Engelhardt and Parrot are of opinion that the Caspian originally stood at as high a level as the ocean, and that its surface has gradually sunk 324 feet, and thus laid dry a vast tract of country originally covered with water.

From this very general view of the surface of the terrestrial portion of the globe, it is obvious that a great proportion of it consists of level plains, while the mountainous regions, though considerable in point of extent, are confined to particular chains. The level districts of the earth are either covered with soil or with sand, or with stratified rocks, while the mountainous regions consist of rocks partly stratified and partly unstratified. When we dig into the level parts of the globe, we come always to beds of rock regularly stratified and deposited one above another, often horizontally, sometimes in an inclined position, and sometimes standing almost, or quite vertical. These rocks are sometimes composed of sand agglutinated together; sometimes of clay; sometimes of limestone; and many of them abound with fossils, consisting chiefly of sea shells, but sometimes of vegetable impressions, and sometimes of the bones of amphibious animals, quadrupeds or birds.

From the regular way in which these different beds are laid upon each other, from the nature of the ingredients of which they are composed, and from the sea shells with which they are frequently mixed, it is evident that these strata have been deposited at the bottom of the sea, and afterwards elevated either by the subsidence of the ocean or the elevation of its bed. They must therefore have been washed down from the mountainous parts of the earth by the action of the rain and rivers. These mountains must have in the course of ages been carried into the ocean, and immersed under its surface. Some notion of the length of time that must have elapsed before such a transference could be accomplished may be formed from this, that ever since the commencement of history, or for a period of at least 3000 years, the surface of the earth has been pretty much in the same state as at present.

For example, St. Michael's Mount, in Cornwall, is a small hill about 500 yards south from the dry beach, over against Merazion. It is about 231 feet high. During low water it is attached to the main land, so that you can walk to it from Merazion; but at high water it is an island being on all sides surrounded by the sea. This little island has been exposed to a very boisterous sea, yet during almost two thousand years its size and distance from the land has been very little altered; for Diodorus Siculus, who wrote during the reign of Augustus, and therefore rather before the commencement of the Christian era, gives an account of it under the name of Iktis (ἰκτις). He informs us that it was an island adjoining to Britain; that during the recess of the tide the intervening space is left dry, but at full tide, this passage being overflowed, it becomes an island.* This description would apply accurately to St. Michael's Mount at this day. Had any considerable change happened to it in an interval of at least 1800 years, surely it would have become either an island or a peninsula. The description of all the mountains, and most of the countries of Europe left us by the ancients, would apply almost exactly to them at the present day. It is true that in some places the sea has encroached somewhat upon the land, while in others the land has encroached upon the sea; but the alterations, taken as a whole, are insignificant. Athos, a conspicuous mountain in Macedonia, and running into the sea, was described with some minuteness by the ancients, and was represented by them as the highest in Greece. They even inform us how far its shadow extended at a particular season of the year, from which a tolerable inference may be drawn respecting its height. Now, Captain Gauttier measured it barometrically, and found its elevation above the sea to be 6,763 feet, a height which rather exceeds that deduced from the observations of the ancients.

Another remarkable circumstance connected with the strata of which the external crust of the globe is composed, is, that no remains of man are ever found fossilized in them. The lowest beds of all contain no fossils whatever. The next set of beds contain both animal and vegetable remains: the animal remains are shells, not one of which is identical with any shells at present existing in the ocean or in lakes. The same remark applies to the fossil plants, which, though numerous, cannot be identified with any vegetable bodies at present existing. We ascend a considerable way in the series before we come to amphibious animals; but the skeletons of several of these, of enormous size, and differing from any at present existing, have been met with in these strata. Quad-

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* Diodorus, Book v.

rupeds* and birds never appear till we come to those beds which are situated above the chalk; and even in these beds not a single bone has been discovered which can be identified with that of any quadruped or bird at present existing. Higher up still in the series we meet with beds containing shells partly similar to those at present existing, and partly consisting of extinct species. The proportion of those recent fossil shells increases as we advance upwards in the series. But we do not arrive at beds containing no fossil remains, but of animals at present existing on the earth or in the sea, till we come to those beds which are at present forming by the action of the sea, or rivers, or by the filling up of lakes, and therefore called *alluvial.* The remains of man, so far as is known at present, are confined to these alluvial beds.

From the preceding statement it is evident that a vast number of years must have elapsed before the earth was brought into the state in which it is at present. What was its appearance when it came originally out of the hands of the Creator we have no data to determine. No doubt its surface was partly land and partly sea; and at least from the period when plants and land animals made their appearance on it, the surface must have been unequal, and consisted of mountains and valleys as at present, otherways rain and rivers, to which the original surface owed its destruction, could not have existed.

The vegetable remains met with in such abundance in the coal beds resemble most those plants which at present are confined to the torrid zone. The same remark applies to the bones of amphibious animals and quadrupeds which occur in such abundance in Siberia, North America, and in England. They constitute pretty frequently extinct species belonging to genera at present confined to the torrid zone. This circumstance has led to the opinion that the temperature of the temperate and frozen zones is at present much lower than it once was, and that this change of temperature may have been one of the causes of the extinction of many species of animals which now no longer exist.

Be that as it may, it is impossible to doubt that both the animals and vegetables belonging to this globe have undergone very considerable changes since the original creation. Not a single species of the aboriginal animals and vegetables

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* In the Stonefieldslate, however, which is a portion of the Oolite formation, fossil *remains of a species of* Didelphis have been found.

any longer exist. The earth may have contained an indefinite number both of animals and vegetables, which disappeared in succession during the course of a very long series of ages. But we can only reason from those animals and vegetables whose fossil remains still exist.

Now, if we attend to the different strata of which the crust of the earth is composed, placed as they are above one another, it is obvious that the lowest of these strata must have been first formed, and that the order of formation must be the order of position. Consequently the animal and vegetable fossils in the lowest beds must be the most ancient inhabitants of the earth of which we can ever attain any knowledge. When strata, however distant from each other, contain the same fossil remains, we must conclude that they were deposited either simultaneously, or at least while the earth was inhabited by the same species of animals and vegetables. When the fossil remains alter in their nature, and present new tribes of animals and vegetables, we are sure that the temperature or some other essential circumstance has altered, and that the strata were deposited at a different period. How great an interval of time elapsed between the deposition of these and the former strata we have no means of even conjecturing. The little alteration which has taken place during the 4000 or 5000 years which have elapsed since the beginning of history, warrants our concluding that the interval between two such periods must be very long. Such is the mode by which we are enabled to form some notion of the relative antiquity of the different beds constituting the crust of the earth. Let us now turn our attention to these different beds.

CHAP. III.

OF FORMATIONS.

WHEN mineralogists first began to study the rocks, they observed that some of them contained the fossil remains of animals and vegetables, while others were quite destitute of any traces of such fossils. This induced Lehman, a German mineralogist, when he published his work *On the Strata of the Earth*, in 1759, to divide rocks into two classes, *primary* and *secondary*. The *primary* were those which contained no animal or vegetable remains; the *secondary*, those in which such remains existed, or at least those which alternated with strata containing such remains. This division has been attended to by all subsequent geologists, and may be considered as a first step towards a classification of rocks.

The primary and some of the secondary rocks were studied with great care by Saussure, who devoted the greatest part of his life to an examination and description of the Alps; and by Pallas, who, after much laborious travelling, drew up a geological account of the mountainous portion of the Russian empire.

But it is to Werner that geology is chiefly indebted for the high rank which it at present holds among the sciences. He was Professor of Mineralogy in the Mining Academy of Freyberg, in Saxony, and possessed an influence over the minds of his students that has seldom been equalled and never exceeded. He examined the structure of that part of Saxony where he resided, and determined the relative position of its different rocks. He then boldly generalized his observations, and affirmed that the structure of the whole earth was precisely similar to that portion of Saxony which he had examined. His pupils, actuated by an enthusiasm which nothing could damp, set about verifying the opinions of their master. Every corner of Europe was examined with that particular object in view. At first they scarcely ventured to differ from the dogmas of their teacher; yet knowledge accumulated prodigiously, and after the examination of the volcanic regions of the globe, which the Saxon professor had never had an opportunity of studying, some of the most fundamental positions of Werner were combated and rejected.

The regular distribution of the secondary rocks on every part of the earth's surface, was still maintained by the pupils of Werner. These secondary rocks or *formations* (as Werner had named them) were distinguished by appropriate names, derived from the nature of the rocks of which they were considered as composed; they were found in every part of Europe and America, and from the practice of giving the same name to rocks situated at a great distance from each other, and from considering them as having been deposited at the same time on every part of the earth where they occur, much confusion got into the descriptions, and geology was in danger of reverting again to a state of chaos and confusion; when Mr. William

Smith conceived the happy idea of verifying formations by the fossils which they contain, and of tracing the same formations by means of the identity of their fossils to great distances, and of determining this identity, even when the stony matter of which they were composed was entirely different.

Mr. Smith was a practical engineer in the neighbourhood of Bristol. The country round that city has been cut through in various directions, in consequence of the peculiar position of its coal beds. This made Mr. Smith well acquainted with the numerous rocks or formations in that interesting neighbourhood. The rocks round Bristol are full of animal remains, consisting chiefly of shells. It struck Mr. Smith as very remarkable, that every particular formation contained, and was distinguished by containing, particular species of shells not to be found in the other formations. He made a collection of these shells, and found, that by his knowledge of them, he could trace the particular formations to a great distance from Bristol. He generalized these observations, and concluded that every *formation* may be best distinguished by the petrifactions which it contains.

To verify this idea, he undertook a survey of England and the south of Scotland, and after an arduous labour of twenty years, produced his geological map of England, exhibiting the mineralogical structure of that kingdom.* It was this map which laid open the geology of England to the Geological Society of London, which had been formed a few years before. They have prosecuted the subject with an enthusiastic zeal and a liberality and perseverance, which does them infinite honour. Mr. Greenough, the original founder of the society, assisted by some of the most eminent of the Fellows, constructed a new geological map of England, in which the scientific names were introduced, and several corrections made upon the original map of Smith. Not satisfied with this, they have published a considerable number of volumes of Transactions, filled with original observations of the most valuable kind, in which they have thrown a new light, not only on the geology of England, but of every accessible part of the globe.

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* This map was published in the year 1815. But Mr. Smith was acquainted with the structure of a great part of England, and with the fossils peculiar to each bed, as early as the year 1799, if not earlier; for, during that year, he communicated his views on the subject to Mr. Townsend and various other geologists.

The errors of the Wernerian geology have been pointed out and expunged from the science, and the arrangement of the secondary rocks has been based upon the fossils which they contain, and not upon any supposed identity in their constituents.

The formations constituting the outer crust of the earth, so far as it has been penetrated, may be arranged under the following divisions; beginning with the uppermost and proceeding regularly in the order of position:—

1. Alluvial beds.
2. Diluvial.
3. Pliocene.
4. Miocene.
5. Eocene.
6. Chalk.
7. Green sand.
8. Oolite.
9. New red sandstone.
10. Coal beds.
11. Mountain limestone.
12. Old red sandstone and greywacke.
13. Clay slate and mica slate.
14. Gneiss.

Besides these, which, with their subdivisions, constitute the regular strata in the order of position, there occur other rocks, which seem to have forced themselves up through these regular strata, and either spread over them or insinuated themselves between them. These rocks are distinguished by the names of *granite*, *trap*, and *porphyry*. Several of these are peculiar, while others resemble the lavas from volcanoes. These it will be proper to consider, after having described the regular beds.

CHAP. IV.

OF ALLUVIAL AND DILUVIAL FORMATIONS.

In what state the earth came originally from the hands of the Creator, we have no means of knowing. Even supposing it to consist entirely of crystallized rocks, still there must have been part of the surface covered with water and part in the state of dry land as at present; and this dry land must have been distinguished by mountains and valleys, otherwise the economy of nature could not have been similar to what it has been since it was inhabited by man. We must admit that the vicissitudes of summer and winter, of rain and sunshine, followed each other as they do at this day. These wasting causes acted upon the mountains and rocks. The frosts in winter would loosen fragments of stone, which the rains and torrents would gradually carry to the low country, breaking them in their descent into smaller fragments, or to grains of sand. By this means the valleys and flat country would come gradually to be covered with soil, which is nothing else than rock comminuted or reduced to impalpable powder. Upon this soil vegetables would grow, and by their decay would naturally accumulate a matter fit to be employed as the food of plants. Animals would next make their appearance, after the earth became covered with a sufficient crop of plants to support them.

Now, this disintegration of rock, which must have commenced immediately after the creation of the earth, still continues and gives origin to various beds of clay, sand, gravel, pebbles, &c., which we occasionally meet with. The torrents which, after rain, run down the steep faces of the mountains, gradually wear deep ruts in them, and of course carry the fragments of rock removed from these places into the valley below. These fragments rubbing against each other are partly converted into powder and partly into rounded pebbles. The pebbles of course are soon deposited when the declivity begins to diminish; but the powder being light remains in suspension so long as the water continues to move rapidly. These streams, when they reach a lower level, naturally discharge their water into it, and thus form a lake. Here the water remaining stagnant, will deposit the mud with which it was impregnated, and make its escape at the farther extremity of the lake in a state of transparence and purity. If this process be allowed to go on long enough, the lake will be gradually filled up on all sides, except a channel through which the united streams will make their way in the form of a river. What constituted originally the bottom of the lake, will now be alluvial soil of greater or less thickness, and composed of an indefinite number of strata. These strata may be clay or sand, or loam, or gravel, &c., according to circumstances; or they may consist of alternations of these in every conceivable proportion. If the lake contained shell-fish, it is obvious that the remains of these shells will be mixed with the beds. If these shells be very numerous, they may convert the whole of the deposits into what in this country is usually called *marl*, and which is employed as a manure. Such is the case with the beds at the bottom of the lake Bakie in Forfarshire, described by Mr. Lyell.* Similar deposits of marl have been observed in different parts of Berwickshire.

In like manner it may be inferred from the appearances of the valleys of Sanquhar and Closeburn, in Dumfries-shire, that they were formerly lakes, which have been drained by the Nith forcing a passage at their lowest extremity, and thus carrying all their waters into the sea. Nor is it unlikely that the valley of the Annan, in the same county, was also at one time an extensive inland lake.† Humboldt is of opinion that the vast valley of the Mississippi and Missouri was at a remote period covered with water, but was drained by these rivers forcing a passage and carrying off the surface water into the Gulf of Mexico.

The Falls of Niagara furnish another remarkable example of a lake in the progress of draining. That river flows from Lake Erie to Lake Ontario; the former lake being 330 feet above the latter, and the distance between them being 32 miles. The river before reaching the falls is propelled with great rapidity, being a mile broad, about 25 feet deep, and having a descent of 50 feet in half a mile. It is precipitated over a ledge of hard limestone in horizontal strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the limestone forms an overhanging mass projecting 40 feet or more above the hollow space below. The disintegration of the shale is constant, and the limestone falls occasionally in huge masses with a noise like that of an earthquake. The waters, which expand at the Falls, are contracted again after their union into a stream not more than 160 yards broad. The bed of the river below the falls is strewed over with huge fragments which have been hurled down into the abyss. By the continued destruction of the rocks, the Falls have, within the last 40 years, receded nearly 50 yards. Through this deep chasm the Niagara flows for about seven miles; and then the table-land, which is almost on a level with Lake Erie, suddenly sinks down at a place called Queenstown, and the river emerges into a plane which continues to the shores of Lake Ontario.

There seems good reason for believing that the Falls were once at Queenstown, and that they have gradually receded

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* Geological Trans. (second series), ii. 71.

† See Jameson's *Mineralogical Description* of the County of Dumfries, *p. 22.*

about seven miles. This at the rate of 50 yards in 40 years must have required a space of almost 10,000 years; and should the erosion go on at a similar rate, at least 30,000 years will elapse before they reach Lake Erie. When that time comes, Lake Erie, the depth of which does not exceed 12 fathoms, will be suddenly drained, and a tremendous deluge will be the result.

Another source of alluvial soil is the action of the sea upon its shores. When the shore is rocky, the continual dashing of the spray against the face of these rocks, and the corroding effects of air and moisture cause their constant disintegration. Huge blocks are loosened, and tumble into the sea below. These masses are violently dashed against each other, and against the rocky shore, when the sea is agitated by a tempest; thus their corners are rubbed off, and they are converted into rounded water-worn shingles, which are piled up against the rocky shore, and thus the sea in such places raises a barrier against itself. This action of the sea is very well seen on the rocky shore of Scotland from St. Abb's Head, the southern extremity of the Firth of Forth to Berwick-upon-Tweed. The rocks are partly greywacke, and partly greenstone, and basalt, and porphyry. The fantastical shapes into which they have been worn, and the immense collection of fragments at their feet, and within the limits of the sea, are not a little striking. Nor are the phenomena less striking, though the nature of the rocks is different from the Redhead, at the northern extremity of the Firth of Tay to the Bullers of Buchan, at the northern termination of Aberdeenshire. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated 150 yards inland, where it has maintained its ground ever since, the new village having been built farther inland upon a new shore.*

Even the chalk cliffs at Flamborough Head are perceptibly yielding to the destroying action of the sea. But the waste is much more rapid between that promontory and the Spurn Point. This tract consists chiefly of beds of clay, gravel, sand, and chalk rubble. The irregular mixture of the clay beds causes many springs to be thrown out, which facilitates

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* *Lyell's* Geology, i. 302.

the undermining process. Apprehensions are entertained that before long the Spurn Point will become an island, and that the ocean entering into the estuary of the Humber will cause great devastations. For the devastations committed by the sea upon the coasts of Norfolk, Suffolk, and Kent, and the south of England, we refer the reader to Mr. Lyell, who has described them in detail, and in his usual interesting manner.*

Even in the estuary of the Forth, the sea has committed great devastations within the memory of many persons living. About forty years ago there was a road from Leith to Newhaven along the sea shore, between which and the sea there was a considerable beach. The whole of this beach, together with the road, was swept away by the sea in one winter. Even that part of the beach which lies between the battery and the sea, though protected by a stone wall raised at a great expense, has been repeatedly injured.

To these inroads of the sea, on various parts of the coast, we are to ascribe the submarine forests which have been observed in various places on the coast of England. A submarine forest on the coast of Lincoln was described many years ago by Correa de Serra.† A number of islands extending a considerable way along the coast were found to consist almost entirely of roots, trunks, branches, and leaves of trees and shrubs intermixed with some leaves of aquatic plants.

In 1832 Mr. Yates gave an account to the Geological Society of London of a submarine forest in Cardigan Bay. It extends along the coast of Merionethshire and Cardiganshire, being divided into two parts by the estuary of the river Dovey, which separates those counties. It is bounded on the land side by a sandy beach and a wall of shingles. Beyond this wall is a tract of bog and marsh formed by streams of water which ooze out through the sand and shingles. The remains of the forest are covered by a bed of peat, and are distinguished by an abundance of *Pholas candida* and *Teredo navalis*. Among the trees, of which the forest consisted, is the pinus sylvestris, or Scotch fir. The tradition is, that this forest was submerged in the year 520.

Mr. Charles Harris discovered evident traces of a fir wood

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* Lyell's Geology, i. 306, &c.

† *Phil. Trans., 1799, p. 145.*

beneath the mean level of the sea at Bournmouth, in Hampshire, the formation having been laid open during a low spring tide. It is situated between the beach and a bar of sand about 200 yards off, and extends 50 yards along the shore, cropping out from beneath the sand and shingle. The formation consists of a stratum of soft peat, in which are implanted several large stumps of fir from one to two feet in height, the roots and bases of which still retain their bark.*

Forests buried under the surface of the ground are met with occasionally at a distance from the sea. There is a remarkable example of this about four miles west from Newcastle-upon-Tyne, near the river. About five years ago a new road was made in that direction, and a field was dug through to the depth of about four feet. It was found to consist of a vast number of trees lying on their sides, and only a few feet below the surface. Many of the trees were almost fresh. The moss of Kincardine, about six miles west from Stirling, consists of a bed of peat from 8 to 12 feet thick. At the bottom of it are a vast number of trees which have been cut down, and lie usually with their tops turned eastwards. Even the hatchets with which the trees had been cut down are occasionally found in the moss. It has been supposed by some that this is the remains of the Caledonian forest which was cut down by Agricola.

It is exceedingly probable that forests either cut down on purpose or allowed to fall down from old age after they have ceased to vegetate, have given origin to many of the mosses which are found in such abundance in the temperate regions of the northern hemisphere; at least there are few mosses in Great Britain or Ireland in which the trunks of trees (especially pines) are not found. This is even the case in the mosses of Caithness; though at present that county is nearly destitute of wood, and though the proprietors have not been able to succeed in making trees to grow, at least to any height.

The trees, after falling, occasioned a quantity of water to stagnate round them, and thus converted the tract into a bog. In this bog different species of sphagnum naturally made their appearance. This moss has the property of decaying below, while a new crop vegetates on the surface; and in this way a considerable thickness of decayed vegetable matter was accumulated round the trees. This matter, from the combined

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* *Lyell's* Geology, ii. 274.

action of water and pressure, gradually assumed the nature of peat, so that the whole tract was converted into a moss.

Considerable tracts of alluvial land have been accumulated round the coast of Denmark, partly in the state of islands, and partly attached to the main land. Of the formation and history of these tracts, a very interesting account is given in the first volume of M. de Luc's *Geological Travels*, to which we refer the reader for much curious information respecting the way in which land is formed on the borders of the sea.

Besides these alluvial formations, there are others of a similar nature, but which, judging from the fossil remains which they contain, must have been formed at a time when the state of the earth was different from what it is now. These formations bear unequivocal marks of deriving their existence from the action of water. On that account they have been distinguished by Dr. Buckland, and most modern geologists, by the name of *diluvial* deposits.*

A very remarkable *diluvial* formation occurs under the town of Brighton, in Sussex, which has been very well described by Mr. Mantell.† Brighton is situated on an immense accumulation of water-worn materials, which fills up a valley or hollow in the chalk. It is enclosed in chalk on every side, except the south, where it is washed by the sea, forming a cliff, from 70 to 80 feet high. It is composed of broken fragments of chalk, with angular pieces of flint, imbedded in a calcareous mass, of a yellow colour, constituting a hard and coarse conglomerate. It is not stratified, but is merely a confused heap of alluvial materials. In the inferior portion of the mass the chalk is reduced to very small pieces, which gradually become large in proportion to their height in the cliff. At length fragments of flint appear, and these increase in size and number as they approach the upper part of the bed, of which they constitute the most considerable portion. These flints are more or less broken, and resemble those which have been long exposed to the atmosphere. It contains also water-worn blocks of siliceous sandstone, and ferruginous breccia. Thus, all its constituents are obviously derived from the rocks in the neighbourhood, which must have been forcibly broken and triturated by the violent action of water, though at present they are several hundred feet above the level of the

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* From the Latin word *diluvium*, which signifies *a flood*.

† *Geology of the South East of* England, p. 29.

sea; and before the upper portions of them were worn away they must undoubtedly have been considerably higher.

The organic remains discovered in this deposit are the bones and teeth of the ox, deer, horse, and of the Asiatic elephant. These occur but seldom, and are generally more or less water-worn; but in some instances they are quite entire, and cannot have been subject to the action of the waves. It is obvious from this, that this deposit (called by Mr. Mantell the *elephant bed*) must have been formed at a time when the south of England was inhabited at once by the Asiatic elephant, the ox, the deer, and the horse, and therefore at a time when the climate was milder than at present.

The city of Glasgow is built upon a thick bed of siliceous sand, composed of grains of quartz obviously water-worn. To the north and west of the city there are low hills composed of clay, interspersed with fragments of other rocks, most commonly clayslate, greenstone and sandstone, though I have met with a few fragments of granite and porphyry. These fragments are often of the size of the human head, or even larger. They are all rounded, and obviously water-worn. The hill at the west end of the city is elevated at least 200 feet above the surface of the Clyde. This hill, called Blythswood hill, is composed of the same clay as the other hills in the neighbourhood. The sand is very similar in appearance to what constitutes at present the bed of the Clyde. We might therefore suppose that it had been formed in the course of ages by the action of that river, which might perhaps have repeatedly altered its course, and thus given birth to a pretty broad tract of sand. But the existence of Blythswood hill, and the hill to the north of the city, which consist of beds of sandstone, covered at the top by eight or ten feet of clay, could not well be ascribed to any such deviations of the course of the river. The sand and the clay can be observed in contact nowhere in the immediate neighbourhood of Glasgow; but at Dalmuir, about seven miles down the Clyde, the sand is seen very evidently overlying the clay. We may therefore conclude, from analogy, that at Glasgow the clay (constituting the rising grounds) is an older deposit than the sand.

But the remarkable circumstance, which throws back the formation of this deposit of sand to a very remote era, is, that it is traversed from east to west by two dykes or veins of greenstone, which probably hold a direction approaching to parallel, at a distance of about half a furlong from each other.

The farthest south of these dykes was cut through about 16 years ago, in making a common sewer in Virginia Street. The greenstone dyke was found to cross the street somewhere about the middle of its length. The other dyke was detected about 5 years ago, while digging the foundation of the Bank of Scotland, on the north side of Ingram Street, at the end of Glassford Street. About a year after, the same dyke was met with at the western extremity of College Street, while digging the foundation of the Chemistry laboratory and Class-room. This situation is a little to the north of the former. Hence, the dyke seems to run from east by north, to west by south. It was not possible to determine the thickness of these dykes, nor to examine their junction with the sand. They consisted of a hard small-grained greenstone, very similar to other rocks of the same formation in the neighbourhood. If these greenstone dykes were deposited after the formation of the sand, it is evident that the date of this diluvial deposit, upon which Glasgow is built, must be very remote.

The hill on the north side of the city of Glasgow, and upon which the oldest portion of the town is built, may be about 300 feet above the bed of the Clyde. It is a round-backed hill, running from west to east, and gradually sinking at both extremities. The under portion of this hill is composed of thick beds of coal sandstone, alternating with thin beds of slate clay and shale. The upper portion is a thick bed of strong blue clay, without any visible stratification. It is full of water-worn pebbles of different sizes; the largest, which consist of rounded blocks of greenstone and granite, are found towards the bottom; the smaller pebbles, of red and yellow sandstone, clay slate and quartz, are nearer the surface. These pebbles are all quite smooth, and those of greenstone and granite are often almost spherical.

No shells have been observed in the gravelly soil upon which Glasgow is built; but the same kind of bed may be traced a considerable way down the Clyde, and depôts of shells have been observed at Rothesay, Paisley and Roseneath. Near Dalmuir, in the parish of Old Kilpatrick, about 7 miles west from Glasgow, there occurs a bed of shells, at least 8 feet thick. This bed lies in the gravel, and constitutes a circular space about 4 yards in diameter. All the shells are recent, and most of them belong to species still existing in the sea on the west coast of Scotland. The following 29 species were picked up by my son in this bed, during about half an hour's examination on two separate days:—[*]

Echinite.

1. Echinus esculentus.

Shells.

1. Serpula,
2. Balanus scoticus,
3. Mya truncata,
4. Saxicava rugosa,
5. Amphidesma Boysii,
6. Tellina tenuis,
7. Lucina flexuosa,
8. Astarte minima,
9. Cyprina vulgaris,
10. Nucula minuta,
11. Cardium edule,
12. Anomia ephippium,
13. Mytilus edulis,
14. Modiola albicostata,
15. Pecten Islandicus,
16. Pecten pusio,
17. Patella parva,
18. Fissurella Noachina,
19. Velutina communis,
20. Helix lævigata,
21. Natica glaucinoides,
22. Littorina vulgaris,
23. Trochus cinerarius,
24. Lacuna vincta,
25. Rissoa,
26. Fusus Bamffius,
27. Fusus lamellosus,
28. Buccinum undatum,
29. Buccinum striatum.

These shells are all natives of the British sea, with the exception of the Fusus lamellosus, which has only been observed about the Straits of Magellan, and the natica glaucinoides, which is a crag fossil. But the most common shells in the neighbouring sea are the rarest at Dalmuir; while those found at Dalmuir in the greatest profusion are mostly rare in the sea. Thus of the Mya truncata, one of the commonest shells in the Firth of Clyde, only one imperfect specimen was found at Dalmuir; while the Fusus Bamffius, Lacuna vincta, Fissurella Noachina, and Astarte minima, none of which are common shells, together with Natica glaucinoides, a crag fossil, are very common at Dalmuir.

The carse of Stirling bears some resemblance to the alluvial formation round Glasgow. The uppermost bed of the carse is a stiff blue clay, containing numerous fragments of shells about a foot and a half below the surface, but so tender and so much broken that only two species have been made out; namely, the *cardium edule* and the *turbo littoreus*. There is a third species (perhaps a *tellina*), but so much broken that it cannot be determined with certainty. These shells are

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[*] See his paper in the Records of General Science, i. 131.

common in the Frith of Forth at this day. They show in the most unequivocal manner, that the whole carse has been covered by the sea since it has been inhabited by the same shell fish that live in it at present.

Below the clay lies a bed of sand of unknown thickness. The clay bed is thickest at the east end, and gradually thins out to the west. At Touch, about 3 miles west of Stirling, it is only a few inches thick. At the Castlehill of Stirling its thickness is 21 feet. Farther east than this I am not aware that the sand has been observed under the clay, though its existence may probably be inferred from analogy.

That part of Inverness-shire through which the Caledonian canal has been cut consists of a diluvial gravel of very considerable thickness. It is composed of water-worn pebbles, chiefly or entirely derived from the rocks in the neighbourhood.

The east coast of Sutherland from the Ord of Caithness to the Firth of Dornoch, a few spots excepted, consisted some years ago of a deep mould thickly mixed with rounded boulders of granite of all sizes, from several tons weight to the size of a pea. The late Duke of Sutherland improved a considerable portion of this tract at an immense expense, by trenching the whole and blasting the boulders, which were built up into walls by which the fields were divided.

Connected with these diluvial deposits are the immense masses of rock which have been carried to a great distance from the mountain masses whence they were taken, and deposited upon the surface. Thus the west coast of Ayrshire, in Scotland, is scattered thick with blocks of granite, obviously of the same kind as what constitutes the central Arran mountains. Now, between Arran and Ayrshire there is interposed a portion of sea, which in its narrowest part is twelve miles broad. It seems impossible to conceive that these blocks were transported through the sea. The transport must have taken place either at a time when Arran was joined to the mainland of Scotland, or when the coast of Ayr was sunk under the sea, and at least as deep as any part of the sea between it and Arran.

At Crieff, in Perthshire, there occurs a series of low hills running parallel to the Grampians. These hills consist of old red sandstone and greywacke. On one of them, the Cnock, the village of Crieff is built. Upon the south-east side of this hill, *towards the southern* extremity, not far from the summit, there are deposited a number of boulder stones of syenitic granite. The largest of these is called the *cradlestone.* It is nearly spherical, quite smooth on the surface, and 29 feet in circumference. It has been split in two by lightning, (according to the tradition of the place,) and one of the fragments has made one complete revolution down the hill and then stopped. The weight of this boulder is about 30 tons. The nearest mountains of syenitic granite, are those in the neighbourhood of Bennevis, distant more than 60 miles north-west, and between which and the Cnock, a considerable number of mountains are interposed, composed of porphyry, mica slate, and clay slate. It is impossible that such a block could have made its way to such a distance and over such obstacles. It is obvious, that when it was transported to Strathearn, the mountains at present interposed could not have existed.

Many similar boulders have been observed in the vales of Westmoreland and round the Solway Firth, and indeed in many parts of England.

Dr. Hibbert found fragments of rocks at Papa Stour, in the Shetland islands, which must have travelled twelve miles from Hillswickness. At Soulam Voe, open to the northern ocean, there are boulders three or four feet high, which do not correspond with any rocks in the country, and were probably derived from the northwards.

The vast number of erratic blocks of granite on the south side of the Baltic, and indeed scattered over the surface of Sweden and Russia, have been long known. All these correspond with the mountains on the north of Scandinavia and Russia. Count Razomouski informs us, that where many blocks are accumulated, they form parallel ranges with a direction from north-east to south-west. These blocks are very numerous between St. Petersburgh and Moscow, and are all composed of Scandinavian rocks. In some places, particularly in Esthonia, they appear and disappear at greater or smaller intervals, apparently owing to the form of the land at the time of their transport. They occur abundantly on the heights, and are but rarely and thinly scattered over the lowlands. Professor Pusch informs us, that the erratic blocks, from the Duna to the Niemen, are composed of granite resembling that of Wiborg in Finland, of another granite with Labrador felspar from Ingria, of a red quartzose sandstone from the shores of lake Onega, and of a transition limestone from *Esthonia and Ingria.*

In eastern Prussia, and in that part of Poland situated between the Vistula and the Niemen, the granitic blocks are abundant: three varieties of granite are the same as those found in Finland, at Abo, and Helsinfors: another coarse-grained granite and a syenite, are also from the north. The hornblende blocks of the same countries, are from southern and central Finland. The quartzose blocks are exactly the same as the rocks named Fjall Sandstein, between Sweden and Norway. While the porphyry blocks have the same character as the porphyries of Elfsdalen in Sweden. From Warsaw to the west, towards Kalish and Posen, the blocks of red granite of Finland diminish in number, but those composed of hornblende rocks and gneiss become more abundant, as is also the case with those of porphyry. Few Finland rocks are found there, while those of Sweden are common.*

Blocks of extraordinary magnitude have been observed at the foot of the Alps, and at a considerable height in some of the valleys of the Jura, exactly opposite the principal openings by which rivers descend from the Alps. These blocks are composed of the same materials as the rocks of the Alps, from which they must have proceeded. Many speculations have been indulged in to account for the transportation of these blocks, such as ice, torrents, the rising or subsidence of the mountains. But it seems unnecessary to enter upon such speculations, because nothing better than conjecture has been advanced in their support.

Another remarkable class of substances which have been considered as diluvial, are collections of bones accumulated in caverns. Geologists are obliged to Dr. Buckland for first turning their attention to this subject, and for contriving a theory, so ingenious and plausible, that it has been generally adopted. The cavern of Kirkdale, in Yorkshire, was discovered in 1821. Dr. Buckland visited it in the autumn of that year, and inserted a full account of the fossils found in it in the *Philosophical Transactions* for 1822. The cavern occurs in a bed of oolitic limestone, and is situated about 36 feet above the bed of the Hodge Beck. It lies on the north side of the valley of Pickering, in Yorkshire, distant about 25 miles from the city of York. The cave was accidentally opened by workmen while engaged in quarrying the rock.

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* Pusch, Jour. de Geologie, ii. 253, as quoted by De la Beche, Manual, p. 172.

It is a low zig-zag cave extending in length above 150 feet and from 2 to 7 feet in height. It is partly filled with stalactite and stalagmite, and the bottom contains a bed of mud, in which the bones are irregularly distributed. The bones are those of a *hyæna*,* similar to the species which occurs at the Cape of Good Hope, of the *bear (ursus spelæus)*, the *tiger*, the *fox*, the *wolf*, the *elephant*, the *rhinoceros*, the *hippopotamus*, the *ox*, a very large *deer*, various species of *deer*, the *water-rat*, the *rabbit*, the *mouse*, the *raven*, the *pigeon*, the *duck*, the *hog*. No complete skeleton of any of these animals occurred, but only detached bones. These bones were much worn down, or *gnawed*, as Dr. Buckland expresses it. And fragments of a substance like album græcum, which he considers as the excrement of hyænas, were also found. Dr. Buckland also mentions bones of the *horse* among those found in the cave; but Mr. Young assures us that these bones had been introduced by some persons in the neighbourhood with the malicious design of misleading the doctor in his researches. Dr. Buckland is of opinion, that at a very remote period when hyænas, and other tropical animals, were inhabitants of England, this cave was occupied as a den of hyænas. That these animals had dragged fragments of the carcasses of the larger quadrupeds into their den, and after devouring the flesh had left the bones. The smaller animals were dragged in altogether. The *flood*, he is opinion, surprised these animals in their den, but did not enter with such rapidity as not to permit them to escape. Hence the reason why no skeletons of hyænas have been found in this cave. The cave being filled with muddy water, this mud gradually subsided and enveloped the bones.

Such is the theory of Dr. Buckland respecting the bones in this cavern, and he has rendered it by his ingenuity exceedingly plausible. Even though we should hesitate about adopting his conclusion that the cavern was a hyæna's den, still it could scarcely be doubted from the phenomena that the cavern had been filled with turbid water, at a time when the animals, whose bones are found, inhabited England, and consequently when the climate was very different from what it is at present.

Caverns with similar deposits of bones and muddy matter

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* Of the bones found in such caverns about eleven-twelfths belong to carnivorous animals. Three-fourths are the bones of *bears*, one-sixth of *hyænas, and the remaining* one-twelfth, the bones of all the other animals.

are found in other parts of England. Thus three different caverns were met with in the limestone rock at Oreston in Catwater, near Plymouth, by the workmen while quarrying stones for the Plymouth breakwater. An account of these caverns by Mr. Whidbey has been published in the *Philosophical Transactions.**

The bones found in the first cavern, discovered in 1816, belonged all to the rhinoceros. One cavern, found in 1820, contained bones and teeth of the bear; and another contiguous contained only bones of a deer or antelope. In the cavern discovered in 1822 were found the bones of the ox, the deer, the horse, the hyæna, the wolf and the fox. These caverns communicated with each other, and the bones of the herbivorous animals were found huddled together, but those of the carnivorous at a distance from each other: those of the hyæna being in one cavity, and those of the wolf and fox in another. Some of these bones were partially covered with stalagmite, but most of them were merely imbedded in a stiff clay which filled the bottom of the caverns. From the trials of Mr. Clift it appeared that these bones had been deprived of almost all their cartilaginous matter, which was not the case with those in the Kirkdale cavern.

Banwell cave, in the Mendip hills, was found to contain bones of the bear, cat, deer, ox, and some other animals. Similar caverns have been met with at Torquay, and in different parts of Wales.

The German caverns of Gailenreuth, Küloch, Bauman, &c. contain an abundance of bones, nearly identical, according to Cuvier, over a space of 200 leagues, by far the greater proportion being referrible to two extinct species of bear, *Ursus spelæus* and *Ursus arctoideus.* The remainder consist of the extinct *hyæna* (the same as in the Kirkdale cave), a *felis*, a *glutton*, a *wolf*, a *fox* and *polecat.* In these caves there is more or less of a stalagmitic crust, beneath which the bones are discovered, the stalagmitic matter being frequently transfused through the previously deposed sediment. They contain occasionally also some water-worn pebbles.

I think it unnecessary to describe similar caverns which have been met with in various parts of France; nor the osseous breccias of Italy, Sardinia, Gibraltar, Corsica, and other places on the shores of the Mediterranean.

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* Phil. Trans., 1823, p. 78.

But it may be worth while to notice a similar cave discovered in New South Wales, and described by Major Mitchell. The principal ossiferous cavity is situated near a large cave in Wellington valley, about 170 miles from Newcastle, through which valley flows the river Bell, one of the principal sources of the Macquarrie. The cavern is a wide and irregular well or fissure, accessible only by ladders or ropes, and the breccia is a mixture of limestone fragments of various sizes, and bones enveloped in an earthy red calcareous stone. The bones have been referred to the *kangaroo*, *wombat*, *dasyurus*, *koala* and *phalangista*, all animals at present existing in New Holland. But bones also of the elephant have been met with in it, and in another cavern bones of a kangaroo, exceeding by one-third the largest known species of that genus.

Dr. Bigsby has described a cavern at Lanark, in Upper Canada. The floor is covered with the debris of a brown granular limestone, similar to that of the rock in which the cavern exists, forming, with the bones, a kind of breccia, similar to that in the cavern of Adelsberg.

In some of these ossiferous caverns in France, along with the bones there occur fragments of ancient pottery, and occasionally human bones, showing that at least a portion of these bones were deposited in the caverns after the country had been inhabited by man. In some of the Welsh caves human bones have been found, but from the way in which they are deposited there is reason to believe that they had been employed as burying places.

It is evident from these examples, and many more might have been adduced, that what have been called *diluvial deposits* are of very different ages, and that, like all the other beds constituting the crust of the earth, they owe their origin to the action of water. It would not be an easy matter to distinguish between alluvial and diluvial deposits; probably, in many cases there is no real distinction in the agents, excepting, perhaps, in their amount.

CHAP. V.

OF PLIOCENE FORMATIONS.

THE term *pliocene** has been contrived by Mr. Lyell, and applied to certain tertiary deposits distinguished by the great number of recent shells which they contain, but mixed with many species which no longer exist. These beds he subdivides into two groups, namely, *newer* pliocene, and *older* pliocene; the former containing a greater proportion of recent shells than the latter. The following table exhibits Mr. Lyell's arrangement of these strata:—

I. *Newer Pliocene.*

Character.	Localities.
Marine.	Strata of the Val di Noto, in Sicily, Ischia, Morea? Uddevalla.
Fresh water.	Valley of the Elsa, around Colle, in Tuscany.
Volcanic.	Older parts of Vesuvius, Etna and Ischia—volcanic rocks of the Val di Noto.

II. *Older Pliocene.*

Character.	Localities.
Marine.	Northern sub-appenine formations, as at Parma, Asti, Sienna, Perpignan, Nice—English crag.
Fresh water.	Alternating with marine beds near the town of Sienna.
Volcanic.	Volcanoes of Tuscany and Campagna di Roma.

We shall treat of these two groups in their order.

I. *Newer Pliocene Formations.*

The most remarkable of these beds exists in the Island of Sicily. About two-thirds of this island are occupied by primary and secondary rocks, the remaining third is covered by tertiary formations, which are of great extent in the southern and central parts of the island.

The Val di Noto is a district which intervenes between Etna and the southern promontory of Sicily. A considerable tract of it, containing within it hills which are from 1000 to 2000 feet in height, entirely composed of limestone, marl, sandstone,

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* From *πλειων*, *greater*, and *καινος*, *new*.

and associated volcanic rocks, belongs to the newer pliocene era. These rising grounds of the Val di Noto are separated from the cone of Etna and the marine strata whereon it rests by the low flat plain of Catania, just elevated above the level of the sea, and watered by the Simeto. The whole series of its strata are divisible into three groups, exclusive of the associated volcanic rocks. The uppermost mass consists of limestone, which sometimes constitutes a bed 700 or 800 feet in thickness. Below this, but much inferior in thickness, the following beds occur in the order in which they are named :—

2. Calcareous sandstone.
3. Conglomerate.
4. Shistose limestone.
5. Blue marl.

The whole of these beds contain shells and zoophytes, nearly all of which are referrible to species now inhabiting the contiguous sea.

The uppermost, or *great limestone* bed, often resembles the yellowish-white building stone of Paris, well known by the name of *calcaire grossière*, or coarse limestone; but it often passes into a much more compact stone. In the valleys of Sortino and Pentalica it is in strata nearly horizontal, and very regular. It abounds in natural caverns. The shells in this limestone are often very indistinct, sometimes nothing but casts remaining; but in many localities, especially where there is a slight intermixture of volcanic sand, they are more entire, and can almost all be identified with recent Mediterranean testacea. Several species of pecten, particularly the *Jacobæus*, or large scallop, now so common on the coasts of Sicily, are very numerous. The following shells, at present found in the Mediterranean, have been figured by Mr. Lyell as occurring in this formation :—

Turbo rugosus,
Trochus majus,
Solarium variegatum,
Tornatella fasciata,
Pleurotoma vulpecula,
Buccinum prismaticum,
Cassidaria echinophora,
Cytherea exoleta.

A list of the other shells belonging to this formation will be found in M. Deshayes's tables of fossil shells, inserted at the end of the third volume of Lyell's *Geology*, to which the reader is referred.

The mineral characters of this great calcareous formation vary considerably in different parts of Sicily. In the south, *near* the town of Noto, the rock puts on the compactness, together with the spheroidal concretionary structure of some of the Italian travertins. At the same place it contains the leaves of plants and reeds. At Spaccaforno, and other places in the south of Sicily, a similar compact variety of limestone occurs, where it is for the most part pure white, often very thick, and without any lines of stratification. This hard white rock is often four or five hundred feet in thickness, and appears to contain no fossil shells. It has much the appearance of having been precipitated from the waters of mineral springs, such as frequently rise up from the bottom of the sea in the volcanic regions of the Mediterranean.

This great limestone passes downwards into a *white calcareous sand*, which has sometimes a tendency to an oolitic and pisolitic structure. At Florida, near Syracuse, it contains a sufficient number of small calcareous pebbles to constitute a conglomerate, where also beds of sandy limestone are associated, replete with numerous fragments of shells, and much resembling the English cornbrash. In some parts of the island this bed seems to be represented by yellow sand, like that superimposed on the blue shelly marl of the Subappenines in the Italian peninsula.

Under the preeeding beds is found an argillaceous deposit of variable thickness, called *creta* in Sicily. It resembles the blue marl of the Subappenine hills, and like it, encloses fossil shells and corals in a beautiful state of preservation. A list of these shells will be found in Deshayes's table at the end of Lyell's Geology. Almost the whole of them are identical with shells at present existing in the Mediterranean.

This bed usually rests on an older series of white and blue marls, containing skeletons of fish interposed between the thin laminæ of the white marls.

The volcanic rocks associated with these beds, constitute a very prominent feature in the Val di Noto. These lavas sometimes lie under and sometimes over the stratified rocks. For we find dykes of lava intersecting both the marl and limestone, while in other places calcareous beds repose upon lava, and are unaltered at the point of contact. Thus the shelly limestone of Capo Santa Croce, rests in horizontal beds upon a mass of lava, which had evidently been long exposed to the action of the waves, so that the surface has been worn quite smooth. This limestone is unchanged at its junction, and encloses within it pebbles of lava.

The volcanic rock of the Val di Noto, usually consists of the most ordinary variety of basalt with or without olivine. It is sometimes compact, often very vesicular. The vesicles are either empty or filled with calcareous spar, arragonite, and zeolites. The structure is sometimes spheroidal and sometimes, though rarely, columnar.

The formation of these different pliocene rocks seems to have been a very slow process. Near Lentini, Mr. Lyell found some imbedded volcanic pebbles, covered with full grown serpulæ. At Vizzini, a bed of oysters, the same as our eatable species, and twenty feet thick is seen resting upon a current of basaltic lava. Upon the oyster bed is superimposed a second mass of lava, together with tuff and piperino. Near Galieri, a horizontal bed about a foot and a half thick, composed entirely of a common Mediterranean coral (*Caryophyllia cespitosa*) is seen in the midst of the same series of alternating igneous and aqueous formations. These corals stand erect as they grew, and after being traced for hundreds of yards, are again found at a corresponding height on the opposite side of the valley.*

Similar deposits of newer pliocene formations were observed by Mr. Lyell at the foot of Mount Etna. At the base of the cone there runs a low line of hills formed of clays and marls, associated with yellow sand, similar to the formation provincially termed *Creta* in different parts of Sicily. This marine formation, composed partly of volcanic and partly of sedimentary rocks, is seen to underlie the modern lavas of Etna. Its extent cannot be determined; but it contains the same shells and constitutes a similar formation with that in the Val di Noto already described.

The same formation exists on the east side of Etna and in the Cyclopian islands, in the larger of which it seems to have been heaved up and contorted by masses of columnar lava that lie under it. Mr. Lyell is of opinion, that the whole of Mount Etna, except what has been formed during the historical era, belongs to the newer pliocene formation. On the eastern side of the mountain there is a deep valley called Val del Bove, where the structure of the mountain may be studied. It is a vast amphitheatre four or five miles in diameter, surrounded by vertical precipices, varying from 1000 to above 3000 feet in height. Here a great multitude of vertical dykes may be seen in all directions traversing the volcanic

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* Lyell's Geology, iii. 62.

beds, which all dip towards the sea. Some of those dykes are compact trachyte, others consist of blue basalt with olivine. They vary in breadth from 2 to 20 feet and upwards, and usually project from the face of the cliff. They consist of harder materials than the strata which they cut, and therefore waste away less rapidly. They obviously consist of lava currents which made their way through rents in the older lavas.

Mr. Lyell is of opinion, that these newer pliocene beds were gradually deposited at the bottom of the sea by aqueous attrition from the rocks, &c., on the contiguous land, that there they were mixed with the shells which existed in the Mediterranean at the time of their deposition; and that they were gradually and slowly hardened and elevated by volcanic energy. He has produced a great many proofs, that the sea coast in many parts of Italy has been raised within the historical era. One of the most remarkable of these examples, is the temple of Serapis at Puzzuoli. The base when built, must have been above the level of the sea. Afterwards it sunk below that level, as is obvious from the columns, to the height of 20 feet being perforated by Lithodomous shells. Finally, it must have been again elevated at least as high as when originally built.[*]

Mr. Lyell has pointed out the existence of similar newer pliocene formations in Campania, at Conception bay in Chili, the parallel roads of Coquimbo in the same country, at Honduras, Madeira, and in several other localities.

Several fresh water formations of the same period are also enumerated by him, as the valley of Elsa in Tuscany, between Florence and Sienna, where we meet with fresh water marls and travertins[†] full of shells, belonging to species which now live in the lakes and rivers of Italy. Valleys several hundred feet deep have been excavated through the lacustrine beds, and the ancient town of Colle stands on a hill composed of them. The travertins and calcareous tufas which cap the hills at Rome, may belong to the same period. The terrestrial shells enclosed in these masses, are of the same species as

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[*] Lyell's Geology, i. 517.

[†] The term *travertin* is applied by the Italians to a limestone deposited from the water of springs holding lime in solution. The Germans give to the same substance the name of *kalktuff*. The Italian word is a corruption of the term *Tiburtinus*, the stone being formed in great quantity by the river *Anio at Tiber, near Rome*, and hence it was called by the ancients *Lapis Tiburtinus*.

those now abounding in the gardens of Rome; and the accompanying aquatic shells are such as are found in the streams and lakes of the Campagna. On Mount Aventine, the Vatican, and the Capitol, we find abundance of vegetable matter, principally reeds encrusted with calcareous tufa, and intermixed with volcanic sand and pumice.*

Several fresh water breccias belonging to the same period occur in Sicily. Thus, for example, caves occur in the newest pliocene limestone of the Val di Noto, containing a breccia in which bones of extinct species of the elephant and hippopotamus occur. Similar caves are met with near Palermo. Mr. Lyell assigns the erratic blocks of the Alps to the same period.

In the pliocene formations there occur about 55 species of plants. Of these 27 belong to recent species, 22 are confervæ, 5 are palmæ. The remaining 10 species are too imperfect to enable us to refer them to any peculiar class.

II. *Older Pliocene Formations.*

These formations are not covered by the preceding, but are considered as of a more ancient era, because they contain a much greater number of extinct fossil shells. Like the preceding formations they exist in greatest perfection in Italy.

The Appenines constitute a range of mountains which branches off from the Ligurian Alps and passes down the Italian peninsula. At the foot of these mountains, both on the side of the Adriatic and the Mediterranean, is found a series of tertiary strata, which form a line of low hills occupying the space between the older chain and the sea. Brocchi first observed, that more than one-half of the shells in these tertiary strata agree with species now living in the Mediterranean, or in other seas chiefly of warmer climates.

The most important of these beds is a marl, which varies in colour from greyish brown to blue. It is very aluminous, and usually contains much calcareous matter and scales of mica. Sometimes it is thinly laminated, but often exhibits no lines of distinction throughout a considerable thickness. In some of the hills near Parma, this marl acquires a thickness of nearly 2000 feet, and is charged throughout with shells, many of which are such as inhabit a deep sea. They

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* For an account of the Geology of Rome, we refer to an excellent paper *by Hoffmann, accompanied* by a geological map inserted in Poggendorff's *Annalen, xvi. 1.*

often occur in layers so as to indicate a gradual accumulation. They are not flattened, but are filled with marl. Beds of lignite are sometimes interstratified, as at Medesano, four leagues from Parma. Subordinate beds of gypsum also occur in many places, as at Vigolano and Bargonæ, in the territory of Parma, where they are interstratified with shelly marl and sand.

The other member of the Subappenine group, the yellow sand and conglomerate, constitutes usually a border formation near the junction of the tertiary and secondary rocks. In some cases, as near the town of Sienna, we see sand and calcareous gravel resting immediately on the Appenine limestone, without the intervention of any blue marl. Alternations are there seen of beds containing river shells, with others filled exclusively with marine species, and oysters are attached to many of the limestone pebbles.

These tertiary strata have resulted from the waste of the rocks which now form the Appenines, and which had become dry land before the older pliocene beds were deposited; even at present, the rivers carry into the sea a sediment exactly similar to the marl above described. And yellow sand is thrown down by the Tiber near Rome, and by the Arno at Florence. The northern part of the Appenines, consists of a grey micaceous sandstone with an argillaceous base, alternating with shale, from the degradation of which brown clay and sand would result.

The shells contained in these tertiary-beds are soft when first taken from the marl, but they become hard when dried. The superficial enamel is often well preserved, and many shells retain their pearly lustre, and even part of their external colour, and the ligament which unites the valves. The microscopic shells abounding near Sienna are very perfect. In some large tracts of yellow sand it is impossible to detect a single fossil, while in other places they occur in profusion. These testacea are referrible to species and families of which the habits are extremely diversified, some living in deep, others in shallow water, some in rivers or at their mouths. Mr. Lyell saw a specimen of a *fresh water* univalve (*Limnea palustris*) taken from the blue marl near Parma full of small *marine* shells. Blocks of Appenine limestone are found in this formation drilled by lithodomous shells. The remains not only of testacea and corals but of fishes and crabs, are met with, as also those of cetacea, and even of terrestrial quadrupeds.

Mr. Lyell has pointed out the existence of these older pliocene formations along the coast of the Mediterranean, from Genoa (or at least the base of the Maritime Alps) to Nice. There is also a considerable thickness of the same tertiary strata on the borders of the Mediterranean at the eastern extremity of the Pyrenees, in the valleys of the rivers Tech, Tet, and Gly. They are very similar to the Italian beds, consisting partly of a great thickness of conglomerate, and partly of clay and sand, with subordinate beds of lignite. They abut against the primary.

Marine strata of the older pliocene period occur in patches at Malaga and Granada, in Spain. They have also been observed in the Morea by MM. Boblaye and Verlet.

The reader will find a list of the principal shells hitherto found in the older pliocene formations, at the end of the third volume of Lyell's Geology.*

A portion of the older pliocene formation occurs on the coast of Norfolk and Suffolk, where it is locally known by the name of *crag*, which is said to be a term applied in Suffolk to *sand*.

The extent of the *crag* has not yet been accurately defined. It rests sometimes upon the London clay, and sometimes upon chalk. It is first seen at Walton Nase, in Essex, where it is exposed on the cliff for 300 paces in length. It caps the cliffs on both sides of Harwich. Quarries of it are worked on the southern bank of the river Orwell, in Suffolk; and near Southwold, which is about two miles south of Lowestoff, it appears in the cliff together with sand and red loam covering the London clay. The same bed of shells is found upon digging through Suffolk and a great part of Norfolk. Mr. Woodward informs us that it is found at Cromer, and westward of that town at Coltishall, and round Norwich. Mr. Richard Taylor of Norwich has given us a section of its strata as they appear at Bramerton, on the southern bank of the Yare resting on the upper chalk.† The strata visible are twelve in number, and are as follows, beginning with the uppermost:—

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* The preceding account of the pliocene formations in Italy is taken from the third volume of Mr. Lyell's Geology.

† *Geological* Transactions (second series), i. 371.

	Thickness. Feet.	
1.	5	Sand without organic remains.
2.	1	Gravel.
3.	4	Loamy earth.
4.	1½	Ferruginous sand, containing hollow nodules.
5.	1½	Coarse white sand with a vast number of shells.
6.	1½	Gravel with fragments of shells.
7.	15	Brown sand with a seam of fragments of shells.
8.	3½	Coarse white sand with shells. Tellinæ and murices most abundant.
9.	15	Red sand with organic remains.
10.	1	Loamy earth with large stones and crag shells.
11.	1	Large flints in situ in the chalk.
12.	15	Chalk.

The thickness, exclusive of the chalk and flints, amounts to 49 feet.

Mr. Taylor has given us the following table of the shells found by him in this section:—

Shells.	Number of the bed in which the shell is found.
Emarginula reticulata	8
Turbo littoreus, 4 varieties	8
Scalaria similis	5, 8
Trochus similis?	8
——— concavus?	8
Turritella conoidea	8
——— trilineata (Smith)	8
Murex striatus	5, 8
——— carinatus	5, 8
——— latus	8
Cerythium?	8
Mya lata	5, 8, 10
Tellina ovata	5, 8, 10
——— obtusa	5, 8, 10
——— obliqua	5, 8, 10
——— bimaculata (Smith)	8
Mactra arcuata	8
——— cuneata	8
——— dubia	8
——— ovalis	8
Cardium Parkinsoni	5, 8, 10
——— angustatum	5, 8, 10
——— *Edulina*	5, 8, 10

Shells.	Number of the bed in which the shell is found.
Mytilus edulis	8, 10
——— antiquorum	8, 10
Modiola pallida	8
Pecten?	8, 10
Cyclas cuneiformis	8
Astarte plana, 3 varieties	8
Venus lentiformis	8
——— equalis	8, 10
Nucula Cobboldiæ	8
Balanus tesselatus	5, 8
——— crassus	5, 8
Fragments of lobsters and crabs	8
Palates and vertebræ of fishes	5, 8
Fragments of bone	5
Horns, vertebræ, and teeth, of large herbivorous animals	8
Fragments of wood	5, 8
Fragments of coal	5, 8

Mr. Lyell has given an interesting account of the constitution and position of these crag-beds along the coast of Norfolk and Suffolk. It lies over the chalk in an unconformable position; it consists often of beds alternately inclined and horizontal, and consisting of sand and comminuted shells. It would appear from Mr. Lyell's description, that these beds of sand must have experienced considerable derangement since they were originally deposited, for they occur bent, folded, and in every conceivable position with respect to each other.*

Mr. Lyell is of opinion that the extinct volcanic rocks at Olot, in Catalonia, belong to the older pliocene period. This volcanic tract extends about fifteen miles from north to south, and about six miles from east to west. The volcanic matter made its way through secondary rocks of sandstone and nummilitic limestone, supposed to be contemporary with the English green sand and chalk. There are about fourteen cones or craters, and the volcanic matter is basalt, scoriæ, &c. The reason for supposing these volcanoes to be of the age of the older pliocene rocks is that they in some places cover old alluvium.†

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* *Lyell's Geology*, iii. 171.

† Ibid. p. 183.

The date of the extinct volcanoes of the lower Rhine and the Eissel is equally uncertain with that of the Catalonian lava. Mr. Lyell has stated his reasons for referring these volcanic eruptions also to the older pliocene period.*

CHAP. VI.

MIOCENE FORMATIONS.

THE term *miocene*† has been applied by Mr. Lyell to those tertiary formations which contain shells, about one-sixth of which only belong to living species, while the remaining five-sixths constitute extinct species. A table containing 1021 of such shells is inserted at the end of Lyell's Geology, of which only 176 (or $\frac{1}{5\cdot 8}$) are recent, while all the rest belong to extinct species. Mr. Lyell has given figures of the most characteristic shells found in this formation. They are

Voluta rarispina,
Mitra Dufrenii,
Pleurotoma denticula,
Nerita Plutonis.
Turritella Proto,
Fascioloria turbinelloides,
Pleurotoma tuberculosa.

The miocene beds lie under the older pliocene when both happen to occur together. The area covered by them in different parts of Europe is very considerable. For they occur in Touraine, in the basin of the Loire, and still more extensively in the south of France, between the Pyrenees and the Gironde. They have also been observed in Piedmont, near Turin, and in the neighbouring valley of the Bormida, where the Appenines branch off from the Alps. They are largely developed in the neighbourhood of Vienna, and in Styria. They abound in parts of Hungary, and they overspread extensive tracts in Volhynia and Podolia.

The miocene strata, called the *Faluns* of the Loire, have been observed to repose on a great variety of older rocks between Sologne and the sea, in which line they are seen successively to rest on gneiss, clayslate, coal measures, oolitic limestone, greenstone, chalk, and upper fresh-water formations of the Seine. They consist chiefly of quartzose gravel, sand, and broken shells. The beds are generally incoherent,

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* Lyell's Geology, iii. 193.

† *μειων*, *less*, and *καινος*, *new*.

but sometimes agglutinated together by a calcareous or earthy cement, so as to serve as a building stone. The thickness does not exceed 70 feet. They often bear a striking resemblance to the crag in appearance, the shells being stained of the same ferruginous colour, and being in the same state of decay, serving in Touraine, just as in Norfolk, to fertilize the arable land. Like the crag also they contain mammiferous remains, which are not only intermixed with marine shells, but sometimes encrusted with serpulæ, flustra, and balani. These terrestrial quadrupeds belong to the genera mastodon, rhinoceros, hippopotamus, &c. The assemblage considered as a whole being very distinct from those of the Paris gypsum. In these *faluns* M. Desnoyers has discovered the bones of the following quadrupeds:—

Palæotherium magnum,
Mastodon angustidens,
Hippopotamus major, minutus,
Rhinoceros leptorhinus, minutus,
Tapir gigas,
Anthracotherium (small species),
Sus,
Equus (small species),
Cervus,
An undetermined species of rodentia.

This formation resembles the *crag*, but is distinguished by the smaller number of recent shells which it contains.

The hills of Mont Ferrat and Superga, near Turin, belong also to the Miocene formations. The strata of these hills are inclined at an angle of more than 70 degrees. They consist partly of fine sand and marl, and partly of a conglomerate composed of primary boulders, which forms a lower part of the series. The high road which leads from Savona to Alessandria intersects these beds in its northern descent, and the formation may be studied along this line at Carcare, Cairo, and Spinto, at all which localities fossil shells occur in a bright green sand. At Piana, a conglomerate interstratified with this green sand, contains rounded blocks of serpentine and chlorite slate, larger than those near the summit of the Superga, some of the blocks being not less than nine feet in diameter.

When we descend to Acqui, we find the green sand giving place to bluish marls, which also skirt the plains of the Tanaro at lower levels. These newer marls are associated with sand

and are nearly horizontal, and appear to belong to the Older Pliocene Subappenine strata.

In Savoy, at the northern base of the great chain, there occurs a soft green sandstone associated with marls and conglomerate. It is called *molasse*, doubtless from its softness. It is of vast thickness, but shells have been so rarely found in it that they do not supply sufficient data for correctly determining its age. Mr. Lyell, from analogy with the Bormida beds, seems disposed to consider the molasse as a miocene formation.

A long succession of marine strata intervenes between the Alps and the plains of Hungary, which are divisible into three natural groups, each of vast thickness, and affording a great variety of rocks. They lie in strata nearly horizontal, but have a slight easterly dip, so that in traversing from west to east we commence with the oldest and end with the youngest beds. At their western extremity they fill an irregular trough-shaped depression, through which the waters of the Mur, the Raab and the Draven make their way to the lower Danube. They here consist of conglomerate, sandstone and marls, some of the marls containing marine shells. Beds also of lignite occur, showing that wood was drifted down in large quantities to the sea. In parts of the series there are masses of rounded siliceous pebbles, resembling the shingle banks which are forming on some of our coasts.

The second principal group is characterized by coralline and concretionary limestone of a yellowish-white colour. It is finely exposed in the escarpments of Wilden and in the hills of Ehrenhausen, on the right bank of the Mur. This coralline limestone is at least four hundred feet thick at Wilden, and therefore exceeds some of the most considerable of our secondary groups in England, as, for example, the *coral rag*. Beds of sandstone, sand and shale are associated with this limestone.

The third group, which occurs at a still greater distance from the mountains, is composed of sandstone and marl, and of beds of limestone, exhibiting here and there a perfectly oolitic structure. In this system fossil shells are numerous.

The middle group of these formations belongs indisputably to the miocene period; for the species of shells are the same as those of the Loire, Gironde, and other contemporary basins before noticed. The inferior or first group from the shells enumerated by Sedgewick and Murchison probably belongs to the same period. They specify

Mytilus Brardii,
Cerithium pictum,
——— pupæforme,
——— plicatum.

All of which characterize the miocene period.

The third or newest system which overlies the coralline limestone contains fossils which do not differ so widely from the miocene type as to authorize us to separate them.*

Mr. Lyell points out other miocene formations in Auvergne, Velay, Orleanais, the Upper Val d'Arno, Cadibona, Hungary, Transylvania, and Styria. The bones of fossil quadrupeds found in the Upper Val d'Arno by Mr. Pentland, belong to the following species:—

1. *Feræ.*

Ursus cultridens,
Viverra Valdarnensis,
Canis lupus, and another of the size of the common fox,
Hyæna radiata, fossilis,
Felis, a new species of the size of the panther.

2. *Rodentia.*

Histris, nearly allied to dorsalis,
Castor.

3. *Pachydermata.*

Elephas Italicus,
Mastodon angustidens,
——— taperoides,
Tapir,
Equus,
Sus scrofa,
Rhinoceros leptorhinus,
Hippopotamus major,
fossilis.

4. *Ruminantia.*

Cervus megaceros?

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* See Sedgewick and Murchison's paper in the Geol. Trans. (second series), iii. 301; and Lyell's Geology, iii. 212.

Cervus Valdarnensis,
——— new species,
Bos, bubalo affinis,
—— urus,
—— taurus.*

These are quite different from the animals whose bones are found in the Paris basin.

CHAP. VII.

EOCENE FORMATIONS.

THIS name† has been given by Mr. Lyell to a set of formations deposited at an earlier period than the miocene. The name was imposed, because an extremely small proportion of living species are contained in these beds. They indicate what may be considered as the *dawn* or commencement of the existing state of the animate creation upon the earth.

The total number of shells of this period is 1234, of which 42 only are living species, being nearly in the proportion of 3⅓ per cent. Of fossil species not known as recent 42 are common to the eocene and miocene epochs. In the Paris basin alone 1122 species have been found fossil, of which 38 only are still living. A list of most of these shells may be seen in M. Deshayes's table, at the end of the third volume of Lyell's Geology. Mr. Lyell has given figures of the following shells in plate third of the third volume of his geology, as characteristic of this formation:—

Voluta costaria,
——— digitalina,
Pleurotoma clavicularis,
Cassidaria carinata,
Nerita tricarinata,
Calyptræa trochiformis,
Turritella imbricataria,
Natica epiglottina,
Solarium canaliculatum,
Cardita planicosta.

The celebrated Paris basin was the first of the eocene for-

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* Lyell's Geology, iii. 220.

† *From ηως, aurora, and καινος, new.*

mations which were accurately explored. For our knowledge of these deposits we are indebted to the labours of Cuvier and Brongniart. They were ascertained to fill a depression in the chalk, which constitutes the fundamental rock at Paris and the neighbouring country.

Mr. Lyell considers many of the Paris beds as identical with certain beds in Auvergne, which seem to have been gradually deposited in lakes at that time existing in that part of France.

Immediately over the chalk in the Paris basin lies a layer of broken chalk flints, often cemented into a breccia by siliceous sand.

Upon this flinty stratum, or if it be wanting, upon the chalk itself rests frequently a deposit of clay and lignite, called the *first fresh water formation* or *plastic clay formation*, by Brongniart and Cuvier. It is composed of fresh water shells and driftwood, and was at first regarded as a proof that the Paris basin had originally been filled with fresh water. But it has been since shown that this group is not only of very partial extent, but is by no means restricted to a fixed place in the series, for it alternates with the *calcaire grossier*, and is repeated in the very middle of that limestone at Veaugirard, Bagneux, and other places where the same Planorbes, Paludina, and Limnei occur, as has been shown by M. Constant Prévost. Its origin was doubtless a river entering a bay of the sea, charged with argillaceous sediment, and drifting down occasionally fresh water shells and wood.*

The next bed was called by Cuvier and Brogniart *calcaire grossier* or *first marine formation*. It is composed of a coarse limestone, often passing into sand. It contains by far the greater number of the fossil shells, which characterize the Paris basin. No fewer than 400 distinct species have been derived from a single locality near Grignon. They are imbedded in a calcareous sand chiefly formed of comminuted shells, in which nevertheless individuals in a perfect state of preservation, both marine, terrestrial, and fresh water species are mingled together, and were evidently transported from a distance. Some of the marine shells may have lived on the

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* Brongniart, in his *Tableau des terrains qui composent l'écorce du Globe*, published in 1829, (p. 184), defends his original opinion with much ingenuity, and advances arguments in support of it possessed of considerable weight. But the opinion of Prévost is so much simpler, and explains the seeming anomalies in so satisfactory a way that I am disposed to adopt it.

spot, but cyclostoma and limnea must have been brought there by rivers and currents, and the quantity of triturated shells implies considerable movement in the waters. Nothing is more remarkable in this assemblage of fossil shells than the great proportion of species referrible to the genus Cerithium. There occur no fewer than 137 species in the Paris basin, and almost all of them in the *calcaire grossier*. Now the living testacea of this genus inhabit the sea near the mouths of rivers, where the waters are brackish. Hence their occurrence in the marine strata of the Paris basin accords with the statement of M. Prévost, that a river flowed into the gulf and gave rise to the beds of clay and lignite in the plastic clay bed above mentioned.

The next bed in order is a compact siliceous limestone, called by Brongniart and Cuvier *calcaire siliceux*. It resembles a precipitate from the waters of mineral springs. It is for the most part void of animal remains ; but in some places it contains fresh water and land species, and never any marine fossils. The siliceous limestone and the calcaire grossier occupy distinct parts of the basin, the one attaining its fullest development in those places where the other is of slight thickness. They also alternate with each other towards the centre of the basin, as at Sergy and Osny, and there are even points where the two rocks are so blended together that portions of each may be seen in hand specimens.

From these facts and some others, it has been concluded, that while to the north, where the bay was probably open to the sea, a marine limestone was formed, another deposit of fresh water origin was introduced to the southward or at the head of the bay.

The next group in order is the *gypsum*, and the *white* and *green marls* of Cuvier and Brongniart. These were once considered to be entirely subsequent to the groups already described. But Prévost has shown that, in some localities, they alternate repeatedly with the calcaire siliceux, and in others with some of the upper members of the calcaire grossier. The gypsum, with its associated marls and limestone is in greatest force towards the centre of the basin where the two groups just mentioned are less fully developed. And M. Prévost infers, that while those two principal deposits were gradually in progress, the one towards the north and the other towards the *south*, a river descending from the east *may have brought down* the gypseous and marly sediment.

The next group, called the *second* or *upper marine formation*, by Cuvier and Brongniart, consists in its lower division of green marls, which alternate with the fresh water beds of gypsum and marl above described. Above this division the products of the sea exclusively predominate, the beds being chiefly formed of micaceous sand, 80 feet or more in thickness, surmounted by beds of sandstone with scarcely any limestone. The summits of a great many platforms and hills in the Paris basin consist of this upper marine series, but the group is much more limited in extent than the calcaire grossier.

The uppermost of the formations in the Paris beds is called by Cuvier and Brogniart the *third fresh water formation.* It consists of marls interstratified with beds of flint and layers of flinty nodules. One set of siliceous layers is destitute of organic remains, the other replete with them. Gyrogonites, or fossil-seed vessels of charæ, are found abundantly in these strata, and all the animal and vegetable remains agree well with the hypothesis, that after the gulf or estuary had been silted up with the sand of the upper marine formation, a great number of marshes and shallow lakes existed, like those which frequently overspread the newest parts of a delta.

The entire series of these Paris beds must have required a long lapse of ages for its accumulation, yet they all belong to the eocene period. The shells of the different fresh water groups, constituting at once some of the lowest and uppermost members of the series, are nearly all referrible to the same species, and the discordance between the marine testacea of the calcaire grossier and the upper marine sands is very inconsiderable. M. Deshayes has made a curious observation respecting the changes which one species, the *cardium porulosum*, has undergone during the long period of its existence in the Paris basin. Different varieties of this cardium are characteristic of different strata. In the oldest sand of the Soissonais (a marine formation underlying the regular beds of the calcaire grossier) this shell acquires but a small volume, and has many peculiarities which disappear in the calcaire grossier. In these the shell attains its full size and many peculiarities of form, which are again modified in the uppermost beds of the calcaire grossier, and these last characters are preserved throughout the whole of the upper marine series.

In some parts of the calcaire grossier microscopic shells are very abundant. They belong to the order of *Cephalopoda*, the animals of which are the most free in their motions, and most advanced in their organization of all the mollusca. They are often in an excellent state of preservation, and their forms are singularly different from those of the larger testacea.

The gypsum at the base of Montmartre, is seen distinctly to alternate with soft marly beds of the calcaire grossier, in which cerithia and other marine shells occur. But the great mass of gypsum may be considered as a purely fresh water deposit, containing land and river shells, together with fragments of palm wood, and great numbers of skeletons of quadrupeds and birds, an assemblage of organic remains which have given great celebrity to the Paris basin. In this gypsum formation, Cuvier discovered the bones of two new genera of animals, which he distinguished by the names of *Palæotherium* and *Anoplotherium*. The palæotherium resembles the tapir. Ten species have been described by Cuvier, varying in size from that of the rhinoceros to that of the hog and sheep. They appear all of them to have been herbivorous animals. The genus anoplotherium resembles the camel. The tail is as long, if not longer, than the body, at the same time very thick and strong. Five species are described by Cuvier, all of which occur in this gypsum formation.

The remains of three carnivorous animals have been found in the same beds. One of these resembles the fox; the second is either an unknown species of *canis*, or of a genus intermediate between the *canis* and *viverra*: the third is allied to the ichneumon, but is double its size.

The *Lophiodon* is another new genus, nearly allied to the tapir. Twelve species have been determined by Cuvier, and one of them is of gigantic dimensions.

The bones of a species of tapir of gigantic size were also found in the same formation. It is 18 feet long and 12 feet high, thus equalling the skeleton of the mastodon or the elephant.

Cuvier has ascertained and classified the fossil remains of 78 different species of extinct quadrupeds, found either in this formation or in those above it in the series. Forty-nine of these are species hitherto entirely unknown to naturalists. Eleven or 12 others have such entire resemblance to species already known, as to leave no doubt of their identity. The remaining 16 or 18 have considerable traits of resemblance to known species; but the comparison has not been made with so much precision as to remove all doubt.

Of the 49 new species, 27 are referrible to 7 new genera, while 22 are referrible to genera or subgenera already known. The whole genera and subgenera to which the fossil remains of quadrupeds hitherto investigated are referrible, are 36, including those belonging both to known and unknown species.

Of the 78 species, 15 which belong to 11 genera, are animals of the class of oviparous quadrupeds; while the remaining 63 are of the mammiferous class. Of these last, 32 species are hoofed animals, not ruminating, and reducible to 10 genera; 12 are ruminating animals belonging to 2 genera; 7 are gnawers referrible to 6 genera; 8 are carnivorous quadrupeds belonging to 5 genera; 2 are toothless animals of the sloth genus; and two are amphibious animals of two distinct genera.

For a particular account of all these fossil animals (many of which have been found in alluvial beds) we must refer the reader to Cuvier's great work on *the Fossil Remains of Quadrupeds.* But it may be interesting to specify a few of the most remarkable.

1. *Megatherium.* This animal belongs to the order of *bradypus*, or *sloth.* A complete skeleton was found in the alluvial soil near Buenos Ayres, and sent to Madrid. Afterwards another was discovered near Lima, and a third in Paraguay. The Madrid skeleton is 14 feet long and 7 feet high. It is so rude and unshapely, that the clumsy skeleton of the elephant and rhinoceros, and even the massive and rugged bones of the hippopotamus, appear, when placed beside it, slender and light. It is one of the largest and most massive of all the fossil quadrupeds hitherto discovered. Judging from its structure, its motions seem to have been slow and dragging; and, with the exception of its claws, it appears to have been more defenceless than any other of the large quadrupeds. The form of the teeth shows that it lived on vegetables. Its long claws are supposed to have been used for digging up the roots on which it is conjectured to have fed.

2. *Elephant.* The fossil elephant, or mammoth, as it is called by the Russians, is different from both the species of that animal at present existing. The alveoli of the tusks are much larger, and the zigomatic arch of a different form. The

vacuity between the branches of the jaws at the fore part is wider, and the lower jaw, instead of terminating in a kind of pointed apophysis, is rounded off. The tusks are more incurvated.

The remains of this animal have been found both in North America and in Asiatic Russia. Indeed an entire animal was discovered in the latter country in a state of complete preservation, having been frozen in the snow. It will be worth while to transcribe Cuvier's account of this curious discovery.

"In the year 1799, a Tungusian fisherman observed a strange shapeless mass projecting from an ice bank near the mouth of a river in the north of Siberia, the nature of which he did not understand, and which was so high on the bank as to be beyond his reach. Next summer he observed the same object, which was then rather more disengaged from the ice, but he was still unable to conceive what it was. Towards the end of the following summer, in 1801, he could distinctly see that it was the frozen carcase of an enormous animal, the entire flank of which, and one of its tusks, had become disengaged from the ice. In consequence of the ice beginning to melt earlier and to a greater degree than usual, in 1803, the fifth year after the discovery, the enormous carcase became entirely disengaged, and fell down from the ice crag on a sand bank forming part of the coast of the Arctic Ocean. In the month of March of that year, the Tungusian carried away the two tusks, which he sold for 50 rubles, and at this time a drawing was made of the animal, of which Cuvier got a copy.

"Two years afterwards, or in 1806, Mr. Adams went to examine the animal, which still remained on the sand bank on which it had fallen from the ice, but its body was then greatly mutilated. The Jakuts of the neighbourhood had taken away considerable quantities of its flesh to feed their dogs, and the wild animals, particularly the white bears, had also feasted on the carcase. Yet the skeleton remained quite entire, except that one of the fore legs was gone. The entire spine, the pelvis, one shoulder blade, and three legs, were still held together by their ligaments and by some remains of the skin, and the other shoulder blade was found at a short distance. The head remained covered by the dried skin, and the pupil of the eyes was still distinguishable. The brain also remained within the skull, but a good deal shrunk and dried; and one of the ears was in excellent preservation, still retaining a tuft of strong bristly hair. The upper lip was a good deal eaten away, and the under lip was entirely gone, so that the teeth were distinctly seen. The animal was a male, and had a long mane on its neck.

"The skin was extremely thick and heavy, and as much of it remained as required the exertion of ten men to carry away, which they did with considerable difficulty. More than 30 lbs. weight of the hair and bristles of this animal were gathered from the wet sand bank, having been trampled into the mud by the white bears while devouring the carcase. Some of this hair was presented to the Natural History Museum of Paris, by M. Targe, censor in the Lyceum of Charlemagne. It consists of three different kinds; one of these is stiff black bristles, a foot or more in length; another is thinner bristles, or coarse flexible hair of a reddish brown colour; and the third is a coarse reddish brown wool which grew among the roots of the long hair. These afford an undeniable proof that this animal had belonged to a race of elephants inhabiting a cold region and now no longer existing, and by no means fitted to dwell in the torrid zone. It is equally evident, that this enormous animal must have been frozen up by the ice at the moment of its death."

Remote, then, as the period must be when this animal existed on the earth, still it must have been when the temperature of the globe was nearly the same all over the surface as at present.

3. *Cervus giganteus*, or *Irish Elk*. This gigantic and magnificent species is found in a fossil state in Ireland, Isle of Man, England, France and Germany. There is a complete skeleton from the Isle of Man in the College museum of Edinburgh. It is six feet high, nine feet long, and from the ground to the tip of the right horn nine feet seven inches. It was imbedded in a loose shell marl, in which were numerous branches and roots of trees.

4. *Ornithocephalus*. This is a most extraordinary animal, found imbedded in limestone at Eichstadt. There are two species described by Sommering, the *longirostris* and *brevirostris*. Naturalists are not agreed in opinion to what tribe of animals it ought to be referred. Cuvier considered it as amphibious, Blumenbach as a bird, Collini as a fish, while Sommering conceives that it belongs to the mammalia, and places it near the bats.

5. *Man*. During the agitation of the diluvial controversy,

many descriptions appeared of the fossil remains of man, said to have been found in various places; but a closer examination showed that all these supposed fossil human bones belonged in reality to inferior animals. Thus the famous *homo diluvii testis* of Scheuchzer was found to be a gigantic fossil lizard. The fossil bones of Cerigo, so confidently described by Spallanzani as human, are now admitted to belong to quadrupeds. Human remains, however, have been found in the fissures of rocks, and in alluvial strata. About the beginning of the present century, human bones were found in a compact calcareous rock in the island of Guadaloupe. The rock is composed of the debris of corralines and shells, and is obviously of very recent formation. The annual formation of a similar rock may be witnessed at present on the Cornish coast.* A mass of this Guadaloupe rock, containing a well preserved human skeleton, but wanting the head, was sent home by the French commander of that island, during the French revolutionary war, to Paris. The ship containing it having been captured by Sir Alexander Cochrane, he sent the fossil skeleton to Lord Melville, who was at that time first Lord of the Admiralty. His Lordship presented it to the British Museum, where it may still be seen.†

Human bones have been occasionally met with in caverns, but these remains, in all cases hitherto observed, are comparatively recent.

(1.) They have been found encrusted with stalactite in a mountain limestone cavern at Barrington, in the Mendip hills. This cave was either used as a place of sepulchre in early times, or resorted to as a place of refuge by wretches who perished in it during some of the numerous cases of devastating warfare that occurred in ancient times. The bones are chiefly deposited on one side of the cavern, as in a sepulchre catacomb.

(2.) Two analogous caves occur in mountain limestone in South Wales; one at the Mumbles, near Swansea. From the position of the bones they seem to be the remains of a number of bodies thrown in after a battle. The other cavern is also in mountain limestone at Llandebie, in Caer-

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* Dr. Paris has given an interesting account of this formation in the first volume of the Transactions of the Geological Society of Cornwall.

† An excellent account, with an engraving, of this fossil skeleton, together with an account of the rock in which it occurs, drawn up by Mr. König, may be seen in the Phil. Trans. for 1814, p. 107.

narvonshire. About twelve skeletons were found in it, arranged in parallel rows. This cave had obviously been used as a place of burial.

(3.) The cavern discovered at Bize, in the Department of l'Aude, at the foot of the Pyrenees, in 1829, contains also human bones attached to the rock, and mixed with the bones of other animals, and of land shells. Some of these bones belong to two different species of the stag at present extinct; but other bones are mixed with them of animals still existing, and also both sea and land shells belonging to species to be found still in the neighbouring country, and in the Mediterranean sea. With these are mixed fragments of pottery, very similar to those kinds known under the name of Etruscan pottery. From these facts it is obvious that the bones found in this cavern are of two different eras: 1. Those of the extinct animals are doubtless of the same era as the similar bones found in the Kirkdale and other caverns. 2. The human bones, and those of other animals still existing, are probably of a very remote date, but they must belong to a period when the face of the earth was similar to what it is at present.

Human bones have been found also in the caverns of Pondre and Souvignargues, in the department of Gard, near the mouth of the Rhone. These caverns exist in limestone of the newest formation. They are filled with the soft mud to which Buckland has given the name of *diluvium*. It contains the bones of hyænas, rhinoceroses, stags, &c. precisely in the same state as in the cave of Kirkdale. The human bones are mingled with these sparingly, and are described as absolutely in the same state. Along with them occur also fragments of the rudest kind of pottery. The human bones, those of the extinct animals, and the pottery, as far as can be determined from their position and state, seem all of an age. If any instance occur of antediluvian human bones, this is one; but the best description of these caverns which I have seen is imperfect. A more minute and careful investigation would be requisite before we can consider a fact of so much importance as established.*

The celebrated basins of London and Hampshire, first accurately described by Mr. Webster, belong also to the eocene period. The London basin is bounded by rising grounds

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* *See the* Annales des Mines (second series), v. 517.

composed of chalk, except where the sea intervenes, and there is every reason for believing that the chalk passes beneath all the tertiary strata of which this basin is composed. The strata belonging to the London basin have been divided into three series or groups:—

1. The plastic clay and sand, which is lowest,
2. The London clay,
3. The Bagshot sand, which is uppermost.

The plastic clay, in some places, attains a thickness of 400 or 500 feet. It consists principally of an indefinite number of beds of sand, shingle, clay and loam, irregularly alternating. Some of the clay is used in potteries: hence the term *plastic clay* has been applied to the whole formation. The beds of shingle are composed of perfectly rolled chalk flints, with here and there small pebbles of quartz. Heaps of these materials seem to have remained long covered by a tranquil sea. Dr. Buckland, in a part of this formation at Bromley, observed a large pebble, to which five full grown oyster shells were affixed in such a manner as to show that they had commenced their first growth upon it, and remained attached through life.*

In some of the associated clays and sand perfect marine shells are met with, which are of the same species as those of the London clay. Indeed, the line of separation between the London and plastic clay is quite arbitrary. In the midst of the sands of the lower series a mass of clay occurs 200 feet thick, containing septaria, and replete with the usual fossils of the neighbourhood of London.

The arenaceous beds are chiefly laid open on the confines of the basins of London and Hampshire, in following which we discover in many places great beds of perfectly rounded flints. This is the case with the hills of Comb Hurst and Addington, which form a ridge stretching from Blackheath to Croydon. Here they have much the appearance of banks of sand and shingle formed near the shores of the tertiary sea.

Organic remains are extremely rare in the plastic clay, but when any shells occur they are of the eocene species. Vegetable impressions and fossil wood sometimes occur, and even beds of lignite. But the *species* of none of these plants has been ascertained.

This formation occupies a greater extent of surface in the

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* *Geol.* Trans. iv. 300.

south portion of Hampshire than in Essex, Surrey and Kent. For the fullest account of its extent in these places we refer to Conybeare and Phillips' *Outlines of the Geology of England and Wales*, and to Mr. Greenough's *Geological Map*.

The London clay consists of a bluish or blackish clay, occasionally passing into a calcareous marl, rarely into a solid rock. Its thickness sometimes exceeds 500 feet. It contains many layers of ovate or flattish masses of argillaceous limestone, which in their interior are generally traversed in various directions by cracks, partially or wholly filled by calcareous spar. These masses, called *septaria*, are sometimes continued through a thickness of 200 feet.

A great number of the marine shells of this clay have been identified with those of the Paris basin. A list of these has been given by Mr. Lyell, in the Appendix to the third volume of his *Geology*. The list was drawn up by M. Deshayes from specimens in his own collection.

No remains of terrestrial mammalia have as yet been found in this clay, but the occurrence of bones and skeletons of crocodiles and turtles prove the existence of neighbouring dry land when the clay was deposited. About 800 different kinds of ligneous seed vessels of plants, some of them resembling the cocoa nut and other species of tropical regions, have been found in the Isle of Sheppey in this formation.*

In the London clay 15 species of fossil plants have been discovered, none of which are recent plants. Of these, twelve are plants belonging to the cryptogamia class ; two are palms; and one is a caulinites, described by M. A. Brongniart.

The third and uppermost group, usually termed *Bayshot sand*, rests conformably on the London clay, and consists of siliceous sand and sandstone, devoid of organic remains, with some thin deposits of marl associated. From these marls a few marine shells have been obtained, which are in an imperfect state, but appear to belong to the eocene species common to the Paris basin. Mr. Warburton collected several, of which the following are the chief:—The Reading oyster, a Pecten, a large and small cardium, a pectunculus, nucula margaritacea, two species of Citheræa, a shell resembling solen radiatus, a tellina, a dentatium, strombus pes-pelecani, calyptræa trochiformis in great perfection, and several imperfect turbinated

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* See an account of these, with figures, by Dr. Parsons, Phil. Trans., *1757, p. 396.*

shells. He found also a shark's tooth, pyritous wood, and what appeared to be the seed vessel of a plant.*

For an account of the eocene formations in the Isle of Wight and the opposite coast of Hampshire, we refer the reader to Mr. Webster's papers in the *Geological Transactions*, to Englefield's *Isle of Wight*, to Sedgewick's paper in the *Annals of Philosophy* for 1822, and to Lyell's papers in the *Geological Transactions*, vol. 2d, second series.

Remains of tortoises and the teeth of crocodiles have been found in the Isle of Wight basin, and more recently bones of mammalia corresponding with those in the Paris gypsum beds. In marl, alternating with a limestone quarried for building near Ryde, the tooth of an Anoplotherium, and two teeth of the genus Palæotherium, were found. The tooth of the Anoplotherium was first observed by Mr. Allan, and his discovery was confirmed and extended by Mr. Pratt.†

The British eocene strata are nearly conformable to the chalk on which they rest, being horizontal where the strata of chalk are horizontal, and vertical where they are vertical. The surface of the chalk had been furrowed by the action of the waves and currents, before the plastic clay and its sands were superimposed. Thus at Rochester and Gravesend, in the quarries, fine examples are seen of deep indentations on the surface of the chalk, into which sand, together with rolled and angular pieces ofchalk flint, have been swept.‡

Mr. Lyell considers the beds in the lacustrine basins of Auvergne, Cartal, and Velay, to belong also to the eocene period. Many of the extinct volcanoes of that country may be of the same age. A portion of eocene formation occurs also in the Cotentin, and small portions of it are scattered over the primary deposits in Bretagne.

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* See Warburton on the Bagshot sand, Geol. Trans. (2d series), i. 48.

† Proceedings of the Geological Society, No. 18, p. 239.

‡ See Lyell's Geology, iii. 282, and Conybeare and Phillips' Outlines of the Geology of England and Wales, p. 62.

CHAP. VIII.

CHALK FORMATION.

THE chalk, which constitutes so important a feature in the south of England and the north of France, constitutes the uppermost of what geologists denominate the *secondary formations.*

The nature and qualities of chalk are so generally known, that it is unnecessary to describe it minutely. The best chalk used for economical purposes is of a pure white, has an earthy fracture, a meagre feel, adheres to the tongue, and stains the fingers. It is dull, opaque, soft, has a specific gravity of 2·3, and is never crystallized. When pure it contains nothing but carbonate of lime. Magnesia has been detected in some specimens of French chalk. Clay and sand are rather common mixtures in it. Some of the lower beds have a red colour, probably derived from iron.

In the south of England chalk is occasionally used as a building stone. The abbey of Hurley in Berkshire, and its parish church, anciently a chapel, are said to be built of it. The mullions and arches of St. Catherine's chapel, near Guildford, are of chalk that contains flints. The abbey of St. Omar, ruined during the French revolution, was entirely constructed of flints, and retains all its beautiful gothic ornaments in great perfection.

The chalk formation is usually divided into three beds, namely, the *upper chalk*, the *lower chalk*, and the *chalk marl*, which is lowest of all.

The upper chalk appears in most places in England, whenever occasional openings have been made in the very large tract of country occupied by it. The inferior beds may be traced along the lower regions of the escarpment presented by the hills of this formation.

The upper chalk is soft, but the lower is much harder, does not mark, and is usually distinguished by the name of *hard chalk.* One of the most remarkable circumstances connected with chalk, is the occurrence of those numerous nodules of flint which alternate through the greater part of its mass. They are constantly present in the upper chalk, but rare in the under chalk, at least in England, for the rule is said not to hold in France. The chalk which occurs in the county of Antrim, in Ireland, is as hard as common mountain limestone, yet it contains abundance of flints. Hence it was probably at first in the state of soft chalk, but indurated by the action of the numerous trap beds which seem to have been forced up in that country in a state of fusion.

These flint nodules assume the most extraordinary forms. The siliceous matter seems to have been in a state of solution, probably in water, and to have been gradually deposited in alcyonia, sponges, &c., at that time existing in the chalk-beds.

Veins of flint traversing the regular strata at various angles may be observed generally when any extensive range of chalk cliffs are exposed. For example, in the Isle of Thanet, near Brighton, and in the Isle of Wight. The flint filling such veins is usually tabular.

The flints which have been washed out from the chalk at a remote period occur in the various deposits of gravel. From their superficial position, and the loose texture of the mass in which they occur, exposed for ages to the influence of the atmosphere and the percolation of water, they have been much altered and have undergone changes somewhat analogous to those which may be produced in them by fire. The black colour is rendered less intense, or changed to brown, yellow, or red. These different colours are sometimes arranged in zones parallel to the outward surface of the pebble.

The flint nodules often contain cavities lined with tubercular chalcedony or quartz crystals. Whenever chalcedony occurs in flint, a careful examination will generally detect the presence of a sponge or alcyonium.

Besides flints, subordinate beds of fuller's earth are occasionally met with in chalk. The chalk very often contains masses of iron pyrites, varying in size from that of a pea to several inches in diameter. They are usually crystallized, and exhibit when broken a diverging fibrous structure. They frequently occur cylindrical, and were formerly picked up and preserved under the name of *thunderbolts.*

At Bishopton down, near Warminster, in Wiltshire, enormous blocks of crystallized carbonate of lime occur in chalk. One of these, weighing 50 cwt., and measuring between 30 and 40 cubic feet, was cut into slabs for chimney pieces at Mr. Noel's, a stone mason at Warminster.

A brown or blackish brown substance has been observed *coating the chalk in several* places in Suffolk. It has sometimes the appearance of a sooty powder, but is occasionally fibrous. It is conjectured to be oxide of manganese.

The chalk formation stretches with little interruption from Flamborough Head, a remarkable promontory on the coast of Yorkshire, to near Sidmouth, on the coast of Devonshire, forming a range of hills often of considerable elevation, and of which the most precipitous escarpment is generally on the north-western side. Another range of hills branches from it in the south of England.

From Flamborough Head the chalk proceeds south as far as Bridlington quay, but from that to the mouth of the Humber the coast is alluvial. The chalk hills pass south, constituting the wolds of Yorkshire and Lincolnshire. They disappear in the Wash, which is entirely alluvial. Near the shore of the north western part of Norfolk, the chalk appears again, constituting a ridge of hills running south about 15 miles, and then disappears, sinking under the diluvial sand of Norfolk. It appears again on the north of Thetford, and passes on uninterruptedly by Newmarket in Suffolk, a little to the east of Cambridge, till it reaches Marlborough Downs in Wiltshire, where it is broken through by the village of Kennet.

In Wiltshire the chalk formation exhibits its greatest extent, being more than fifty miles long, from east to west, and about twenty miles broad from north to south.

From this great central mass a branch of chalk hills passes south-west through Dorset, and bending east, not far from Dorchester, constitutes the northern part of the isle of Purbeck, and passing across Alum Bay forms the central and most elevated portion of the Isle of Wight, extending quite across the island, and terminating at the east end in a precipitous cliff.

Another branch runs almost due east, by Winchester, Arundel and Lewis, till it terminates in the sea at Beachy-head.

A third branch runs a little north-east, by Farnham and Guildford, and terminates by its southern side in the Channel at Folkestone, west of Dover.

Each of these branches constitutes so many chains of low round-backed hills, in general remarkable for their beauty and fertility. The number of plants found growing on the chalk is in general greater than on any other soil, and the crops which it produces, are, in general, excellent.

The isle of Thanet, which is composed of chalk, though not far from the north-west chain, is, in fact, unconnected with it, being separated by a trough occupied by the plastic clay formation, which lies above the chalk.

The fossils in the chalk beds are numerous, but the variety of genera and species is not very great, and not one of them agrees in every respect with animals at present inhabiting the earth. Hence it was obviously formed at a period indefinitely earlier than the eocene beds.

The remains of several vertebral fish occur; teeth of a species of shark, nearest in appearance to those of the *squalus galeus;* two varieties of palate bones belonging to unknown genera, have been found, not to mention various vertebræ and scales of fish.

We find in the chalk the following univalve and bivalve shells:

Ammonites.
Scaphites.
Belemnites.
Trochus.
Cirrus.
Turbo.
Serpulæ.
Spirorbes.
Ostreæ.
Pecten.
Terebratulæ.
Majus.
Plagiostoma spinosa.
Dianchora lutea.
Inoceramus.
Balanus.*

The family of echinites may be considered as characterizing the chalk formation, and the species are at least equal in number to that of all the shells found in it. The following table exhibits a list of the zoophytes found in chalk.

Ananchites ovata.
———— pustulosa.
Nucleolithes rotula.
Galerites albogalerus.
———— vulgaris.
———— subrotundus.
———— conoideus.
Spatangus cor-anguinum.
———— Bufo.
———— rostratus.
Cidarites vulgaris.
———— saxatilis.
———— Könïgii.
———— corollaris.

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* See a table of the different species given by Brongniart in his *Tableau des Terrains qui composent l'écorce du Globe*, p. 403.

Cidarites papillata.
Asterias.
Pentagonaster semilunatus.
Pentaceros lentiginosus.
Apiocrinites ellipticus.
Pentacrinites.
Marsupites ornatus.
——— Milleri.
Caryophyllia cyathus.
——— costellata.
Turbinolia Königii.
Alcyonium pyriformis.
Spongia ramosa and many other species.
Choanites subrotundus.
——— flexuosus.
Königii.
Ventriculites radiatus.
——— alcyonoides.

The plants found in chalk are:

Confervites fasciculata.
——— egagropiloides.
Fucoides lyngbianus.*

The following subdivisions of the family of echinites found in the chalk may be of use to beginners:—

1. Helmet shaped—*Echinocorys*, *Ananchytes*.
2. Conical—*Conulus*, *galerites*.
3. Heart-shaped—*Spatangus*.
4. Spheroidal, with the mouth and vent on opposite poles. Lamark has divided them into two genera. 1. Tubercles perforated to admit the passage of muscular filaments, which assist in the motion of the spines—*Cidaris*. 2. The tubercles imperforate; the spines, which are smaller, being moved by the contractions of the outer skin only—*Echinus*.

The substance of sponges, found in such abundance fossil in chalk, consists, as to their interior texture, of a mass of interwoven fibres, penetrated by larger pores regularly or irregularly disposed. These fibrous reticulations sometimes run confusedly together, so that the meshes present no regular or determinate figure; sometimes they are regularly disposed so as to give the whole mass a plicated character. Of the irre-

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* This table is taken from Brongniart's *Tableau des Terrains*, because of its shortness. The reader will find a much more complete list in De la *Beche's Manual* of Geology, p. 270.

gularly reticulated sponges at least four genera have been observed; namely:

1. Ramifying.
2. Palmated.
3. Turbinated or funnel-shaped.
4. Fig-shaped.

Only fourteen species of fossil plants have been hitherto observed in the chalk: of these thirteen species are cryptogamous plants, eleven being fucoides and two confervites. One species belongs to the order of Cycadeæ, and is therefore a dicotyledonous plant.

It has been already mentioned that the chalk formation is usually hilly; but the hills are not high. The highest chalk hill in England, Inkpen, in Wiltshire, is 1011 feet above the level of the sea. Wilton Beacon, the highest chalk hill in Yorkshire, is 809 feet high, and various hills in Hampshire, Kent and Surrey, are nearly as elevated. Near Dover the chalk with flints is about 480 feet thick, while the thickness of the chalk without flints is about 140 feet. At Handfast Point, on the coast of Dorset, the flinty chalk is 600 feet thick, and that without flints about 200 feet. At Culver Cliff in the Isle of Wight, the beds of chalk are vertical and extend about a quarter of a mile or 1300 feet. This may be considered as the greatest thickness of the chalk in England.

The chalk formation appears to extend over an area of great extent, occupying the interior of the great European basin, reaching probably from the banks of the Thames to those of the Dniester. But the beds cannot be traced continuously throughout the borders of this area, though this can be done with the western limits of it in England and France. In the central parts of Europe it is greatly concealed, partly by the overlying of the more recent tertiary deposits, and partly by the vast accumulation of diluvial debris which conceal from observation the rocks throughout so large a portion of the north of Germany.

The northern limit may be traced in the line of the Baltic in the island of Rugen, where chalky cliffs present themselves on its northern coast. They occur also on the neighbouring continent, in Pomerania and Mecklenburg. A small chalk cliff may be observed near Malmo, in Sweden, crossing to the opposite coast of Zealand, and including the small island of Mona on the south. From Mona the line of chalk has not been traced. It probably traverses Holstein to the mouth of the

Elbe, where it crosses the German Ocean to Flamborough Head.

In France the limits of the chalk correspond to the south coast of England. Its western edge is at the mouth of the Seine. It proceeds south to Blois on the Loire, where the formations above the chalk overlie and conceal its southern extremity. It appears again at Montargis, and turning northwards runs by Troyes, Rheims and Valenciennes. North of Valenciennes the edge of the chalk appears to trend east, but it is generally covered by the sandy superstrata of the Netherlands. It may, however, be seen on the south of Maestricht and at Henri Chapelle, near Aix.

From a memoir by M. Dufrenoy,* it appears that there is a large tract of country in the south-west of France and upon the declivity of the Pyrenees, on the French side, which corresponds in its fossils with the chalk and green sand of the north of France and England, and of course belongs to the same era.

This formation, besides the fossils which characterize the chalk beds, and which have been already enumerated, contains several others peculiar to itself, which have been enumerated by M. Dufrenoy. It contains also subordinate beds, which had never been suspected to exist in chalk; namely, beds of fossil wood, of gypsum, of sulphur, and probably also of rock salt.

The chalk, instead of possessing the softness, and dulness and opacity, which characterize it elsewhere, is frequently hard and crystalline. This is the reason why, before the investigations of Dufrenoy, the district had been referred to formations at least as old as the oolite and new red sandstone. M. Dufrenoy has elucidated his description by various sections, exhibiting in detail the structure of the country.

The chalk appears again in Westphalia, to the north of the coal fields of Rahn. After an interruption from the alluvia of the Lippe it appears again in Osnaburg, and forms at the foot of the *Muschelkalk* formation, a series of little escarpments.

To the north of the secondary hills of Westphalia, the whole district is well known to present the appearance of an uniform and vast sandy heath, covered with a deep accumulation of diluvial gravel, in the midst of which occur enormous rounded

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* *Annales* des Mines (second series), viii. 175, 321.

blocks of granite from Sweden. The great mass of this gravel consists of chalk flints, well marked, and bearing traces of all the characteristic fossils. At Luneburg the fortifications are partly constructed of a rock of gypsum, and about a quarter of a mile hence on the road to Hamburgh, Mr. Conybeare, to whom we owe all these details, discovered a chalk pit which had escaped the attention of former observers. It contained the usual alternation of flints, and afforded good specimens of inoceramus, echinites and most of the characteristic fossils. Professor Buckland and Dr. Boué have traced the chalk through Hanover and in the north of Brandenburg.

The *quadersandstein* which occurs round Dresden, is by some considered as of the same age as the chalk. Certainly its fossils show that it cannot be much older.

In Poland the chalk formation constitutes a line of hills running parallel to the Carpathians. It is finely exhibited at Cracow. It contains abundance of flints, affords the usual organic remains, and rests on a bed of green sand. Hence, passing by Lemberg, it appears to extend to Russia. Here it occurs in detached points on the north side of the Dniester, to the north-east of Zaleszyky, between the 25th and 28th parallels of longitude, east of London.

According to Dr. Clarke, hills of chalk occur at Kasankaiya on the Don, and the town of Bielogorod, signifying *white city*, is said to take its name from the white chalk hills in its neighbourhood; but Mr. Strangeways is of opinion that the supposed chalk of the Crimea is really a tertiary formation, and that the localities on the Dniester are the only ones which are well ascertained in Russia.*

In Ireland a remarkable deposit of indurated chalk forms the basin of the great basaltic area in the north-east angle of the island. It contains flints and the same organic remains as the English chalk.

It would seem, as has been observed by Buckland and Conybeare, that the induration of the Irish chalk has been owing to the action of the trap rocks connected with it, which were probably in contact with it while in a state of fusion.

In Italy the Scaglia, which covers the extreme secondary chains of the Alps in the Veronese is considered as a variety of chalk. It leans against the group of the Euganean hills, near

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* Geological Transactions (second series), i. 1.

the mouth of the Po, which appear to have forced it upwards. Like the Irish chalk it is indurated, and, doubtless owing to the same cause, being partially covered by the extinct volcanoes constituting the Euganean hills.

According to Dr. Boué, chalk occurs also in the basin of Bohemia and the valley of the Elbe. The formation in this district known by the name of *planer kalk*, is, according to him, really chalk. He notices scattered patches of it in the valley of the Elbe, in the bottom of a sinuosity in the granite near Mahles on the east of Meissen; between Plauen and Strehlod, west of Dresden; and near Zchist, south of Pirna.

The basin of Suabia and Bavaria appears to exhibit cretaceous marls and chloritous chalk, like that of Bohemia, on its southern border at the foot of the Alps. As, for example, south of Munich, at Berg, and near Gastein.

I am not aware that chalk has been met with in America, either on the north or south side of the Isthmus of Darien, nor has it been observed in any part of Africa or Asia.

CHAP. IX.

OF THE GREEN SAND FORMATION.

The formation immediately under the chalk has been denominated *green sand* (*glaucinie* by the French), in consequence of the green-coloured particles frequently visible in its uppermost bed. In Sussex and Kent where this formation is most fully developed, and where it has been most carefully studied, it consists of four subordinate formations, which have been distinguished by the following names, beginning with the uppermost.

1. Upper green sand, called also firestone and Merstham beds.
2. Galt or blue chalk marl.
3. Lower green sand.
4. Weald clay or ferruginous clay.

1. The *upper green sand* is a bed directly under the chalk marl. It consists of marl mixed with green-coloured grains, *which, according* to the analysis of Berthier, are composed of

			Atoms.
Silica,	50	25	16
Protoxide of iron,	21	4·6	3
Alumina,	7	3·11	2
Potash,	10	1·66	1
Water,	11	9·77	6
	99		

Hence its constitution is $KS^3 + 3fS^3 + 2AlS^2 + 6Aq$.

In some places this formation is in the state of sand, while in others it constitutes a stone sufficiently hard for building, and called in the country *firestone*.* The transition from the marl to the firestone, is in many localities so gradual, and the sandy particles are so sparingly distributed, that the *chalk marl* may be said to repose immediately on the *galt*. In other places, however, the characters of the firestone are very peculiar, so much so, that some geologists have deemed them sufficiently important to rank as an independent formation.

It may be seen very well exposed at Southbourn, a little to the east of Beachyhead, where it lies immediately under the chalk marl.

The fossils discovered in this bed, are, with but few exceptions, similar to those which are common in the chalk marl, namely,

Ammonites varians,
———— Mantelli,
———— planulatus,
Turrilites,
Scaphites,
Grypheæa vesiculosa,
Echinus Murchisoni,
Fucoides Targionii.

In attempting to trace this bed through the interior of the country, we find its course in many localities but obscurely indicated; and in some, the prevalence of a few green particles in the lower beds of chalk constitutes the only evidence of its existence.

2. Immediately under the upper green sand lies a bed of stiff marl, varying in colour from a light grey to a dark blue, and abounding in marine shells, and called *galt* or *gault*,† from a provincial term used in Cambridgeshire. It generally constitutes a valley within the central edge of the chalk of Sussex, Hampshire, Surrey, and Kent, and may be traced with little interruption from Southbourn to Folkstone, in Kent, near

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* *Macigno crayeux* of Brongniart.

† *Marne bleue de la glauconie* of Brongniart.

which town it forms a cliff, celebrated for the beauty and variety of its organic remains.

It forms a soil remarkable for its tenacity, and is usually distinguished by the term *black land*. It seldom exceeds 100 feet in thickness. It may be traced with little difficulty from near Loughton Place, six miles north-east of Lewis, almost round the amphitheatre of chalk hills which encloses the Wealds of Kent and Sussex, and always under the upper green sand where that bed can be distinguished. In the more northern and western chalk districts the galt bed is not so distinct. In Cambridgeshire it is called *galt*, in Surrey, *malm*.

The fossils in this bed are remarkable for their beauty, the pearly covering of the shells being generally preserved. They consist of

Ammonites,
Hamites,
Nautili,
Belemnites,
Nuculæ,
Inoceramus, sulcatus, concentricus,
Turbinolia,
Caryophyllia.

The crustacea in the galt are but few. Some of the most remarkable have been figured by Mr. Mantell. They are

(1.) A species of a new genus of the family *Leucosiadæ*, nearly related to the genus *Arcania*. The shell, or crust of the thorax, alone remains. It is of a suborbicular form, rather inflated, obscurely trilobate, with 12 or 13 aculeated tubercles. The margin is dentated.

(2.) A species of a genus of the family *Carystidæ*. The shell is oblong, ovate, depressed; the surface covered with minute granulæ, the margin bidentated near the front. No vestiges of the legs, antennæ or claws remain.

(3.) A species of the genus *Etyus*, of the family *Canceridæ*. Transversely obovate, obscurely trilobate; the surface covered with irregular papillæ.

(4.) A species of a genus belonging to the family *Coristidæ*, intimately related to *Corystes*. This species is longitudinally obovate, convex, with a tuberculated dorsal ridge, having a row of three tubercles on each side. The shell is truncated posteriorly, and the margin literally tridentated. The abdomen is composed of six or seven arcuate segments, and there are three or four legs on each side.

(5.) Fragments of the abdomen of two species of *Astacidæ*.*

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* *See Mantell's* Geology of the South-East of England, p. 166.

3. *Lower green sand.* This formation is also called *shanklin sand*, because it is very conspicuous at Shanklin, on the east side of the Isle of Wight. It consists of sands and sandstones, of various shades of green, grey, red, brown, yellow, and white, with subordinate beds of chert, limestone, and fuller's earth. These beds are but obscurely seen in the east of Sussex; but as we proceed towards the west they gradually rise into hills of considerable altitude, and form a striking feature in the physical geography of the country. These beds admit of a triple division, as was first shown by Dr. Fitton.*

The first or uppermost consists of sand with irregular concretions of limestone and chert, sometimes disposed in courses oblique to the general direction of the strata. The top of this sand in the vicinity of Folkstone and Hythe, forms an extensive plateau, resembling that of the Blackdown range of hills in Devonshire.

The second consists chiefly of sand, but in some places is so mixed with clay, or with oxide of iron, as to retain water. It is remarkable for the great variation in its colour and consistency.

The third and lowest group abounds much more in stone; the concretional beds being closer together and more nearly continuous.

In the south-eastern parts of Sussex, this formation occupies but an inconsiderable extent on the surface, and in many instances, a few insulated hillocks are the only indications of its presence. In Kent and Surrey, the lower green sand occupies a more considerable space, Hythe, Maidstone, Sevenoaks, Tilvester hill, Riegate, and Godalmine, are situated in it. In the Isle of Wight, it constitutes a very considerable portion, interposed between the chalk hills which traverse that island towards the north and the undercliff on the south. Shanklin and Sandown bay constitute its termination on the east. In the other parts of England, near the chalk hills, it has not been so accurately distinguished.

The only remains of the higher animals hitherto found in this formation, are a few teeth of fishes, both of a conical and lanceolated shape. The shells are very numerous. A pretty copious list of them has been given by Mr. De la Beche, in his Manual of Geology.†

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* *Annals of Philosophy* (2d series), viii. 365.

† Page 303.

In Parham park, casts of univalves and bivalves, particularly of trigoniæ, gervilliæ, and rostellariæ, are found in perfection in the indurated blocks of ferruginous sand. Many new species have been discovered by Mr. Martin in the middle and lower group of sands in the vicinity of Pulborough. Among these are

Mya mandibula,	Pholadomya,
Trigonia spinosa,	Lenia,
Nucula impressa,	Lucina,
Mytilus edentulus,	Modiola, &c.

4. *Weald clay.* The term wealden was suggested by Mr. Martin, to designate the strata which, in the south-east of England, are interposed between the lower arenaceous beds of the sand formation and the Portland oolite.

Taken in a general view, this formation may be considered as a series of clays and sands with subordinate beds of limestone, grit, and shale, containing fresh water shells, terrestrial plants, and the teeth and bones of reptiles and fishes; univalve shells prevailing in the upper, bivalves in the lower, and saurian remains in the intermediate beds. The state in which the organic remains occur, showing that they have been subject to the action of river currents, but not to attrition from the waves of the ocean. The district of this formation may be described as an irregular triangle, the base extending from near Pevensey in Sussex, to Seabrook in Kent, and the apex being situated in Western Sussex, near Harting Combe.

Mr. Mantell has divided this formation into the three following subordinate ones.*

1. *Weald Clay.*

It constitutes a stiff clay of various shades of blue and brown, with subordinate beds of limestone and sand containing septaria. The fossil remains in it are

Poludinæ,	Bones of reptiles, rare,
Cypris faba, cyclides,	Scales and bones of fishes.

It may be seen in the Wealds of Sussex, Surrey, and Kent, forming the vale between the Downs and the Forest ridge.

2. *Hastings Beds.*

a. *Horsted Sand.*

Grey white, ferruginous, and fawn-coloured sand and fria-

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* *Geology* of the South-East of England, p. 182.

ble sandstone, with abundance of small portions of lignite. This sand contains traces of carbonized vegetables.

b. *Strata of Tilgate Forest.*

Sand and *friable sandstone*, of various shades of green, yellow, and ferruginous; surface often deeply furrowed.

Tilgate stone, very fine compact, bluish or greenish grey, grit, in lenticular masses, surface often covered with mamillary concretions; the lower beds frequently conglomerate, and containing large quartz pebbles.

Clay or *marl*, of a bluish grey colour, alternating with sand, sandstone, and shale.

The fossils are rarely bones and shells, ferns, and stems of vegetables.

c. *Worth Sandstone.*

White and yellow friable sandstone and sand. The fossils are ferns and arundinaceous plants, lignite, &c.

3. *Ashburnham Beds.*

A series of highly ferruginous sands, alternating with clay and shale, containing ironstone and lignite. The fossils are ferns and carbonized vegetables.

Shelly limestone, alternating with sandstone, shale and marl, and concretional masses of grit.

The fossils are Cypris; shells of the genera cyclas and cyrena; lignite and carbonized vegetables.

1. *Weald clay.* This formation is remarkably favourable to the growth of the oak. Its out crop forms a valley between the lower green sand on the one hand, and the forest ridge on the other, throughout the northern and north-western division of the southern denudation of the chalk. But in the south-eastern part of Sussex, where the lower green sand is scarcely seen on the surface, it constitutes a valley at the foot of the northern escarpment of the Downs, its beds of limestone and sandstone forming longitudinal ridges.

The Sussex marble, so strikingly characteristic of the Weald clay, occurs in layers that vary from a few inches to a foot or more in thickness, and are separated from each other by seams of clay, or of coarse friable limestone. It is of various shades of bluish-grey, mottled with green and ochre yellow, and is composed of the remains of fresh water univalves, formed *by a calcareous cement* into a beautiful compact marble. It bears a high polish, and is elegantly marked by sections of the shells which it contains. Occasionally a few bivalves *(cyclas)* occur, and the remains of the minute crustaceous coverings of the *Cypris faba* very constantly.

It is frequently found in blocks or slabs sufficiently large for sideboards, columns, or chimney pieces, and few ancient residences in Sussex are without them. They were used in the time of the Romans; and in the early Saxon times they were placed in the upper arcades of Cathedral churches, as at Canterbury and Chichester. Another general use was for the slabs of sepulchral monuments. Most of the principal Gothic edifices in England contain slabs or pillars of Sussex marble.

The shells in it belong to the genus *paludina*, the recent species of which inhabit fresh water. The remains of the *Cypris faba* are found also in a fresh water limestone in France. Sussex marble has been found in almost every part of the Weald clay.

The following table, drawn up by Mr. Mantell,* exhibits the most remarkable fossils found in the Weald clay:—

Fossils.	Localities.
Scales and bones of fishes apparently of a very small species.	Resting-oak hill.
Bones of saurians.	
Tooth of crocodile.	Swanage bay, Isle of Wight.
Cypris faba.	In the marble and septaria.
Paludina fluviorum.	In the marble.
——— extensa.	Ibid.
——— elongata.	Resting-oak hill.
Cardium turgidum.	Swanage bay.
Melanea attenuata.	Ibid.
——— tricarinata.	Ibid.
Cyclas membranacea.	Resting-oak hill.
Pinna.	Swanage bay.
Venus.	Ibid.
Potamides?	Shipley, near Cowfold.

2. *Hastings beds.* The alternating sands, sandstone and shale which form the central group of the Weald are distinguished by Dr. Fitton by the name of *Hastings beds*, because the cliffs in the neighbourhood of Hastings present the most instructive and extensive section that can be obtained.

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* *Mantell's Geology* of the South-east of England, p. 188.

They extend from Bexhill, in Sussex, to Ham Street, near Aldington, in Kent, forming a line of irregular cliffs about 40 miles in length, and from 20 to upwards of 600 feet in height. Crowborough hill, near Tunbridge Wells, which is the highest point in the range, is 804 feet above the level of the sea.

The Tilgate beds consist of irregular alternations of sand and sandstone, and lie immediately under the Horsted beds. The lowermost stratum of these contain large concretional or lenticular masses of a compact calciferous grit or sandstone, which was formerly quarried in the neighbourhood of Tilgate and St. Leonard's forests, near Horsham. These strata were first described by Mr. Mantell in 1822. There are three or four layers of the Tilgate stone varying in thickness from two inches to two feet each. They rest on blue clay and shale, which separate them from the next subdivision. They are the principal repository of the Saurian remains of the waters which deposited the Hastings sands, and are therefore by far the most interesting strata of the formation. They extend from its western extremity at Loxwood, to Hastings, where they occupy the upper part of the cliffs.

The blue clay which supports the Tilgate beds is succeeded by a series of arenaceous strata, some of which afford a fine soft building stone, which is extensively dug at Worth, near Crawley. It is for the most part of a white or fawn colour, and occasionally contains leaves and stems of ferns and other plants. The Worth sands occur in great force at Hastings, occupying the middle of the cliff.

3. The Ashburnham beds occupy the base of the cliffs at Hastings, and appear in many places in the interior. They are succeeded by beds of shelly limestone, alternating with shale, and including layers of a fine grit, precisely similar to the Tilgate stone. This bed abounds with carbonized vegetables *(ferns)*, casts of bivalves and other organic remains.*

Mr. Mantell has described and figured the principal fossils, both vegetable and animal, found in the Wealden strata. Indeed, for the knowledge of not a few of these fossils we are indebted to Mr. Mantell himself. The principal vegetable impressions are of the following plants:—

1. The petrified trunks of large plants, belonging to that tribe of vegetables which is so common in the coal beds, and

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* For a minute description of the different Wealden strata, the reader is referred to Mr. Mantell's *Geology of the South-East of England*, which is chiefly occupied with an account of these interesting beds.

which seem to hold an intermediate place between the Equiseta and the Palms. Of these the most interesting is the

Clathraria Lyellii, figured by Mr. Mantell in his first plate.
Endojinites erosa, also figured by Mantell in his first plate.
2. Cycadites Brongniarti, figured by Mantell, p. 238.

Sphenopteris Sillimani,
———— Phillipsii, } Figured by Mantell, p. 239.
———— Mantelli, Ibid. p. 241.
Lonchopteris Mantelli, Ibid. p. 243.
Lycopodites?
Calamites?
Equisetum Lyellii, Ibid. p. 248.
Carpolithus Mantelli, Ibid. p. 246.

The shells described by Mantell are:—

Paludina elongata,
———— carinifera,
———— fluviorum,
Neretina Fittoni,
Psammobia,
Cypris faba.*

Cyclas membranacea,
——— media, } Mantell, p. 249.
Melanopsis, or Melanca,
Unio antiquus,
—— compressus, } Ibid. p. 250.
—— aduncus,
—— porrectus,

Psammoben, Mantell, p. 248, fig. 6.
Mytilus.

The remains of fishes in the Wealden beds consist of detached bones, teeth, scales, and fins. In some rare cases the scales and skeleton lie in juxta position. These are referred by Mantell to the

Lepisosteus Fittoni.

The remains of various species of turtles, both fresh water and marine, have been discovered in the strata of Tilgate Forest.

Teeth of the crocodile have been found in Tilgate Forest. They are figured by Mantell, p. 261.

Scales resembling those of the alligator.

Megalosaurus Bucklandi.

Iguanodon. The teeth, vertebræ, and horn of this animal were discovered by Mr. Mantell in the coarse conglomerate of the forest as early as 1822, and he has given an interesting

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* All figured by Mantell, p. 248.

account of the remains of this extraordinary reptile, which seemingly fed upon vegetables.* Nothing like a perfect skeleton of this remarkable animal has hitherto been found.

Plesiosaurus, probably *dolichodeirus*, the same as occurs in the *lias*.

Bones of a bird, probably of a species of *ardea*.

Megalosaurus. Teeth.

Cylindricodon. Teeth.

Hylæosaurus.†

Traces of the *green sand* formation may be observed underlying the escarpments of chalk in Yorkshire. It appears very decidedly in the vale of the *white horse* in Berkshire, near Childray and Wantage. Hence it may be traced through the counties of Wilts and Dorset. In Wiltshire it frequently constitutes a secondary range of hills standing in advance of those of the chalk formation, and nearly rivalling them in height. This is the case at Warminster and Stourhead. It forms also the vales of Pewsey and Wardour.

On the confines of Dorset and Devon, it presents many high and insulated masses, constituting outliers. In this way it forms the extensive table-land of Blackdown, which stretches far into the west, covering a great part of the eastern district of Devonshire. Still farther west and beyond Exeter we have another outlying mass of this formation, capping the long range of Haldon Hill, which is divided only by an intermediate valley from the granite of Dartmoor.

On the continent the green sand formation may be seen on the coast of France opposite to Kent. The western boundary is near Havre and Honfleur, and the eastern boundary at Valenciennes, where the green sand assumes a conglomerate character, and is known by the name of *Tartia*. This tract has been described by Omalius d'Halloy under the name of *lower chalk*.

On the northern borders of the Alps, the highest beds of the exterior calcareous chain consist of a dark coloured limestone, often mixed with sand and green particles, and agreeing in its fossils with the green sand formation in England. Similar beds, and in a similar position, are described as occurring on the skirts of the Maritime Alps of Nice.

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* P. 269. See also Phil. Trans., 1825, p. 179.

† An interesting description (with figures) of the skeleton of this animal, discovered by Mr. Mantell in the sandstone of Tilgate Forest in 1832, will be found in his work so often referred to, p. 331.

The *quadersandstein* of Saxony is considered by some to belong to the green sand formation; but the more general opinion is that it constitutes a bed in the oolite formation.

M. Thirria describes a considerable superficial deposit of clay with pisiform iron ore in the department of the Haute Saone, part of which he considers as referrible to the green sand.

M. Brongniart notices among the cretaceous rocks of the Isle d'Aix, and the embouchure of the Charenti, a marl which he refers to the Wealden clay, containing nodules of amber, pieces of lignite, and silicified wood, in which holes formed by some perforating animal are replaced by agates.*

According to Professor Pusch, there is a ferriferous deposit in Poland, situated between the Jura limestone and the cretaceous rocks, which may be considered as the equivalent to the Weald clay and iron or Hastings sand of England. He gives a detailed description of this formation in the second volume of the *Journal de Géologie.*

The fossil plants hitherto met with in the green sand amount only to seven species. Of these five species are monocotyledonous, namely, four species of *zosterites* and one species of *clathraria.* Two species are ferns, namely one species of *sphenopteris* and one of *lonchopteris.*

CHAP. X.

GREAT OOLITE FORMATION.

This formation is of great importance, not only on account of the space which it occupies, and the numerous beds of which it is composed, but because it was first made out in all its subdivisions in Great Britain. For this most important step in geology we are in a great measure indebted to the sagacity of Mr. Smith, who first determined the beds, pointed out their distinguishing characters, and even distinguished them by name.

This formation begins in Yorkshire, a little to the south of the Tees, and extends southwards along the sea coast as far as the Wash in Lincolnshire, a breadth of about ninety miles.

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* Tableau des Terrains, p. 217.

But in the interior of the island its breadth scarcely exceeds thirty miles. From the sea coast of Yorkshire it passes in a south-westerly direction to the south of England, and reaches the sea on the coasts of Devon and Dorset, its western extremity being not far from Sidmouth, and its eastern the Isle of Purbeck, constituting a breadth little short of forty miles.

This great tract of country is composed of a series of oolitic limestones, of mixtures of sand and limestone, of clay and marly beds alternating with each other, and generally repeated in the same order. When we cross over this formation, travelling from south-east to north-west, we may observe, that it consists of three series of low hills running parallel to each other, and separated by considerable valleys. These three chains naturally divide the formation into three parts or systems, which are distinguished by the names of

1. Upper oolite.
2. Middle oolite.
3. Lower oolite.

The three intervening valleys are occupied by clays, or calcareous clays, which are distinguished by the names of

1. Kimmeridge clay.
2. Oxford clay.
3. Lias limestone.

This great formation is remarkable for the numerous fossils which it contains.

Impressions of no fewer than 43 species of plants have been enumerated. Of these 27 are cryptogamous plants, namely, 22 ferns and 1 equisetaceous species, 1 lycopodiaceous, and 3 fucoides; 4 are *cycadeæ*, 1 Bucklandia, 9 coniferæ, and 2 not well determined. Two of these, namely,

Zamites Bechii,
——— Bucklandi,

have been observed at Lyme Regis, in Dorsetshire.

20 have been observed in the coal beds near Whitby, which occur in the lias, the lowest bed of the great oolite formation. 8 have been met with in the same beds at Här, in Sweden, and 4 in Bornholm. The most remarkable of these are the following:—

Glossopteris Nelsoniana,
Pecopteris Agardhiana,
Clathropteris meniscoides,
Tæniopteris vittata,
Lycopodites patens,
Culmites Nelsonii,
Pterophyllum dubium,
Nelsonia brevis.*

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* An interesting description of the vegetable fossils in the coal beds in

The remaining vegetable impressions have been observed at Neuewelt Stutgard, or in France.

In the undermost beds of this formation corals are rare, one tribe only, the turbinolia, having been met with. But several species of pentacrinite and echinus occur in the lias limestone.

Higher up in the series among the oolite limestones, we meet with alcyoniæ and a variety of corals. Indeed there is one bed almost entirely composed of corals, and on that account distinguished by the name of *coral rag*. The crinoid family is rather conspicuous in the oolite. Among others may be mentioned the *pentacrinites caput Medusæ* and *subangularis*. Species of the genera *conulus*, *cidaris*, *echinus*, and *clypeus* of the echinus family are met with, and more rarely, fragments of crustacea.

A very considerable number of shells, both univalves and bivalves, occur in this formation. A list of 199 species, together with the localities where each was found, has been given by Brongniart in his *Tableau des Terrains*. But by far the most complete list is given by De la Beche in his Manual of Geology. He enumerates 42 species of plants, 327 species of zoophites, 748 species of shells, 34 species of reptiles, besides several insects and fishes whose species have not been determined.

The remains of fish are not uncommon in the lower beds of this formation, but they are always in a very imperfect state. I am not aware that any of them has been referred even to a genus, except the *Dapedium politum*, described by De la Beche as occurring at Lyme Regis.

In this formation the bones of several oviparous quadrupeds make their appearance, and no quadrupeds are met with lower down in the series. They consist mostly of the remains of amphibious quadrupeds, which are capable of living both on land and in water. These are the remains of turtles and of various species of animals belonging to the genus lizard, but differing in structure from all the species at present known to exist, and in such particulars as must have fitted them to live entirely in the sea. These are the *Ichthyosaurus*, *Plesiosaurus*, and *Megalosaurus*. The last must have been an animal of prodigious size. A skeleton of one, 40 feet long, has been found at Stonefield.

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the south of Sweden, which seem to belong to the lias formation, may be seen in the *Kông*. Vet. Acad. Handl. for 1823 and 1824.

Four species of Ichthyosaurus have been found at Lyme Regis, namely,

Ichthyosaurus communis,
——— plytyodon,
——— tenuirostris,
——— intermedius.

The plesiosaurus dolichodeirus has been met with at the same place. And the

Plesiosaurus carinatus,
——— pentagonus,
——— trigonos,

have been found in the north of France.

The bones of a well characterized crocodile have been met with at Boll in Wirtemberg, namely, the *crocodilus Bollensis.* It has been met with also in England. It is a different species from any of the crocodiles at present existing.

But the most singular fact is the occurrence of the bones of a species of didelphis, or opossum, in the Stonefield slate near Woodstock, in Oxfordshire. The opossum tribe has been observed only in America and New Holland, and never in any part of Europe, Asia, or Africa.

The Stonefield slate, so abounding in curious petrefactions, contains also legs and thigh bones, apparently belonging to birds. But even the genus to which they belong has not been determined.

Two or three species of coleopterous insects (at least so pronounced by Dr. Leach) have been met with also in Stonefield slate. In the same slate occur several vegetable impressions, principally flags, ferns, and mosses. The most characteristic shell in the Stonefield slate, is a small studded *trigonia.*

From these petrifactions, there can be little doubt that the great oolite formation was formed at the bottom of the sea. At the time of the deposition of the beds, the sea was inhabited by fishes and zoophites. It would appear also, that some enormous amphibious animals, now extinct, at that time existed.

The great oolite formation, then, marks a remarkable era in the history of the earth—the period when amphibious animals began to exist, and when the opossum tribe, and also birds, began to make their appearance. We must now take a more particular view of the different beds of which this great formation is *composed.*

1. *Upper Oolitic System.*

This subdivision of the oolite may be divided into three subordinate formations; namely,

1. Argillo-calcareous strata of Purbeck, which constitutes the highest of the oolitic series.
2. Oolitic strata of Portland, Tisbury, and Aylesbury.
3. Kimmeridge clay—Oaktree clay of Smith.

(1.) The Purbeck beds, so called, because they are best seen at Purbeck in Dorsetshire, to the west of the Isle of Wight, consist of many thin strata of argillaceous limestone, alternating with slaty marls, and forming an aggregate of more than 300 feet in thickness.

The Purbeck stone consists chiefly of shells (principally the helix vivipara), partly whole and partly in a state of comminution, imbedded in a calcareous cement, which is sometimes very pure and crystallized, and sometimes in a state approaching to indurated marl. These beds are separated by others entirely without shells, and also by layers of shale and marl, the shivery nature of which allows the stone to be quarried with great ease.

The stone well known by the name of Purbeck marble, and which was formerly much used in the Gothic churches in the south of England, for columns and monuments, was nearly the uppermost of these beds, and differs from the common Purbeck stone only in the purity of its calcareous matter, and in the shells being more entire. It is almost identical with the Petworth marble, but is now out of use, and the quarries are filled up and scarcely known.

Beautiful impressions of fish are frequently met with by the quarrymen, between the laminæ of the limestone, and abundance of fragments of bones, some of which belong to the turtle. Mr. Johnson of Bristol, possesses a very perfect head of a crocodile found in Purbeck, but it is not quite certain whether it belongs to the Portland or Purbeck beds.

The thickness of the beds at Purbeck is about 291 feet. And the greatest thickness of the upper oolitic system is about 1011 feet.

The Portland beds first make their appearance in Buckinghamshire. They appear very conspicuous in the upper part of Shotover hill, near Oxford, immediately under the Hastings or iron sand, which constitutes the summit of the hill. At the foot of the ridge, at Shotover, the Kimmeridge clay *makes its first* appearance near the village of Headington.

The beds may be traced south till they are lost by a thick covering of chalk in Wiltshire. On the south side of the chalk, an opening between Stourhead and Shaftesbury again exposes the subjacent strata. From this they may be traced till they terminate on the sea coast, in the isles of Portland and Purbeck, which constitute the southern extremity of Dorsetshire. At Fonthill, Chilmark, and Tisbury, these beds have been much disturbed, and instead of their usual horizontality, have been greatly raised, and dip to the north and east at an angle of 40°.

(2.) The second member of the higher oolitic system is the Portland stone. This formation consists of several beds of coarse earthy limestone. The different beds often vary in their characters; nor are the same beds of an uniform texture in different localities.

The calcareous rocks are most commonly a fine-grained white oolite, or a loose granular limestone of earthy aspect, and of various shades of yellowish-grey; and more rarely a compact cretaceous limestone, having a conchoidal fracture. In Wiltshire and Dorset, many of the beds contain layers of chert, alternating with them, like the flints, in the chalk formation. The lower beds are very sandy and often very abundant in green particles.

The more oolitic varieties, principally quarried in the Isles of Purbeck and Portland, afford most of the stone used in London for architectural purposes.

The uppermost beds in the Isle of Portland, consist of an oolitic rock, and they are numerous. That which appears on the summit, and is called the *cap*, is of a yellow colour and porcellaneous character. It is only burnt for lime. The next bed is worked for sale, being the best building stone. Those below this bed contain numerous casts of shells that injure the stone, which is only used for coarser purposes; and with these beds others alternate, consisting of chert.

The whole thickness of these beds is about 120 feet.

The remains of fish are occasionally met with in the Portland beds. The following table exhibits a list of the principal shells occurring in this formation:—

Ammonites triplicatus,
———— giganteus,
———— Lamberti,
———— Nutfieldiensis,
Turritella,
Natica,
Solarium conoideum,
Trochus,
Ostrea expansa,
Crenatula,

Pecten lamellosus,
Trigonia clavellata,
———— gibbosa,
Astarte cuneata,
Lutraria ovalis,
Nerita sinuosa,
Unio,
Cardita,
Cyclas,
Venus.[*]

Of these shells the Ammonites triplicatus, and pecten lamellosus, are most characteristic.

No other zoophitical remains are mentioned, than those of a beautiful aggregated madrepore, specimens of which, imbedded in a semitransparent chert, occur at Tisbury in Wilts. Large fragments of wood are common.

(3.) *Kimmeridge clay.* The beds of this formation consist of a blue slaty or greyish-yellow clay containing selenite. But it sometimes contains beds of highly bituminous shale; as, near Kimmeridge, on the coast of the isle of Purbeck, where it is used as fuel, and has obtained the name of *Kimmeridge coal.* The beds are finely displayed near that place. They are also well exposed on the coast of the isle of Portland.

Near Smedmore, in the parish of great Kimmeridge, is found, what the country people call *coal money*, generally on the top of cliffs, two or three feet below the surface, enclosed between two stones set edgeways, and covered with a third. Along with the coal money, there is always the bones of some animal. The pieces called coal money, are from two to three inches and a half in diameter, and a quarter of an inch thick; round, on one side flat and plain; on the other, convex with mouldings. On the flat side there are two, sometimes four, small holes, probably the central holes by which they were fixed to the turning lathe. They are supposed to have been either *amulets* or *money.* There has also been found in the neighbourhood, a shallow bowl of Kimmeridge coal, six inches high and as many in diameter, containing coal money.

The Kimmeridge clay beds, where thickest, which is on the shore of the isle of Purbeck, are about 600 feet in thickness; but they thin out as we proceed north. Near Oxford the beds are only 100 feet thick. Farther north they disappear altogether.

Remains of the ichthyosaurus and plesiosaurus have been found in this formation, at Kimmeridge and Headington. The shells observed in it are the following:—

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[*] *Conybeare and Phillips'* Geology of England and Wales, p. 175.

Nautilus,
Ammonites, 5 species,
Belemnites,
Trochus,
Turbo,
Melania Headingtoniensis,
Ostrea deltoidea,
—— cristagalli, and three other species,
Astarte lineata,
—— ovata,
Trigonia costata,
Trigonia clavellata,
Venus,
Modiola,
Cardita,
Cardium,
Mactra,
Tellina,
Chama, 2 species,
Avicula,
Pecten,
Terebratula,
Serpulæ.*

Of these shells, the ostrea deltoidea appears to be the most characteristic. The water in this formation is deficient, and of bad quality.

2. *Middle oolitic system.*

The thickness of the congeries of beds, which constitutes the middle oolitic system, is between 500 and 600 feet. It constitutes the second range of hills, together with the valley situated between that range and the third range of hills. Like the preceding, it may be divided into three subordinate beds; namely,

1. Coral rag,
2. Calcareous sand and grit,
3. Oxford clay, or clunch clay of Smith.

It will be more convenient to consider the first two of these beds together, as they are, in fact, intermingled. They constitute a series of beds, occupying a thickness of from one to two hundred feet; in the upper part of which, the calcareous matter, and in the lower, the siliceous, prevails.

The *coral rag*, properly so called, occurs principally towards the middle of the series. Such, at least, is the disposition of the beds near Oxford, where they have been most attentively examined. And it has been ascertained, that the same order prevails in Wiltshire.

The *upper calcareous beds*, are a calcareous freestone, of tolerably close texture, full of shells comminuted into fragments, generally too small to admit the determination of the genus; more or less oolitic, frequently very indistinctly so; but occasionally passing into beds, in which the oviform grains

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* *Conybeare and Phillips'* Geology of England and Wales, p. 178.

are much larger than in any of the other oolites. The colour of all these beds is of a yellowish white, becoming palest in the most oolitic, and passing occasionally into shades of light grey. It affords a tolerable building stone, but far inferior to the oolites of the uppermost and undermost systems. Oxford has to regret her vicinity to this formation, as it has had rather an injurious effect upon the beauty and durability of her splendid buildings. It is a tolerable limestone, but contains from one-tenth to one-third of sand.

The coral rag which lies under this freestone, consists, as its name imports, of a loose rubbly limestone, mingled with, and often almost entirely made up of, a congeries of aggregated and branched madrepores. Two or three irregular courses of this rock intervene between the freestone and the inferior sandy beds. They often assume a marly character, and grey colour: they are used for lime, and for mending the roads.

The sandy, or, rather, siliceo-calcareous beds, consist of a thick deposit of yellow-coloured quartzose sand, usually containing about one-third of calcareous matter, and traversed by irregular strata, and concretions of indurated calcareo-siliceous gritsone. These rest immediately on the subjacent Oxford clay, and may be traced through the whole escarpment of the hills composed of this formation, supporting the coral rag and freestones. It is in the calcareous grit of this sand that the fossils of this formation occur in the greatest plenty, and especially in the beds immediately beneath the coral rag beds. The *ostrea gregaria* characterizes the sand generally.

Iron is generally abundant throughout the sand; so much so, as frequently to give it a red colour.

This formation appears first on the east of Oxford, where it forms the elevated platform rising on the south-west of Otmoor, and occupying the interval between the confluence of the Charwell and Thame with the Isis. This platform supports the still higher ridge of Shotover hill, composed of the upper system of oolite. The whole of its surface, which extends about five miles from east to west, and seven from north to south, is covered with quarries, of which the principal are those of Headington, two miles east of Oxford, at the foot of the high ridge of Shotover, in which the junction of the beds of this formation, and the Kimmeridge clay, which lies above them, is well displayed.

This formation passes regularly from a little north of Oxford, as far south as Frome, in Somersetshire. It terminates a little to the east of that town, between the counties of Somerset and Wilts.

The remains of vertebral animals are scarce in this formation. Yet vertebræ of the Ichthyosaurus have been found in its beds of calcareous grit. The shells are numerous, especially in the beds of calcareous grit. The following are the principal:—

Ammonites, 5 species,
Nautilus,
Belemnite,
Melania,
Turbo muricata,
Helix,
Trochus bicoronatus,
Ampullaria,
Turritella,
Serpula,
Ostrea gregaria, cristagalli,
Pecten fibrosus,
Chama,
Trigonia,
Lima rudis,
Lithophaga,
Mytilus,
Modiola.

Fragments of fibrous shells are common, but not sufficiently perfect to be made out. Many beautiful echinites occur in this formation. The most remarkable of which are

Cidaris, 3 species,
Clypeus, 2 species.

It is in this formation that the clypeus first appears, never being found in any formation situated above it.

Madrepores are abundant in this formation; but in those above it they are few and scarce. The chief are

Caryophyllia, 2 species,
Astrea, 3 species.

Fossil wood is often found in the calcareous grit belonging to this formation.

(3.) The *Oxford* or *clunch clay* forms the valley which separates the middle oolite from the inferior range. It includes subordinate beds of limestone, called Kelloway rock.

It consists of very thick beds of a tenacious and adhesive clay, of a dark blue colour, becoming brown on exposure, and containing argillo-calcareous geodes and septaria. These latter are often called *turtle stones.* The clay beds are often mixed with calcareous, and sometimes with bituminous, matter, affording, in the latter case, an inflammable shale, which has led to various unsuccessful searches for coal.

In 1787, this formation was bored through near Boston, in Lincolnshire, in sinking a well. It was 478 feet thick. At the *village of Donnington*, six miles west of Louth, in Lincolnshire, it was penetrated to the depth of 309 feet, in search of coal. The beds were forty-one in number, and consisted of alternations of clay, bituminous shale, and ironstone. In some beds the clay was indurated, in others soft.

The lower portions of the formation occasionally contain irregular beds of limestone. These have been noticed chiefly at Christian Malford, and Kelloway bridge, near Chippenham, in Wiltshire; and from the latter locality have been called *Kelloway rock.* This stone occurs in irregular concretions, the exterior aspect of which is brown and sandy; the interior being harder, and of a bluish colour. It consists almost entirely of a congeries of organic remains, among which several varieties of ammonite are predominant. The beds of clay which cover this rock, abound in selenite, and below it are found a brown aluminous earth, and bituminous wood. Beds of clay separate the Kelloway rock from the oolites.

This formation appears on the sea-shore at Yew Nab, near Filey bridge. It is probable that the greatest part of the clay vale lying along the Yorkshire Derwent, as far as New Malton, and lying between the chalk and the oolites, belongs to this formation.

South of the Humber it may be traced in a southern direction through Lincolnshire, following the course of the fens along the Ancholme navigation, and the Witham river to Boston. It forms the substratum of the western part of the Cambridgeshire fens, and those which border on Huntingdonshire. Hence it is sometimes called *fen clay.* Where it enters Lincolnshire on the north, it forms a very narrow tract, not more than three miles across. But in the southern part of that county it is a good deal broader, not less than 15 miles, which may be considered as its maximum breadth in England.

A line drawn from Peterborough to Bedford, Buckingham, and Bicester, nearly marks its junction with the subjacent oolite; and another from Huntingdon to Oxford, its superior junction. At Huntingdon its breadth is about 12 miles, and between Bedford and Oxford it is not more, on an average, than 5. West from Oxford it ranges along the valley of the Isis, as far as Cricklade. Thence bending on the east of Malmesbury, it traverses Wilts in a southern direction, following the course of the Avon past Chippenham to Melksam. It passes on, sometimes disappearing, and finally reaches the sea near Weymouth.

Throughout the whole of its course it is very low, though occasionally it rises into moderate heights, as near Buckingham and Bedford. Its average thickness is certainly not less than 500 feet.

In general it forms a poor soil, except when covered by white clay or chalk breccia. The vale from Melbury to Shaftesbury, in Dorsetshire, is famous as a butter country.

Bones of the Ichthyosaurus occur in Oxford clay; but they are rare, and of a different species from those in the lias. It contains also

Ammonites, 3 species
Nautili,
Belemnites,
Rostellaria,
Serpula,
Patella,
Ostrea,
Gryphæa,
Perna.

The petrifactions in the Kelloway rock are

Ammonites, 3 species,
Nautili,
Belemnites,
Rostellaria,
Cardita deltoidea,
Chama digitata,
Gryphæa incurva,
Pecten fibrosus,
Plagiostoma obscura,
Avicula inequivalvis,
Terebratula ornithocephala.

3. *Lower oolitic system.*

This is by far the thickest and most extensive of the three. The beds are very numerous, and many of them have been distinguished by peculiar names; but, as most of these are only subordinate to the great oolitic stratum, we may without impropriety subdivide it, as we have done the other two systems, into three great deposits. These are

1. Great oolite.
2. Calcareous siliceous sand.
3. Lias.

1. *Great oolite.* This name has been imposed by the English geologists, because the chain of hills formed of it may be considered as composed of one great oolitic mass, resting upon the calcareo-siliceous beds below it; but on a more minute examination it will be found, that the upper part of this great oolitic mass presents strata sufficiently distinct to entitle them to a separate description. These, instead of rising in thick masses, are generally fissile or rubbly, are much mingled with clay, forming as it were the link between the pure oolite and the Oxford clay above it. Instead *of the yellowish tinge* of the oolite, they have generally a blue

colour, or in some beds a pasty appearance, and a dead white colour not unlike chalk. It is impossible to trace any general division among these upper beds, which will apply to them in every part of the course of the great oolite. They appear rather as accidental varieties of this great formation. In some instances, indeed, the precipitates of argillaceous and calcareous matter appear to have followed each other alternately, at sufficient intervals to allow the formation of tolerably thick beds of either kind, which may be traced over pretty considerable tracts. This regularity is most distinguishable in the neighbourhood of Bath, and through an extensive tract in the neighbouring counties of Gloucester, Somerset and Wilts. Some idea may be formed of this part of the country by the following section in the neighbourhood of Tellisford and Farley Castle, ten miles south of Bath, beginning with the highest bed:—

1.	Cornbrash,	8 feet to	16 feet
2.	Clay,	8	14
3.	Calcareo-siliceous sandstone,	40	10
4.	Forest Marble,		18
5.	Sand,		2
6.	Clay,	20	60
7.	Great oolite,		130
			250

Let us take a view of the most important of these beds, some of which are of considerable importance.

(1.) The *cornbrash* is a loose rubbly limestone, of a grey or bluish colour; it rises in flattish masses, rarely more than six inches thick. The beds belonging to this stratum in Oxfordshire are often of a pasty or chalky consistence and colour. In Wiltshire it is known by the name of *Cornbrash* or *Corngrit*. At Malmsbury, where it is thick and solid, it is much quarried for building. In other places it is fit only for burning into lime, and for mending the roads.

The upper beds of stone which compose this rock, contain fossils materially different from those in the undermost beds. The clusters of small oystershells and the stems of the pentacrinus lie near together, and not many others are found near the bottom of the rock.

(6.) The *clay* bed lying over the great oolite is usually called *Bradford clay* by the English geologists, because it is best seen at Bradford upon the North Avon, a few miles east from Bath. It consists of a fine blue marly clay which, at the point of its contact with the great oolite, is replete with the remains of the *pear encrinus*, with many small coralloids, and several peculiar terebratulæ.

(3, 4, 5.) The 3d, 4th, and 5th beds are so intimately associated that they require to be described together. This assemblage consists of beds of limestone, generally fissile, and divided by argillaceous partings lying between two beds of calcareo-siliceous sand and gritstone. The undermost bed of sand is usually insignificant, though it sometimes swells into great thickness and importance. These sandy strata appear to contain about one-third of calcareous matter. The gritstone found in them is hard enough to scratch glass, and forms irregular slate-like concretions.

The limestone lying between these sands is called *Forest marble.* Its beds, generally speaking, are thin and slaty. Sometimes, however, beds of two or three feet thick may be found. The colour of the stone is generally gray or bluish, externally brownish, appearing on examination to be frequently composed of a congeries of dark-coloured shells interspersed with white oolitic particles. Bivalve shells are most common in the thick beds, and univalves in the thin. Decomposed pyritical wood often gives a partial redness, and some of the joints have a reddish tinge. The texture of the stone is coarse-grained—the structure of its masses fissile; whence, coarse roofing slates and flag-stones are in general use in the villages on the course of this rock. The more solid beds have been occasionally worked as a coarse marble, being susceptible of a tolerable polish, and variegated by the contour of its imbedded shells. From this circumstance, and the occurrence of these strata in Whichwood forest, Oxfordshire, it has derived its name.

The partings of the clay between the beds of this rock vary in thickness, from less than an inch to more than a foot.

The *calcareous slate of Stonefield* near Woodstock, Oxfordshire, belongs to the same part of the series as the forest marble. This slate is exceedingly remarkable for the singular variety of its organic remains, among which the spoils of birds, land animals and amphibia, occur mingled with vegetables and sea shells. The assemblage of beds worked at Stonefield, consists of two fissile strata of a buff-coloured or gray oolitic limestone called *pendle,* each about two feet thick, separated by a bed of loose calcareo-siliceous sandstone, called race, about the same thickness. Concretions are frequent in the *race*, which are called *whimstones* or *potlids*. They are partially oolitic, sometimes blue in the centre, and vary from six inches to two feet in diameter. Their form is generally that of a flattened sphere. They do not break concentrically, but into parallel planes, and they often contain shells.

The *pendle*, after being quarried, is suffered to lie exposed to a winter's frost, and the blocks being then struck on the edge with a mallet, freely separate into slates sufficiently thin to afford a light material for roofing. The quarries are principally situated in the valley immediately on the south of Stonefield village, which branches off eastwards from that of Evanlode.

In the Forest marble, though its various beds are composed of little else than a mass of shells, loose and whole specimens are rare, and are extracted with considerable difficulty. A few, however, are occasionally found in the clay between the layers of stone. Bones, teeth and wood, firmly imbedded in the rock, are some of its most characteristic indications. The following shells are stated by Conybeare to have been found either in the forest marble or the Stonefield slate:—

Nautilus,
A fusiform belemnite,
Patella rugosa,
Turritella,
Rostellaria,
Ancilla,
Serpula,
Trigonia costata,
Mya,
Venus?
Ostrea cristagalli,
Pecten fibrosus, and another species.

The fossil remains in the Stonefield slate are particularly deserving of attention. It constitutes the oldest rock in which the remains of land animals and birds occur. They consist of

An animal of the opossum tribe,
Crocodile,
Megalosaurus,
Ichthyosaurus,
Plesiosaurus.

The genus to which the birds belong has not been determined.

(7.) *Great oolite.* This bed, both in point of thickness and utility, is by far the most important of the British oolites. It consists of a stratified calcareous mass, varying in thickness from 130 to more than 200 feet. Softer and harder beds alternate in this mass of strata. The former affords the freestone employed for building, which renders the rock so valuable. These strata vary much both in thickness and quality, even in neighbouring quarries.

The Kettering freestone of Northamptonshire is rendered extremely beautiful by the distinctness of its oolitic structure. That of Bath has generally a finer grain; it has been employed in the late repairs of Henry VII.'s Chapel, Westminster. St. Paul's was built principally from quarries about a mile north of Burford in Oxfordshire.

Fragments of comminuted shells may be observed in all the varieties mingled with the ova, but so completely broken down that it is generally impossible to make out the species. This is the reason why we are so imperfectly acquainted with the fossils belonging to this rock.

The colour of the freestone beds is generally white, with a shade of yellow. Of the other beds some are grey, and some almost blue in the middle. Sometimes, also, beds of a brown rusty colour are interspersed, especially at the bottom of the series, near its junction with the fuller's earth. The freestone occurs in thickly bedded masses, which, if traced to a distance, will be often found to thin out. Many of the other beds exhibit a laminated cleavage not parallel to the greater lines of the stratification, for which they have sometimes been mistaken, and described as highly inclined beds alternating with horizontal ones.

The fossil shells in the great oolite are in general so shattered, that it is next to impossible to determine even the genus to which they belong. The only genera mentioned are ill-defined casts which have some resemblance to

Turbo,
Melania,
Ancilla,
Serpula,
Ostrea,
Pecten,
Terebratula,
Plagiostoma.

2. *Calcareo-siliceous sand.* This sandy deposit may be said to form the most universal and characteristic feature of this series; the sands pass almost insensibly by mixture of various loamy and marly beds towards their lower limit into the argillaceous formation which covers the lias; and towards their upper limit by an increase of calcareous matter into the lower oolitic beds. Between this lower oolite and the great oolite (also belonging to the lowest system), a thick calcareo-argillaceous formation, carrying beds of fuller's earth, and sometimes also beds of coarse oolite, is interposed, often forming a

very conspicuous division in this part of the series; though it is frequently wanting altogether.

In the neighbourhood of Bath, the thickness of this calcareo-siliceous formation is about 220 feet. It consists of the six following beds, beginning with the uppermost.

		Thickness.
1.	Calcareous sand, . .	50 + feet.
2.	Inferior oolite, . . .	30
3.	Bastard fuller's earth, .	100 +
4.	Good fuller's earth, . .	8
5.	Blue clay, . . .	15
6.	Yellow clay, . . .	15

The remains of vertebral animals are very rare in these beds. A series of vertebræ were discovered in the marly sandstone of Warkworth, Northamptonshire. They probably belonged to some saurian animal, but were dispersed without having been determined, and none of them have been recovered. Fragments of the crab and lobster families have been discovered at Dundry, and in the north of Oxfordshire.

The distribution of organic remains is thus stated by Townsend:—"The lowest bed is distinguished by its abundant casts of ribbed and studded Trigoniæ; immediately over this is a hard compact coral bed, containing large specimens of Madrepora cinerascens: then succeeds the superior bed, abundantly charged with shells, both univalves and bivalves. Among these are

Ammonites,	19 species	Carditæ, .	4 species
Nautili, .	3	Lutrariæ, .	3
Belemnites,	3	Astartes, .	4
Trochi, .	12	Unios, .	2
Nerita, .	1	Myas, .	2
Cirrhi, .	2	Fistularia, .	1
Planorbis, .	1	Mytilus, .	1
Melaniæ, .	2	Modiolæ, .	2
Turbo, .	1	Donax, .	1
Rostellariæ,	3	Pinna, .	1
Turritellæ,	3	Terebratulæ,	11
Ampullariæ,	3	Ostreæ, .	6
Serpula, .	1	Pectines, .	4
Trigoniæ, .	4	Limæ, .	2
Arca? .	1	Avicula, .	1
Cucullæa, .	1	Perna, .	1
Nucula? .	1	Plagiostomata,	3

These beds present a considerable number of species belonging to the family of echini. They are enumerated by Conybeare in the *Outlines of the Geology of England and Wales.*

3. *Lias.* The lowest bed of all, upon which the whole oolitic formation rests, is called *lias limestone,* I do not know for what reason. The *lias,* taken as a whole, may rather be described as consisting of thick argillaceous deposits intermixed with limestone, than as an argillaceous limestone; the upper portion of these deposits forming about two-thirds of their total depth, consists of beds of a deep blue marl, containing only a few irregular and rubbly limestone beds. In the lower portion the limestone beds increase in frequency, and assume the peculiar aspect which characterizes the lias, presenting a series of thin stony beds, separated by thin argillaceous partings, so that quarries of this rock at a distance assume a striped and ribbonlike appearance. In the lower beds the argillaceous partings become very slight, or almost disappear. Beds of blue marl with irregular calcareous masses generally separate these strata from the red marl belonging to the *new red sandstone,* which lies immediately below. Sometimes as many as 40 alternating beds of clay, marl and stone, may be reckoned, constituting a thickness (in the neighbourhood of Bath) of about 282 feet. In the midland and north eastern counties the thickness is about twice as great.

The lias limestone has a dull earthy aspect and a large conchoidal fracture. In colour, it varies in different beds from light slate blue or smoke grey to white, the former varieties usually constituting the upper, the latter the lower portions of the formation. When purest, it contains about 90 per cent. of carbonate of lime, and ten per cent. of clay; the blue lias makes a strong lime, distinguished by its property of setting under water; the white lias takes a high polish, and may be employed for the purposes of lithography, but we must distinguish it from the stone generally used for that purpose, which is brought from the quarries of Solenhofen, and is a much more recent formation.

The slate clay with which the lias alternates, is grey, brown, or black, is frequently bituminous, and often divides into laminæ as thin as common pasteboard. In the lias no fewer than 36 species of fossil plants have been discovered. Of these, 12 species are cryptogamous plants; namely,

2 equisetums,
9 filices,
1 lycopodites.

23 species belong to cycadeæ, and 1 species is a zosterites.

It is in the lias beds that the bones of the two extinct species of lizard, the *ichthyosaurus* and *plesiosaurus*, occur.

Bones and palates of the turtle have been found in the lias beds. Several species of fish have been also met with, which have been referred to the genera *sparus* and *chætodon;* but probably they belong to fish unknown in a recent state; the radius of a species of *balista* is of common occurrence.

The leech-like palate *tritores* of some species of fish, and teeth in form resembling those of the shark, are occasionally found.

Several species of crab, and a species of *monoculus*, or *limulus* of Lamark, are also found.

The following are the shells enumerated by Conybeare:—

Ammonites 20 species.

The Ammonites having the siphuncle in an elevated ridge between two furrows, are characteristic of this formation. These are

Ammonites stellaris,
——— Walcotii,
——— Brookii,
——— Bucklandi,
——— Conybeari,
Nautili, 3 species,
Scaphites equales,
Belemnites, many species,
Helicina, . 3 species
Trochus, . 3

Tornatilla, . .	1
Melania, . .	1
Modiola, . .	4
Unio, . .	2
Terebratula, .	3
Spirifer or Pentamerus,	1
Gryphæa, . .	2
Pecten,	
Plagiostoma, .	2
Lima, &c. . .	1

The characteristic shells of this formation are the Ammonites Bucklandi, Gryphæa incurva and plagiostoma gigantea.

The lias formation stretches across from the coast of the German Ocean in Yorkshire to that of the channel in Dorsetshire. On the east coast it may be traced from the Peak alum works south of Whitby, nearly to the Teesmouth. Turning southward from the Tees it passes York on the east, and crosses the Humber a little eastwards of the junction of the Trent and Ouse, stretching onwards to the Woldhills, on the borders of Nottingham and Leicester, and the celebrated quarries of Barton-upon-Soar, whence it continues through the counties of Nottingham, Warwick, and Gloucester; its whole course along this extensive line, to a few miles south of Gloucester, is remarkably regular, presenting an average breadth of about 6 miles, bounded on the south-west by the oolites and on the north-west by the red marl, but beyond that point its course becomes much more intricate; for while its eastern limit still continues to occupy the oolitic range through Somersetshire to the coast in Dorset, its western limit becomes very irregular, feathering in and out among the coal fields which occur towards the estuary of the Severn and the upper part of the Bristol channel in Gloucestershire, Somersetshire, Monmouthshire and Glamorganshire, and attended by numerous outlying masses; these intricacies, however, have been minutely traced and explained by the English geologists.

The alum slate at Whitby constitutes a bed in the lias. Over this alum slate lies a bed of hard compact stone from six to twelve feet thick. The workmen call it *dogger*, a name by which they also designate the *septaria* or *cement-stone*, and the component parts of both appear to be nearly the same; the whole of the upper part of the alum slate resembles indurated clay when first worked, but by exposure to the atmosphere it suffers decomposition and crumbles into thin layers; the colour of the slate is bluish grey, it varies in hardness and abounds in pyrites. When a quantity of it is laid in a heap and moistened, it takes fire of itself and continues to burn till the whole combustible portion is consumed.

The coal beds which occur in the neighbourhood of Whitby lie over the lias formation, and consequently are situated in the undermost oolitic system. The Brora coal field on the east coast of Sutherland in the north of Scotland, is similarly situated. It forms part of the deposits which, on the south-east coast of Sutherlandshire, occupy a tract of about twenty miles in length, from the Ord of Caithness to Golspie. Its breadth does not exceed three miles; it is divided into the three valleys of Brora, Loth and Navidale, by the successive advance to the coast of portions of the adjoining mountain range, which bounds them on the west and north-west. The first of these valleys is flanked on the south-west by hills of red conglomerate, which pass inland on the north-east of loch Brora, and give place to an unstratified granite, which forms the remainder of the mountain boundary.

The highest beds at Brora consist of a white quartzose sandstone, partially overlaid by a fissile limestone, containing many fossils, the greater number of which have been identified with those of the calcareous grit, below the *coral rag*, showing clearly that the coal beds are situated lower down in the series than the coral rag, which constitutes the uppermost part of the middle oolitic system. The next bed consists of shale, with the fossils of the Oxford clay, which is the lowest stratum of the middle oolite, overlying a limestone resembling *cornbrash* and *forest marble*, which constitute the upper portion of the lowest oolitic system.

To these succeed sandstone and shale, containing belemnites and ammonites, through which the shaft of the present coal pit is sunk to the depth of near 80 yards below the level of the river Brora.

The principal bed of coal is three feet five inches in thickness, and the roof is a sandy calcareous mixture of fossil shells and a compressed assemblage of leaves and stems of plants, passing into the coal itself. The plant of which the Brora coal appears to have been formed, is identical with one of the most characteristic vegetables of the Yorkshire coast, but differs essentially from any of the plants found in the coal measures situated below the new red sandstone.

The base of the entire series is seen at low water near the north and south *sutors* of Cromarty, where the lias, with some of its characteristic fossils, may be seen resting on the sandstone of the red conglomerate.

There are two beds of coal at Brora, the highest of which crops out on the sea-shore. It began to be worked in 1598, and has been since frequently abandoned and again resumed. Mr. Williams, the well-known author of the *Mineral Kingdom*, took a lease of it in 1764, and worked it unsuccessfully till 1769, when he resigned his lease to Messrs. Robertson and Co., of Portsoy.

The second, or lowest bed which is worked at present, is three feet ten inches thick; but it has a pyrites band in the centre about eight inches thick. This was the origin of the bad character which the Brora coal acquired, and of its supposed liability to spontaneous combustion. It was pointed out and its bad effects obviated by Mr. Beaumont of Limekilns, in 1776, when he was employed to survey the country.

In 1810, Mr. Hughes, from Flintshire, was employed by the Marquis of Stafford to examine the field and open a new pit near Brora. In 1824, the coal raised annually was about 10,000 tons, of which about 6,000 were consumed on the spot in a salt work, which yielded about 300 bushels of salt weekly. The remaining 4,000 tons were consumed in the country.

On the north-west coast of Scotland several members of the oolitic series were recognised by Dr. Macculloch in the isles of Skye, Pabba, Scalpa, Mull, &c., and his observations have been confirmed and extended by Mr. Murchison.

In France, the great oolitic series appears in Normandy, occupying a considerable portion of the department of Calvados, and extending from the west bank of the mouth of the Seine, or a little west of that as far as Carenton, so that the cities of Caen and Bayeux are situated in it. The same formation constitutes the lower part of the range of Mount Jura. Hence the reason why on the continent the term *Jura limestone* is usually substituted for *oolite.*

It occurs also in great force in the north of Germany, though it would be rather hazardous to venture to assign English names to the German terms. The *Muschelkalk* is a formation in the upper part of the *new red sandstone,* which is wanting in Great Britain. Whether the *buntsandstein* of the north of Germany, with its equivalent, *Keuper,* in the south, belong to the new red sandstone or oolite is not so clear. The keuper occurs near Heidelberg in considerable quantity, and seems to lie under the lias;* and Brongniart considers it as constituting a formation immediately under the lias.

The uppermost keuper beds consist of fine-grained calcareous sandstone, the undermost of marl. Thin beds of gypsum are found in the marl. Beds of slate clay occur also in one place under the marl. The following fossil plants have been observed in the keuper:—

Equisetum arenaceum, the *calamites arenaceus major* of Jaeger.

Various leaves, &c., not yet made out.

The *Mergelkalk* of Boué, and the *quadersandstein* of Humboldt, which occupies a large tract of country on the banks of the Elbe above Dresden, and between Pirna, Schanden and Königstein; between Nuremberg and Weissenberg; at Staffelstein in Franconia; at Teufelsmauer at the foot of the Hartz; the valley of the Mozelle, and the neighbourhood of Luxemburg; in Lorrain at Vic; at Nalzen in the country of Foy, and at Navarreins at the foot of the Pyrenees—belong,

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* *See Brown's* Gæa Heidelbergensis, p. 145.

I think, to the oolitic series, though some refer them to the chalk.

In Britain, France and Germany, the oolite consists of very nearly the same beds; but in Poland the mineralogical structure seems to be altered. The undermost beds are more or less white and marly. On this rests *dolomite* generally of a dazzling whiteness, affording the forms so remarkable in rocks of this nature, and composing the picturesque country between Oldkusz and Cracow, and near Kromolow, Niegowomie, &c., rising to the height of 1,400 feet above the sea. The upper part of the Dolomite, from Oldkusz towards Zarki, and especially near Wladowice, contains pisiform iron ore. It there becomes mixed with a coarse sandstone. The upper portion of the group is formed of grey and oolitic limestones and calcareous conglomerate, and passes gradually into the lower beds of the green sand formation. The rocks of the oolitic group rest unconformably on the *coal measures* and *muschelkalk* of Poland. They have a general direction N.N.W. and S.S.E. From Weilun they plunge beneath the great plain of Poland, here and there appearing as islands above it. The organic remains establish the identity of this deposit with the oolitic series of other parts of Europe.*

There occurs, also, a series of equivalent deposits in the Alps, the Carpathians and in Italy, with little or no resemblance to the oolite of this country. But the characters, especially in the Alps, are so peculiar that the formations can only be identified by means of organic remains; and there occur such singular mixtures of these, that the determination of particular deposits is far from certain. Instead of marls, clays, sands, and light-coloured limestones, we have dark-coloured marbles, masses of crystalline dolomite, gypsum and slates approaching to talc and mica slates.

What renders the investigation of the Alps still more difficult, is the confusion into which the rocks have been thrown by the power which elevated them. Whole mountain masses have been thrown over, and the rocks really deposited the latest occur beneath the older strata. These dark-coloured rocks were referred by the Wernerians to the transition class, and we are indebted to Dr. Buckland for first pointing out their more recent origin. Since that time M. Elie de Beaumont has investigated these rocks in Savoy, Dauphiné, Pro-

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* Pusch, Journal de Géologie, t. ii.

vence and the maritime Alps. He showed that the beds described by Brochant in his Memoir on the Tarentaise, and which in many places contain masses of granular limestone and micaceous quartz rock, as well as large masses of gypsum, belong to the oolitic group.

In a notice on the geological position of the fossil plants and graphite found at the Col de Chardonnet (Hautes Alps), M. Elie de Beaumont observes, that as the traveller quits the Bourg d'Oisans (Piedmont) and approaches the continuous range of masses called *primary*, that extend from Mont Rosa towards the mountains on the west of Coni, he will perceive that the secondary rocks gradually lose their original character, though certain distinguishing marks may still be seen—thus resembling a half burnt piece of wood, in which the ligneous fibres may be traced far beyond the part which remains wood. The vegetables found by M. Elie de Beaumont in these situations were examined by M. Ad. Brongniart, and many were found by him to be the same as those which occur in the coal measures. The following are the chief of these plants:—

Calamites Suckowii,
———— Cistii,
Lepidodendron, 2 species,
Sigillaria,
Stigmaria,
Neuropteris gigantea,
———— tenuifolia,
———— flexuosa,
———— Soretii,
———— rotundifolia,
Odontopteris Brardii,
Odontopteris obtusa,
Pecopteris polymorpha,
———— pteroides,
———— arborescens,
———— platyrachis,
———— Beaumontii,
———— Plukenetii?
———— obtusa,
Asterophyllites equisetiformis,
Annularia brevifolia.

These vegetable remains are so far associated with *belemnites*, that the latter occur both above and below them; so that they must have existed both before and after the vegetable deposits. The same series of beds is continued to Digne and Sisteron, where they contain the characteristic fossils of the lias.

It would be impossible, without far exceeding the necessary limits of this work, to give a detailed account of all the Alpine rocks which are referrible to the oolitic group. The reader is referred to the various papers published on the subject by Studer, Boué, Sedgwick, Murchison, Lill von Lillienbach, Lusser, &c. We refer also, for an excellent abridgment of the present state of our knowledge of the oolite group, to De la *Beche's Manual of Geology*, p. 311.

CHAP. XI.

NEW RED SANDSTONE.

This formation lies under the oolite and over the coal measures, but in an unconformable position. In England it begins at the river Tyne at Tynemouth, and extends in a south-westerly direction as far as Cheltenham, covering a considerable portion of the surface of the counties of Durham, York, Nottingham, Stafford, Warwick, Cheshire and Shropshire. The best description of it has been drawn up by Professor Sedgwick of Cambridge.

It consists, in this country, of two distinct subordinate formations; namely, the *new red sandstone*, which is uppermost, and the magnesian limestone, which is undermost. The *muschelkalkstein*, which in Germany exists in the upper part of this formation, has not yet been discovered in Great Britain. It occupies a great proportion of the north of Germany, namely, Hanover and Westphalia. In South Germany it extends from Hanau to Stuttgard.

In the new red sandstone formation a considerable number of petrifactions occur, both vegetable and animal; and, from the researches of Mr. Sedgwick, it appears that they bear a closer resemblance to those found in the coal measures than had been supposed.

The impressions of plants are chiefly observed in the sandstone beds. It is in the neighbourhood of Strasburg that these fossil remains have been chiefly met with. We are indebted to M. Voltz for the description of 20 species of fossil plants, found in that vicinity. Of these, 3 are impressions of equisetums, 6 of ferns, 5 of coniferous plants, 2 of liliaceous plants, and 3 are monocotyledonous, but not referrible to any known tribe. The vegetable remains at Lennel braes on the Tweed, about two miles east from Coldstream, which have been so ingeniously investigated by Mr. Witham, are usually referred to the coal measures, though both the coal measures and the new red sandstone occur at no great distance from them.

In Germany, the beds which correspond with our magnesian limestone, have received the name of *Zechstein*. The magnesian limestone does not abound in fossils; but several shells, all seemingly sea shells, have been found in that formation, especially in Hambleton hill, near Sunderland. It consists of a porous limestone, containing many casts of shells and corallines. The *producta* of Sowerby is conspicuous among these casts. We find also a species of *donax*, with hairlike spines, and smooth-shelled bivalves, from the size of a pea, to that of a cockle, resembling those of the genus *donax*. Casts of arcæ and anomiæ are also met with. Impressions of a reticulated marine production, resembling the genus *flustra;* also encrinites, and alcyonites; also casts of bivalves, resembling muscles, and small round bodies, the nature of which has not been made out.

The *red sandstone formation*, taken in its most comprehensive sense, consists of the following beds, beginning with the uppermost:—

1. Variegated marl,
2. Muschelkalk,
3. Red or variegated sandstone,
4. Zechstein, or magnesian limestone,
5. Red conglomerate, the *Todtliegende* of the German geologists.

1. The *variegated marls* are very conspicuous in the district of the Vosges, and have been minutely described by Elie de Beaumont. They may be seen likewise on the southern coast of England. In the Vosges, they commence beneath the *lias sandstone*, into which they gradually pass. The upper part of these marls has a green colour, and presents thin beds of black slate clay, and of quartzose sandstone, nearly without cement. This last passes gradually into the lias sandstone. In the environs of St. Leger-sur-Dheune, and at Autun, these deposits cannot be separated from the lias sandstone, constituting, in fact, only one deposit with it. This is the case also in the *arkose* of Burgundy. In the Vosges, the variegated marls are usually marked with different colours; the principal of which are, wine red, and greenish or bluish grey. They break into fragments, which have nothing of a slaty structure. In the central portions of them, there are beds of black slaty clay, bluish-grey sandstone, and greyish or yellowish magnesian limestone. The sandstone and clay contains vegetable impressions, and even coal. Masses of rock salt occur in the lower part of these marls; and masses of gypsum are found in the upper and lower portions, but principally in the latter.

These variegated marls, according to M. Dufresnoy, crown *the red sandstone rocks* in the south of France. Mr. De la Beche is of opinion, that the upper part of the red sandstone deposit in England corresponds in its mineralogical character with the variegated marl of the Vosges. There is no apparent transition of the lias into the red sandstone series in England. At the old Passage, near Bristol, there occurs a conglomerate, composed of pieces of limestone, bones, teeth, and other remains of saurian animals and fish, with *coprolites*.[*] This would seem to mark a period when comminuted deposits ceased, and currents of water, sufficient to transport pebbles, were in action. Between Lyme Regis and Sidmouth, on the south coast of England, the upper part of the red sandstone series resembles very closely the variegated marls of the Vosges. The following table exhibits a list of the fossil vegetables found in this bed, as collected by M. De la Beche.[*]

Equisetum Meriani,
———— columnare,
Pecopterus Meriani,
Tæniopteris vittata,
Pterophyllum longifolium,
Pterophyllum Meriani,
———— Jæ̈geri,
Calamites arenaceus?
Filices Stuttgardiensus,
—— lanceolatus.

The following amphibious animals have also been met with in the variegated marls:—

Phytosaurus cylindricodon,
———— cubicoden,
Ichthyosaurus,
Plesiosaurus.

Also,

Posidonia Keuperina,
Saxicava Blainvillii.
Ophiura,

In Poland, between the oolite and muschelkalk, there is an extensive deposit of sandstone, usually termed *white sandstone*, from its colour. It is divisible into two portions, the upper being formed of white sandstone, and the lower of alternations of fine white marly sandstone, slaty sandstone, shale, and other slaty and dark-coloured rocks; the whole enclosing beds of coal, from 3 to 25 inches thick. The white sandstone of the upper part alternates with thick beds of grey-blue marls, partly red, and more rarely variegated. Beds of limestone are also found in it. But the most valuable product is iron ore, which furnishes the largest amount of iron of any rock in Poland, twenty-seven furnaces affording annually about 560,000 quintals of metal. Fossils are rare in this deposit, except vegetable

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[*] This name has been given to the supposed fossil fæces of quadrupeds, found in caverns, &c.

[†] Manual, p. 391.

remains. It seems to unite the characters of the lias sandstones and variegated marls.*

2. *Muschelkalk.* This consists of a limestone, varying in its texture; but most commonly grey and compact. It is occasionally dolomitic, and passes into marls above and below. When very compact, with numerous remains of the *Encrinites moniliformis*, (a very characteristic fossil,) it has much the appearance of the mountain limestone of England. It is sometimes so hard, that it is employed as marble. For example, at Epinal, in the Vosges. In some situations, organic remains are very abundant in it, while in others they are rare. This formation does not occur in England, nor in the north of France. But it is found in the south and east of France, and in Germany, where it is interposed between the variegated marls, and the red or variegated sandstone. According to Pusch, it occurs in Poland, and is described as being grey and yellow. The following table exhibits the organic remains in this formation:—†

Fish teeth,
Plesiosaurus,
Ichthyosaurus,
Another saurus, genus not determined.
Palinurus Sueurii,
Nautilus bidorsatus,
———— nodosus,
Ammonites nodosus,
————— bipartitus,
————— Henslowi?
————— latus,
————— subnodosus,
Buccinum obsoletum,
Turritella terebralis,
Dentalites torquatus,
———— lævis,
Terebratula perovalis,
————— sufflata,
————— vulgaris,
————— orbiculata,
Trigonia vulgaris,
Trigonia pes-anseris,
Mytilus eduliformis,
Avicula socialis,
Myacites musculoides,
———— intermedius,
———— elongatus,
———— ventricosus,
Pecten reticulatus,
Ostrea sphondyloides,
Cardium striatum,
Plagiostoma lineatum,
————— rigidum,
————— lævigatum,
————— punctatum,
Serpula valvata,
——— colubrina,
Encrinites moniliformis,
————— epithonius,
Ophiura prisca,
——— loricata,
Asterias obtusa,
Astrea pediculata.

The only vegetable impression is that of the neuropteris Gailliordoti.

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[*] *Pusch, Jour. de Géologie, tom. ii.*

[†] From De la Beche's Manual, p. 393.

3. *Red or variegated sandstone.* This stone is most commonly red, but is found also white, blue, and green. It is principally siliceous and argillaceous, sometimes containing mica, masses of gypsum, and rock salt. In the neighbourhood of Glasgow, it is characterized by numerous circular spots of a white colour, seemingly composed of indurated clay. In the Vosges, the upper part of the variegated sandstone presents thin beds of marly limestone and dolomite, which gradually becomes more abundant, so that finally they constitute the lower part of the muschelkalk. An oolitic and calcareo-magnesian rock is found in it, in some parts of Germany.

What is called *gres de Vosges*, is considered by Voltz as belonging to the variegated sandstone; while Elie de Beaumont thinks it belongs to a lower part of the new red sandstone series. It is composed of amorphous grains of quartz, commonly covered with a thin coating of peroxide of iron, among which are discovered fragments of felspar crystals. It is often marked by cross and diagonal laminæ, so common in sandstone rocks. It contains quartz pebbles, sometimes in such abundance, as to represent a conglomerate with an arenaceous cement.

The variegated sandstone affords frequently a good building stone, and when nearly free from colour, it has a handsome appearance. There is a quarry of it some miles west from Dundee, upon the Firth of Tay, which has a brownish-white colour, and which constitutes a very durable stone. It is of it that the numerous new streets, at present rising in Dundee, are built. Quarries of it also exist behind Helensburgh, a village opposite to Greenock, on the Firth of Clyde, the stones from which are employed in building that village. The ground rises behind Helensburgh for about a mile, and reaches an elevation of at least 200 feet. It then slopes gently towards Lochlomond, distant about 8 miles. The surface of this elevated valley is pretty smooth, and, where it is not covered with moss, consists of a white arenaceous clay, quite filled with water-worn pebbles of all sizes, from a grain of sand to several tons. By far the greater number of these fragments are clay slate, of which the neighbouring mountains are composed; but pebbles of quartz, granite, greenstone, and even of sandstone, are also frequently observed. Below this alluvial soil, the whole country is composed of beds of sandstone, of various colours, sometimes white, sometimes yellow, and often red, or *brownish red.* The sandstone consists chiefly of fragments of quartz, either white or coloured. Sometimes the quartz grains are so large as to constitute a conglomerate. The beds dip towards the south-east. The sandstone beds vary from 1 foot to 6 feet thick, and are separated from each other by thin beds of fissile blue-coloured slate clay. The beds on the south side of the Firth, at Greenock, and along the sea-shore, as far as Ayrshire, are composed also of new red sandstone: doubtless those behind Helensburgh are a continuation of the Renfrewshire beds.[*]

The red sandstone of the Vosges contains, according to M. Voltz, the following shells:—

Terebratula,
Plagiostoma lineatum,
———— striatum,
Trigonia,
Pecten,
Turritella Schoteri,
Mytilus eduliformis,
Myacites elongatus,
———— musculoides.

M. Ad. Brongniart enumerates the following fossil plants found in this formation at Sulz-les-Bains:—

Calamites arenarius,
———— Mougeotii,
———— remotus,
Anomopteris Mougeotii,
Neuropteris Voltzii,
———— elegans,
Sphenopteris Myriophyllum,
———— palmetta,
Filicites scolopendroides,
Voltzia brevifolia,
Voltzia elegans,
———— rigida,
———— acutifolia,
———— heterophylla,
Convallarites erecta,
———— nutans,
Paleoxyris regularis,
Echinostachys oblongus,
Æthophyllum stipulare.

4. *Zechstein.* This name was applied by Humboldt to distinguish a limestone series of a very variable character, to which various names were given, the term *zechstein* being applied to only one of the varieties. The various beds of it were distinguished by the German miners, by the names of *Asche (friable marl)*, *stinkstein (fetid limestone)*, *rauchwacke*, *zechstein*, and *kupferschiefer* (copper slate). This lowest deposit being worked for the copper which it contains in Mansfield, Thuringia, Franconia, and the Hartz. The mean

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[*] This sandstone lies immediately over the primary clay slate of the neighbourhood. It is therefore usually considered as old red sandstone; but I have been unable to trace any interposing beds between them and the sandstone which, near Glasgow, evidently lies over the coal; and, therefore, must be considered as *new red sandstone*. Fine sections of it may be seen on the borders of the Gare Loch, between the village of Helensburgh and the *Row*.

thickness of the copper slate in these countries is about a foot. The zechstein varies from 20 to 30 yards thick; the rauchwacke, when pure and compact, one yard thick, when cellular, sometimes fifteen or sixteen yards thick. The stinkstein varies in thickness from one to thirty yards, and that of the asche is very variable.

The magnesian limestone of the north of England, which is the equivalent of the German zechstein, consists, according to Professor Sedgwick, of the following subordinate beds:—

1. Marl slate and compact limestone, or compact and shelly limestone and variegated marls.
2. Yellow magnesian limestone.
3. Red marl and gypsum.
4. Thin bedded limestone.

No. 1, he considers as the equivalent for the kupferschiefer and zechstein, and Nos. 2, 3, and 4, to the rauchwacke, asche, and stinkstein, of Thuringia.

For the organic remains in zechstein and copper slate, we refer the reader to the catalogue given by De la Beche.[*]

5. *Red conglomerate.* The name *todtliegende* is given by the Germans to a series of red conglomerates and sandstones, which occur between the zechstein and the coal measures. In Thuringia, the term is applied to those beds that lie immediately under the copper slate. It is for the most part a conglomerate formed from the partial destruction of those rocks on which it rests, the fragments being sometimes angular as well as rolled, and of considerable size.

In England, the magnesian limestone begins at Tynemouth, and extends with little or no interval, as far as Nottingham, or about 147 miles. During this extent, it assumes a great variety of appearances, and perhaps even varies in its composition. In the neighbourhood of Sunderland it constitutes low hills, which are quarried in several places, and being converted into lime, is carried in great quantities to the north-east coast of Scotland, where it is used as a manure. It is a moderately compact limestone of a yellow colour, and is composed of

1 atom carbonate of lime, . .	6·25 or	54·35
1 atom carbonate of magnesia, .	5·25 or	45·65
		100·00

The surface of this magnesian limestone is in many places

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[*] Manual, p. 398.

covered with a poor herbage, uncommon to limestone. This has been ascribed to the magnesia contained in it, which is known to be unfavourable to vegetation.

At Sunderland, the thickness of the magnesian limestone in some places, is at least 600 feet. To the south of Nottingham it may be seen, not far from the slates of Charnwood forest, on the north and north-east border of the Ashby-de-la-Zouch coalfield. Patches of it occur near Bristol: indeed the rock on which Lord de Clifford's house (west of Clifton) stands, is a magnesian limestone.

The magnesian limestone lies immediately over the conglomerate or sandstone bed, which covers the coal measures in an unconformable position. This may be distinctly seen at Cullercoats in Northumberland, near Tynemouth, at the western extremity of its northern boundary. It overlies the 90 fathom dyke, which appears between the strata of coal in nearly a vertical position. This dyke passes through the coal measures, but not the magnesian limestone. Thus, it is evident that the magnesian limestone was deposited not only after the coal measures, but after the dyke had penetrated the coal field.

The coal measures near Whitehaven, on the west coast, may also be seen passing under the magnesian limestone of that district. According to Mr. Farey, the coal beds in Derbyshire extend under the magnesian limestone, and have been wrought under it at Bilborough and Nuthal, a few miles north-west of Nottingham. Coal has never been got at by penetrating through the magnesian limestone; but it has been often worked under that bed, and it is an ascertained fact, (though no good reason can be assigned for it) that the coal covered by the magnesian limestone is of inferior quality.

The new red sandstone which lies over the magnesian limestone, appears on the sea-shore a little to the north of the Tees, in the county of Durham. It passes through the whole county of York, and is broadest at the city of York, which is situated in that formation. It becomes somewhat narrower in Nottinghamshire. In Leicestershire it is very broad, including most part of the counties of Warwick, Stafford, Shropshire, and Cheshire. In the north of England, the new red sandstone covers the valley of Carlisle, and runs south-east into Westmoreland, and north-west into Dumfries-shire. It appears again in Berwickshire on the north banks of the Tweed. On the northern side of that county, it is interrupted by the great transition chain which runs from St. Abb's Head to Loch Ryan; but it appears again in East Lothian, and continues till the coal measures terminate a little to the east of Tranent and Salton.[*]

The greater part of the lowland portion of Perthshire, namely Strathallan, Strathearn, Carse of Gowry, and part of Strathmore, consist of red sandstone beds, which have nearly a horizontal position, and in this respect form a remarkable contrast to the position of the greywacke beds, on the east side of the Grampians. On this account, I have little doubt that the whole of these red, or rather variegated, sandstones, belong in reality to the new red series, though this is not the general opinion of mineralogists. On the east side of Scotland, these red sandstone beds proceed without interruption as far as Stonehaven in Kincardineshire, where the primary rocks make their appearance a little beyond the river. There are strong reasons for concluding, that the greatest part of the County of Caithness, and the whole of the Orkneys, belong to the same formation. That the sandstone round Inverness belongs to the same formation is rendered probable by the nodules of sulphate of strontian which occur in it.

The sandstone on the coast of Ayrshire, indeed, from Greenock to Saltcoats, along the shore, and likewise in the Cumbraes, and at least, a portion of that in the Islands of Bute and Arran, is undoubtedly a part of the same formation. In short, at least as great a proportion of Scotland as of England consists of this great formation. Thin beds of magnesian limestone may be occasionally seen on the banks of the Tweed, and also of gypsum; but the beds of these rocks, which are so thick in England and Germany, are entirely wanting in Scotland.

The fossil plants hitherto observed in the new red sandstone formation, amount to 21 species. Of these 12 are cryptogamous; namely,

4 calamites,
8 filices.

Eight species are flowering plants; namely,

5 coniferæ,
1 æthophyllum,
1 echinostachys,
1 paleæxyris.

One species, a juglans, belongs to a recent plant.

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[*] The sandstone of Berwickshire is sometimes referred to the *old red sandstone* formation. But at Eccles quarry, beds of magnesian limestone may be seen passing under it; and at Lennel braes, on the Tweed, it seems to overlie the coal beds.

CHAP. XII.

COAL MEASURES.

IMMEDIATELY under the new red sandstone formation lie the *coal measures*, fortunately so abundant in Great Britain, as they constitute the great source of our industry and wealth. All the manufacturing districts in Great Britain, with a few exceptions, which admit of an easy explanation, are situated in the immediate vicinity of coal. Bristol, Coventry, Birmingham, Swansea, Wolverhampton, the potteries, Nottingham, Sheffield, Manchester, Halifax, Leeds, Huddersfield, Newcastle, Glasgow, are all situated in coal districts.

Coal fields occur usually in valleys or troughs, of greater or smaller magnitude, and they extend to a considerable distance all round, without any great alteration in the dip or position of the various beds, except where they have been altered by the interposition of *dykes*, or by *slips*, as they are called, that is to say, by the elevation of one portion of a coal field and the depression of another. A remarkable example of this occurs in the Newcastle coal field. A little to the north of Newcastle, there is a narrow dyke which runs west, and consists of nothing but clay. It must have been formed by the coal beds being separated at that particular line. Now, the remarkable circumstance is, that the same beds occur on both sides of the dyke, but the corresponding beds are 70 fathoms, or 420 feet higher upon one side of the dyke than upon the other. It is clear that the beds must have once been on a level. By some unknown convulsion of nature, the whole strata on one side, constituting a surface of many square miles, must have been depressed or elevated 420 feet, while those on the other side remained unaltered in their position.

No connexion can be traced between the different coal fields. On that account, Werner gave to the coal measures the name of the *independent coal formation*. Yet as similar strata occur in all coal fields, there can be no doubt that they were all deposited under similar circumstances, and at the same period of time.

A coal field consists of a great number of beds placed very regularly above one another, varying much in their thickness and in their constitution and generally dipping towards a particular line, which constitutes the lowest part of the basin in which the coal metals are situated.

The rocks which constitute these coal measures, are *sandstone*, *slate clay*, and *coal*. Sometimes *mountain limestone* is intermixed with these beds.[*] This is the case in the Newcastle beds, the Edinburgh beds, and the Glasgow beds. It is said also, that occasionally beds of greenstone and basalt occur in them. It is probable that such beds are only of partial extent, and that they are connected with the trap dykes which constitute so prominent a feature in the coal districts. The slate clay is sometimes mixed with so much coal or bituminous matter, as to give it a black colour, and to make it combustible. It is then distinguished by the name of *shale*, or *bituminous shale*. Beds of *clay ironstone*, or *carbonate of iron*, occur also in the coal measures, especially in the neighbourhood of Swansea, Wolverhampton, and Glasgow. But it is remarkable that they are wanting in the Newcastle coal beds, and in most of those which occur in France.[†] It is from this ore that the prodigious quantity of iron smelted annually in Great Britain (above 600,000 tons) is obtained. The fortunate circumstance of its occurring along with coal greatly reduces the expense of the manufacture of iron in this country. While in France, where this connexion does not exist, the necessary expense of the manufacture is unavoidably much greater.

The coal measures are much intersected by dykes of greenstone and basalt running through them in various directions. In general the coal in the immediate neighbourhood of these dykes is injured in its quality. But what is more remarkable, the beds of the coal measures upon one side of these dykes, are almost always higher than on the other side. Hence these dykes are often called *troubles*, on account of the great trouble which they give the miners to discover the bed of coal upon the other side of a dyke which they have dug out, on the side at which they were working as far as the dyke itself.

The sandstone which occurs in the coal beds varies much in its colour and the size of its grains. The grains are chiefly of quartz, obviously water-worn, and interspersed with particles of mica. Sometimes nodules of slate clay, or of carbonate of iron occur in this sandstone, and it is seldom quite free

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[*] Hence called *carboniferous limestone* by the English geologists.

[†] In Burgundy, however, the ironstone and coal occur in contiguous situations.

from fossil wood converted into coal. About Newcastle it is too soft and friable to answer as a building stone. Near Edinburgh, and in Fife, it is nearly white, small-grained, and very durable. It answers admirably as a building stone. Near Glasgow, the upper beds have usually more or less of a red colour, and the grains are coarser than those of the Edinburgh stone. But the lower beds are as white as the Edinburgh stone, and almost as fine-grained. It constitutes a building stone, hardly, if at all, inferior to the Edinburgh stone as a building material, while the quantity all round the city is prodigious. Hence the new built Glasgow streets are hardly, if at all, inferior to the finest streets in the new town of Edinburgh.

The sandstone is composed of a number of beds lying above each other, like the leaves of a book. Some very thin and some many feet thick. Hence it is easily cut into blocks, or slabs of almost any size, by means of wedges driven into it. The pillars in the front of the college of Edinburgh, are about 28 feet long, and composed each of a single stone. This sandstone is a very lasting building stone. Melrose abbey, which is built of it, was finished in the year 1142, or almost 700 years ago; yet the cornices of the windows are as sharp and as perfect as if they had been carved only a few years ago. The cathedral of Glasgow is about the same age, and yet the stone work of it is still perfectly fresh.

In this sandstone casts of trees are very common. Sometimes these casts are lying in a horizontal position; but in general they are perpendicular, as if the trees had been growing at the time when they were enveloped in the sandstone. I have never been able to observe the branches or upper part of these trees, but only the lower part of the trunk and the roots. These casts consist of the very same sandstone with which they are environed. The trees are recognised by the bark which still surrounds the cast, having been converted into coal. Some conception of the origin of these casts may be formed, by supposing that the trees, of which these casts remain, had ceased to vegetate, had lost their tops and the upper part of their trunk, and that all the wood of the lower part had wasted away, leaving only the hollow bark. This bark would be naturally filled with the sand at the time that it was deposited, and being surrounded with sand would be retained in its original position. This sand was afterwards consolidated into stone under a great pressure, which will account for the conversion of the bark into coal.

These casts of trees are very common round Glasgow. About fifteen years ago there was a very perfect one in the quarry situated on the north side of Sauchiehall street. About 3 feet of the lower part of the trunk were uncovered. This portion was 40 feet below the upper surface of the quarry. The trunk was about 26 inches in diameter, not quite round, but oval, the north and south diameter being somewhat longer than the east and west one. This oval shape is not uncommon in trees at present vegetating in this country. It is owing to the influence of the sun occasioning a greater growth in the south side of the tree than the east and west sides. Four long roots were seen issuing from the trunk and dipping into the earth, pretty much as the roots of our beech trees may be observed to do at present.

About ten years ago an avenue of such fossil trees was uncovered at once, in a quarry situated a little to the west of the aqueduct bridge over the Kelvin, about three miles from Glasgow. The lower portion of four trees was visible, situated in a straight line, and at equal distances from each other. Some years ago, a large stem of a similar tree was found in Craig Leith quarry, near Edinburgh, in a sloping direction.* Such trees are common likewise in the Newcastle coal beds, and doubtless in many other situations. It was supposed that these trees were casts of monocotyledonous plants, but Mr. Witham, by polishing very thin slices, has shown that the Craig Leith tree, and likewise the casts found at Lennel braes to the east of Coldstream on the Tweed, belong to dicotyledonous plants. Indeed he has proved that all the lepidodendrons, so common in the coal beds, are *pines*.

The sandstone of the coal beds always, or almost always, contains plates of mica, sometimes in great abundance, sometimes scanty. When the grains of which they are composed are large, they are called *grits*. A variety of coal sandstone used for mill-stones, and situated in the lower part of the coal measures, is known in the north of England by the name of *millstone grit*. This sandstone is also used for whetstones, grindstones, &c. Coal sandstone is distinguished in England

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* A figure of this remarkable fossil in the position in which it was found, together with its dimensions, is given by Mr. Witham, in his late work on Fossil Vegetables, plate V.

by a variety of names. *Plate*, *post*, *pennant*, are some of the most common of these.

The *slate clay* varies a good deal in its appearance. Often it is a brown coloured soft clay, consisting of very thin slaty beds, lying above one another. Very often it contains a great deal of mica in small scales. Grains of sand are seldom wanting. Not unfrequently slate clay passes into sandstone, and during this passage it puts on a great variety of appearances. These varieties are distinguished by the names of *indurated slate clay*, and *clay sandstone*. In Northumberland and Durham, slate clay is called *hazel* by the miners, obviously from its colour, which in that country approaches to that of the bark of the hazel.

The beds of coal vary in thickness from that of a leaf of writing paper to 30, or even 80 feet.

These beds alternate with each other a great number of times in the coal basins. In the Northumberland coal field there are 240 beds, which have been cut through, constituting a thickness of 4035 feet. Of these, 30 are beds of coal, 62 are sandstone beds, varying much in their appearance. The lowest sandstone bed is 228 feet thick. There are 20 beds of mountain limestone. The remaining 128 beds are chiefly of slate clay.*

The Edinburgh coal beds have been completely cut through. There are 337 beds consisting of sandstone, limestone, coal, slate clay, and shale. There are 80 beds of coal, but most of them are very thin. The beds of limestone amount to eight.

The Bristol coal field is 4440 feet thick. It contains 31 beds of coal, mostly very thin; but beds not exceeding three feet in thickness, are in that district worked with profit.

The coal beds contain a great number of vegetable impressions, a much greater number indeed than all the other formations put together. The species known and described amount to 260. Of these, 12 are coniferæ, 4 palmæ, 2 equisetums, 3 calamites, 107 filices, 12 lycopodites. Many of these, as has been already observed, are the casts of trees, or at least of plants, whose trunks emulated trees in size. These casts occur chiefly in the sandstone beds. Trunks or stems, usually flattened, as if they had been subjected to violent pressure,

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* See Westgarth Forster's Section of the Strata from Newcastle to Crossfell, p. 155.

occur also in the slate clay or shale. In the coal itself, for the most part, no vegetable impressions can be traced, though occasionally portions of coal occur, having exactly the structure and properties of wood charcoal. It is the universal opinion, that coal is nothing more than an accumulation of vegetable matter, which probably has been altered and converted into coal by the action of heat under a very great pressure. In the slate clay and shale, the impressions of leaves of various kinds are met with.

Not a single vegetable impression in the coal beds has been identified with any plant at present growing on the earth. They all probably belong to a warmer climate than ours, and they seem to have reached a size much greater than that of the same tribes of plants at present vegetating on the earth.*

We are indebted to M. Ad. Brongniart for the completest account of fossil vegetables which has yet appeared. His work, when finished, will contain figures of all the species of fossil plants hitherto met with. We shall borrow from his Prodromus a sketch of the fossil plants belonging to the coal beds.

The vegetable kingdom has been divided by botanists into six grand classes; namely, *agamia*, *cryptogamia cellulosa*, *cryptogamia vasculosa*, *phanerogamia gymnospermia*, *phanerogamia angiospermia monocotyledonosa*, *phanerogamia angiospermia dicotyledonosa*.

The *agamia*, so called because they exhibit no traces of flowers or seeds, comprehend the *algæ*, or sea weeds, the *fungi*, or mushroom tribe, and the *lichens*, or plants which vegetate on stones or on the bark of trees.

The *cryptogamia cellulosa* comprehend the *mosses* and *Hepaticæ*. They have no vessels, but they have distinct leaves. The organs of production are evident, but the parts are so small, that the uses of the different organs have not been made out in a satisfactory manner.

The *cryptogamia vasculosa*, consist of the *equisetums*, the

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* From the observations of Mr. Hutton, made in the same way as Mr. Witham's, by cutting thin slices of coal and examining the polished face with a glass, it appears that the structure of coal is organized. Caking coal, splint coal, and cherry coal, besides a *reticulated* structure, exhibit cells filled with a straw-coloured volatile matter, apparently bituminous. These cells vary with the coal. In caking coal they are comparatively few and much elongated. The cherry coal contains two kinds of cells, the one similar to those in caking coal, the other smaller. In cannel coal, the first kind of cell is usually wanting, but the second kind is in abundance.

ferns, the *lycopodiaciæ*, the *marsilliaceæ*, and the *characeæ*. These plants have distinct vessels, and their leaves, in general, are large, and very much developed. The stems, when they are arborescent, have considerable analogy to those of the monocotyledonous shrubs and trees. Brongniart is of opinion, that most of the casts of the trunks which occur in the coal sandstone, belongs to this class of vegetables. But the late discoveries of Witham have thrown considerable doubts about the accuracy of this conclusion. There are reasons for believing that the equisetums, filices, &c. which are found in the coal measures, reached a much greater size than their representatives of the present time, even in the torrid zone. This cannot be explained without admitting, that the heat and moisture of the climate was at that time more favourable to vegetation than even the torrid zone is at the present day.

The fourth class, the *phanerogamia gymnospermia*, consists of two very remarkable families of plants, the *cycadeæ* and the *confervæ*. They are well distinguished from all other plants, by the structure of their organs of production. The seeds being destitute of capsules, receive directly the action of the fecundating substance. They are distinguished also by the organization of their stems, very different in several respects from those of true dicotyledonous plants. I am not aware that any remains of plants, belonging to this class, occur in the coal beds.

The 5th and 6th classes, consisting of monocotyledonous, and dicotyledonous plants, are similar to those which exist at present. Very few vegetable remains of the coal beds belong to these classes, unless we are to except the casts of trees, which Mr. Witham has shown to belong to the class of dicotyledonous plants. There are three species of fossil plants in the coal beds which have been referred to the *palmæ* or *palms*, a well-known tribe of monocotyledonous plants; and one species referred to the *cannæ*, also a tribe of monocotyledonous plants.

The number of species of plants, found in the coal beds, or those immediately below them, amounts to 240; of these, 4 belong to the class of agamia; 220 to the cryptogamia vasculosa; and 16 to the phanerogamia gymnospermia.

The names of the families, to which these plants have been referred are

Equisetum,	*Filices*,
	Calamites,

Sphenopteris, 21 species,
Cyclopteris,
Neuropteris, 11 species,
Pecopteris, 41 species,
Lonchopteris,
Odontopteris, 5 species,
Schizopteris,
Sigillaria, 41 species,
Marsilliaceæ,
Sphenophyllum, 7 species,
Lycopodiaceæ,
Lycopodites, 10 species,
Selaginites, 2 species,
Lepidodendron, 34 species,
Cardiocarpon,
Stigmaria,
Palmæ,
Flabellaria,
Nœggerathia,
Cannæ,
Cannophyllites.

For an account of all these families, with figures of each species, we refer the reader to Brongniart's work. A bare list, which is all that we could give here, would be of little use.

A great number of fossil shells, chiefly sea-water shells, has also been found in the coal measures. For a list of these, together with the localities of each, we refer the reader to De la Beche's *Manual of Geology*, p. 419.

Some fossil fish palates have been also met with near Leeds; and also the remains of fish, which, however, have not yet been referred even to a genus.

The mountain limestone, which alternates with the coal beds, contains also many fossil zoophites and shells. For a catalogue of these, we refer to De la Beche, p. 421.

The northernmost of the British coal fields occupies a considerable portion of the great central valley of Scotland; being cut off on the north by the Ochil hills, and the river Eden, in Fife; and on the south by the transition chain of mountains, running from St. Abb's Head to Loch Ryan, in Galloway. It begins at the south bank of the Eden, where it flows into the sea about 4 miles north from St. Andrew's, in Fifeshire. Its northern boundary for some way is the Eden; then the Ochil hills, till nearly as far west as Alloa. It then crosses the Forth, passes a little to the north of Bannockburn; and proceeding south-west, its boundary is the Campsie hills. About 8 miles west from Glasgow, it crosses the Clyde, and goes, in a south-westerly direction, to the north of Irvine.

On the south side, the coal field begins a little to the east of Tranent and Pitcaitland, in East Lothian. It is bounded on the south by the Lammermuirs and Pentlands. It is broadest of all in Lanarkshire, and gradually contracts as it gets to the west sea, and appears to terminate not far from Girvan, in the south of Ayrshire. There are a few offsets from this great field, constituting small coal tracts in Dumfries-shire. But they are insignificant.

The Mid Lothian portion of this coal field was surveyed, at the expense of the Duke of Buccleugh, by the late Mr. Farey; but the details of the survey have never been given to the public. The field constitutes a lengthened basin, dipping to the north. Hence the lowest beds crop out against the sides of the Pentlands. The uppermost bed may be seen at Musselburgh. These beds may be divided into three series: 1. The coal measures, properly so called, which consist of numerous beds of coal, alternating with beds of slate clay, shale, and sandstone. 2. Under this series lies a set of beds, composed of alternate strata of shale and sandstone, mixed with beds of limestone. The coal beds in it are few and unimportant. 3. In the third or lowest series, the mountain limestone predominates. The coal beds are reduced to slight traces, which have never been worked. The lowest bed of all is a red-coloured sandstone.[*]

There are 337 beds in the Mid Lothian coal field; of these, 84 are beds of coal; but the greater number of them too thin to be worked. There are eight beds of mountain limestone. Altogether these coal beds constitute a thickness of about 5000 feet.

A table of the coal strata of Loanhead, which repose upon a limestone containing marine remains, and constituting a thickness of 2336 feet, is given by Dr. Hibbert, in the *Edinburgh Transactions*, vol. 13, page 250. Among these strata there are 26 beds of coal, constituting together a thickness of 94 feet. Between the limestone constituting the base of the Loanhead strata, occurs a considerable thickness, (not less than 2000 feet,) consisting of strata of shale, sandstone, thin seams of coal and of ironstone, the whole of which rests upon a bed of limestone, 27 feet thick.

This limestone crops out at Burdiehouse, about 4 miles south-east from Edinburgh, where it has been quarried for many years. Dr. Hibbert was the first person who examined this limestone; and he has published a most interesting account of it in the *Philosophical Transactions of the Royal Society of Edinburgh*.

It has a bluish-grey or blackish-grey colour, from the bituminous or vegetable matter which is abundantly diffused through it. In its composition, it very rarely shows any

[*] Vol. 13, p. 169.

crystalline texture, such as is observable in the mountain limestone of neighbouring quarries. It has a dull earthy aspect, and yet is as hard as ordinary limestone. When fractured, it sometimes breaks into a slaty form, particularly when it is alternated with thin striæ of vegetable or bituminous matter. When these are absent, its fracture is conchoidal. In the quarry, it appears in regularly inclined strata, each about 4½ feet thick, and dipping towards the south-east, at angles of from 23° to 25°, while its seams of stratification are so regular as to afford, during the process of quarrying, a continuous surface of almost unlimited extent.

Dr. Hibbert has shown that this limestone is a fresh water formation, containing abundance of the same vegetable impressions that occur in the coal beds. The most common of the fossil plants in it is the sphenopteris affinis, figured by Lindley and Hutton, in their *Fossil Flora of Great Britain*, plate 45. This fern seems to be confined to the lowest part of the coal formation. It is the first plant which occurs above the transition slate in Berwickshire. In a similar position it was observed by Dr. Hibbert in Linlithgowshire and Ayrshire. The Burdiehouse limestone contains also impressions of sphenopteris bifida, sphenopteris linearis, and several other ferns. There occur also many Lycopodiaceæ; for example, the Lepidodendron selaginoides, L. obovatum, L. Steinbergii, Lepidophyllum intermedium, Cyperites bicarinata, Lepidostrobus variabilis, Cardiocarpon acutum.

This limestone contains a prodigious number of Entomostraca, ranging in size from $\frac{1}{12}$ to $\frac{1}{60}$th of an inch. The most remarkable of these is a cypris, to which Dr. Hibbert has given the specific name of *Scoto-Bordigalensis*, from the situation of the limestone.* To another of these minute creatures Dr. Hibbert gives the generic name of daphnoidia. Others resemble the planorbis or spirorbis, but probably constitute new genera.

But the most remarkable circumstance connected with the Burdiehouse limestone is the remains of fossil fish, which it contains in abundance. Dr. Hibbert gives a particular description, together with drawings, of the palæoniscus Robisoni, a new species determined by M. Agassiz, during his visit to Edinburgh, in the autumn of 1834. Another fossil fish found in the same place has been called, by Agassiz, *Eurynotus crenatus*.

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* Burdiehouse is a corruption of Bourdeaux house, so called because it was, in the time of Queen Mary, inhabited by her French attendants.

It constitutes a new genus, belonging to his family of Lepidoides. Another fish is a species of Amblyteras.

But the most extraordinary fossil remains are those of a fish of an immense size to which M. Agassiz has given the name of *Megalychthis*. It is referrible to the Lepidosteus spatula, a fish which at present inhabits certain fresh-water lakes in South America. This fish possesses considerable resemblance to the crocodile of the Ganges. M. Agassiz was permitted to dissect a specimen of this fish preserved in spirits in the British Museum; he found it possessed of lungs, and to have many close analogies with saurian animals. It would appear from this that in those remote periods of the world when the Burdiehouse limestone was deposited, the fish were different in their organization from those which at present exist; being able, from the lungs with which they were supplied, to live either in water or on dry land. This provision of nature was doubtless intended to enable the fish to continue to exist, though subjected to the rapid alternations of dry land and water, which apparently took place at that remote period.

The megalichthys constitutes a new genus of fish, the specific name of which, Hibberti, M. Agassiz, with great propriety, took from the eminent geologist to whose praiseworthy and indefatigable exertions we are indebted for our knowledge of the fossil animal remains which have given so much celebrity to the Burdiehouse limestone.

The magistrates of Stirling are at present boring for coal at the Raploch, on the west shoulder of the Castle hill. The boring has advanced to 46 fathoms, and they intend to continue it to the depth of 72 fathoms. The borings have been all through the usual coal metals, as may be seen by the following table, exhibiting the names and thickness of the various strata through which they have penetrated.

Notes, or Journal of Metals, in a bore at the Raploch, belonging to Cowan's Hospital founded within the burgh of Stirling, begun 9*th Sept.* 1834.

No.				Fath.	Feet.	Inch.
1.	Clay			3	3	0
2.	Gravel mixed with clay .			0	1	6
3.	Blaes			1	3	7
4.	do. mixed with iron . .	2	4			
	White freestone . .	1	1½			
	Grey do. . . .	2	4			
	Light grey do. . .		11½			
	Dark do. mixed with blaes .	1	4			
	Grey freestone . .		9½			
5.	Dark blaes . . .	3	8			
	do. *mixed with iron* . .	2	9			

No.					Fath.	Feet.	Inch.
	A band of iron . . .			2½			
	Dark blaes . . .		8	5½			
6.	do. do.		5	6½			
	A band of iron . .			3			
7.	Dark blaes . . .		1	2½			
	A band of ironstone . .			11½			
8.	Dark blaes . . .		1	7			
	Hard white stone . .			2½			
	Dark blaes . . .	1	1	2½			
					7	0	9
9.	Hard greystone . .					0	8
	Dark grey blaes . .	1	4	9			
10.	do. do. . . .	1	3				
	do. last 2 feet harder .	1	2				
					4	3	9
11.	Hard greystone . .				0	0	6
12.	Dark blaes with thin hard bands		4	9½			
	do. do.		4	3			
	Dark hard stone . .				0	0	6½
	do. blaes mixed with bands .			4			
	do. but harder . .		1	3			
					2	2	3½
13.	do. grey stone, very hard .			9			
14.	do. do. .			8			
					0	1	5
15.	Dark blaes . . .			2			
16.	Grey stone . . .			3			
	White do. . . .			2½			
	Hard bluish do. . .			8			
	Grey plies, hard and blue .			7			
	Hard blue stone . .			7			
	Grey plies . . .			11½			
					0	3	5½
17.	White freestone . .				6	1	7½
18.	Grey do. . .					1	4
	Dark blaes . . .			4			
	A hard band . . .			2½			
	Dark blaes . . .		2	7½			
	do. mixed with foul coal .		1	1½			
					0	4	8½
19.	Hard greystone				0	1	2½
20.	do. Dark blaes with 8 in. of a grey band .				0	2	11
21.	Dark freestone				0	1	6
22.	Hard grey band with 9 inches of blaes .				0	1	8½
23.	Grey plies mixed with dark blaes and 2 in. of coal				1	0	8
24.	Hard grey freestone				1	3	11½
25.	Dark plies mixed with blaes . .				0	3	8½
26.	Hard clear coal				0	0	11½
					32	3	4
27.	Hard white stone				1	3	1½
28.	Dark blaes mixed with hard bands . .				4	4	8½
29.	Hard white stone				3	4	9
30.	Dark blaes mixed with dark freestone .				0	1	11
31.	A band of ironstone with 3 in. of greystone				0	0	3
32.	Dark blaes, very hard, with 4 in. of hard greystone				0	2	2
					46	2	10

30*th Jan.* 1835.

Explanation of the Terms.—Blaes is the local name for slate clay; white and *grey stones are sandstones*; dark blaes, shale.

The Glasgow coal field is much more extensive than the Edinburgh, and has not been penetrated nearly to the same depth. Only the six uppermost beds of coal have hitherto been worked. The following table exhibits the succession of beds, from the surface to the first thin coal bed at the Clyde Iron Works, about four miles east from Glasgow:—

Beds.		Feet.	Inches.
1.	Reddish white sandstone,	4	1
2.	Red quartzy sandstone,	0	3
3.	Hard white slate clay,	0	1
4.	Soft blue slate clay,	5	3
5.	Hard siliceous slate clay,	0	4
6.	Soft blue slate clay,	7	8
7.	Ditto with vegetable impressions,	7	10
8.	Shale,	0	8
9.	Impure coal,	0	3
10.	Gray sandstone full of casts of trees,	3	6
11.	Soft blue slate clay,	8	4
12.	Shale,	0	1½
13.	Coal,	0	5½
		38	10

This first bed of coal, being only 5½ inches thick, is not workable. The uppermost workable coal, where nearest the surface, is at the depth of ten fathoms. It is four feet thick, and consists of *soft* coal, or *cherry* coal as it is called by the miners.

The second workable bed occurs eighteen fathoms below the first. It is three feet six inches thick, and consists partly of *soft* coal, and partly of *splint* or *hard* coal. It has much less lustre than the soft coal, is very tough, and breaks with a splintery fracture. It is not so easily kindled, but burns well, gives out much heat, and lasts longer than the soft coal. Hence it sells at a higher price.

The third bed of workable coal is four feet thick, and lies at the depth of six fathoms below the second. It consists, like the first bed, of soft coal.

The fourth bed of workable coal is three feet thick. It consists, like the preceding, of soft coal, and lies at the depth of twelve fathoms below the third bed.

The fifth bed of coal lies ten fathoms below the fourth. It is three feet nine inches in thickness, and consists almost entirely of splint coal.

The sixth or lowest bed of coal hitherto penetrated, lies 1½ fathom below the fifth bed. Its thickness is seven feet, including some thin bands of stone which occur in it. This bed consists of a caking coal, similar in its properties to the Newcastle coal. It is at present scarcely worked, the demand for this kind of coal not being great.

Thus, the whole depth of the Glasgow beds hitherto worked amounts only (including the coal) to 61 fathoms 4¼ feet, or 370¼ feet. This shallowness is probably the reason why these pits are very seldom obnoxious to fire damp.

The Glasgow coal field dips on both sides to the Clyde, which, of course, constitutes the deepest part of the basin in which the coal measures have been deposited. About six miles north-east from Glasgow a section of the coal measures is exposed by the Garnkirk railway. Here they dip to the north-east. This change of direction has been probably produced by a basalt dyke, which traverses the field on the west side of Bedlay.

At Hurlet, about five miles south-west of Glasgow, there occurs a single bed of coal between five and six feet thick. It has been worked for at least two hundred years. The bed of coal is situated twenty-eight fathoms below the surface. The roof is mountain limestone and the floor shale. The connexion between the Hurlet coal and the Glasgow beds is not well understood. They are separated from each other by a dyke which has deranged all the strata. But it is certainly situated greatly below the Glasgow beds. Its depth below the sixth bed is calculated, by the best coal engineers about Glasgow, to be more than two hundred fathoms.

On the north side of the Clyde, the farthest west coal pit is at Duntocher, (about eight miles west from Glasgow,) in the parish of Old Kilpatrick. Only one bed of coal is known, situated twenty fathoms below the surface. This bed is between four and five feet in thickness, and consists, like the Hurlet coal, of a caking coal a good deal mixed with iron pyrites. The roof of the coal consists of a bed of mountain limestone between four and five feet in thickness, and full of the usual shells which distinguish that formation. The other coal metals, namely, beautiful sandstone, shale and fire clay alternating, constitute the beds between the limestone and the surface. The coal dips to the south-east, and doubtless lies below all the Glasgow beds.

The principal species collected by my son, from one of Mr. Dunn's limestone quarries, were the following:—

Producta Scotica of Sowerby.
——— longispina, S.
——— fimbriata, S.

And three other species which seem to be new, or at least are not figured by Sowerby.

Terebratula, 4 species.

Spinifer, the same species as was observed in the limestone at Swinridgemuir (noticed below), and two other species.

Unio, one species.

Dentalium, one species.

With many encrinites and some other corallines.

Neither has the position of the Johnstone beds, relative to the Glasgow seams, been determined. There was at one time a bed at Johnstone nearly eighty feet thick, but it has been worked out.

The annual consumption of coal in the Glasgow market, taking in what is exported, amounts to about 750,000 tons. Besides this, about 120,000 tons of coals are consumed in the iron works in the neighbourhood of Glasgow; so that the whole annual consumption amounts to about 870,000 tons.

The coal metals continue with little interval from Johnstone to the sea coast at Saltcoats; but the country is so intersected with trap dykes, which heave the beds (always to the east), that the connexion between the coal beds in Ayrshire and those of Glasgow has never been traced. At Swinridgemuir, in the parish of Dalry, the beds dip to the east by south. There are three beds of coal, the two uppermost not more than twenty-two inches or two feet thick, and the highest of these crops out behind the house of Swinridgemuir. Under it lies a bed of limestone, which when thickest is not less than twenty feet, but it thins out to four feet or even less. Between this limestone and the lowest workable bed of coal known is twenty-one fathoms of sandstone, shale and slate clay. The coal is from four to five feet thick. One trap dyke heaves this coal field eighteen feet, another about sixty-eight feet. In these cases the portion of the field on the west side is always the lowest.

The uppermost portion of the limestone bed is full of entrochites, caryophyllia and productas. I think, also, that I observed a new species of spinifer, and a nautilus seemingly also a new species, with some obscure traces of a pecten or some analogous shell, together with the producta Martini. In the slate clay were numerous casts of nucula gibbosa of

Fleming, and a specimen or two of nucula attenuata, Bellerophon Urii and euomphalus catillus. In the limestone there was the impression of a leaf, which is probably new. It had some slight resemblance to a fucoides, only it had a middle rib.

About three miles to the west of Dalry is situated Beadlan-hill, round backed, covered with grass and elevated 903 feet above the level of the sea. This hill, or at least its upper part (which alone I was able to examine), is a mass of basalt. In this rock, some hundred feet below the summit and very near the surface, there is a bed of coal four feet thick dipping to the north-west at an angle of 45°, though the regular coal beds at the foot of the hill dip to the east by south.

Both the roof and floor of this coal is basalt. The coal is without lustre, has a brown colour, does not stain the fingers, is uncommonly hard and exceedingly tough. Its specific gravity is 1·317. It burns with a lively flame for some time, and leaving a matter having the shape of the piece, and which gradually wastes away with a strong sulphureous smell, leaving 25·77 per cent of a red earthy residue, composed of silica and oxide of iron, with a little lime and alumina. This coal differs in appearance from any that I have seen, and, were it not for the great proportion of earth which it contains, would probably answer for manufacturing gas. Its structure is slaty. I observed some vegetable impressions in it, differing from any thing hitherto described among fossil vegetables in coal, as they seemed to be *fucoides*. The coal at Fairhead, in the north-east point of Ireland, is similarly situated. Whether it be similar in its nature to the Beadlan coal I have never had an opportunity of judging.

The mountain limestone at Muirkirk, in Ayrshire, contains the following shells:—

Producta costata, Sow.,
——— hemispherica, Sow.,
(a gigantic specimen,)
Nucula attenuata,
Encrinites and cariophyllia,
Lepidodendron Harcourtii.

The Campsie hills, which bound the Glasgow coal field on the north, consist partly of trap rocks and partly of coal measures. The lower part of these hills consist of alternate beds of slate clay, sandstone, shale and limestone. There occurs a beautiful variety of greenstone in these hills composed of *labradorite*, in large crystals, and hornblende. This kind of greenstone, which has not yet been described by geologists, is rather abundant in the neighbourhood of Glasgow. A great portion of the hills on the south side of Paisley consists of it. Large blocks of it may be seen on the road near Gleniffer.

To enable the reader to understand the situation of the coal fields in the north of England, it will be requisite to give a short sketch of the nature of the country. The whole north of England is traversed by a chain of mountains which the Romans distinguished by the name of the *Penine Alps.* It may be observed branching off from the transition chain of mountains which cross the south of Scotland, but it does not rise to any considerable height till it reaches Geltsdale forest in Northumberland, near to which is Crossfell, the highest summit of the chain, and the highest mountain in England. Thence it proceeds south by Stainmoor forest to form the western moorlands of Yorkshire, and the elevated country between that county and Lancashire. Farther south it enters Derbyshire and Staffordshire, forming the High Peak of the one, and the moorlands of the other, and the chain finally expires on the banks of the Trent. Though this range of hills contains no coal, yet it is composed of rocks obviously connected with the coal measures.

The lowest rock of all is a *red sandstone.* It has been observed only towards the northern part of the chain, forming the fundamental rock beneath the western escarpment of the Crossfell range. It may be observed likewise near Ingleborough in Yorkshire. The mountain limestone occurs extensively towards the north of the chain, occupying the middle region of the hills, especially on their western escarpment. A zone of mountain limestone is here detached from the Penine chain, and encircles the transition mountains of the Cumberland group. The upper part of the Penine hills consists chiefly of a coarse sandstone, called by the English geologists *millstone grit,* mixed with shale.

Thus the uppermost part of these mountains consists of coal measures, and the undermost of strata which lie immediately under the coal beds. Now this Penine chain is in some measure environed by coal fields—at least they occur on the east, west and south sides of it.

The first and most important of these is the great coal field of Northumberland and Durham. It begins at the mouth of the Tweed. Indeed, the coal measures may be traced on the sea shore about half a mile beyond Berwick on the north. A small portion of them is again exposed at Lennel braes on the north bank of the Tweed, about two miles east of Coldstream. Various coal pits exist near Tweedmouth, and extending a few miles to the south. There then occurs an interval of more than twenty miles, in which no coal has been found. This important deposit makes its appearance again at the Coquet river and extends almost to the Tees, constituting a length of about fifty-eight miles, with a breadth of about twenty-four. The lowest part of this coal basin is a line drawn north and south through Jarrow, a colliery about five miles from the mouth of the Tyne. The coal measures on both sides of this ideal line dip towards it, and of course crop out as we proceed east or west. Those on the east, if they ever existed, have been destroyed by the sea, except those which still exist beneath its surface.

The beds belonging to the Newcastle field are eighty-two in number. Twenty-five of these are beds of coal, the remaining fifty-seven consist of alternating beds of sandstone and slate clay. Many of the coal beds are too thin to be worked. The two most important of them have received the names of the *high main* and the *low main;* the former is six feet thick, and the latter six feet three inches. The high main is seventy-five fathoms below the surface, the low main is about sixty fathoms under the high main. Between these two beds occur eight strata of coal, one of which is four feet and another three feet thick. The others are insignificant.

The quantity of coal raised annually in this field is immense. It supplies London and the whole south and east coasts of Great Britain, from the north of Scotland to Devonshire. From the county of Durham alone 1½ millions of chaldrons are shipped annually. Certainly the whole quantity annually exported greatly exceeds two millions of chaldrons or three millions of tons; yet such is the quantity of coal in the district, that at the present rate of consumption it is calculated that it will last for a thousand years to come.

The beds of millstone grit, shale and *craw coal* (as it is called), lying under the Newcastle beds, amount to 152. Of these, ten beds are coal, most of them thin, and all inferior in value to the Newcastle coal.

There are a few detached coal fields in the north of Yorkshire. They are of limited extent, and the coal is seldom more than twenty inches thick. These little basins are provincially called *swilleys.* They seldom exceed a mile or a mile and a half in length, and none of them has been worked.

But at the southern extremity of Yorkshire, and extending into Nottingham and Derbyshire, there is situated a great coal field, scarcely inferior in importance to that of Newcastle itself. It occupies an area nearly triangular, but with a truncated apex; the base, or broadest part, being at the northern extremity, and the apex, or narrowest part, at the southern. Its greatest length, from Leeds to Nottingham, rather exceeds sixty miles; while its greatest breadth, from east to west, is about twenty-two miles.

The position and dip of the beds is the same as that of the Newcastle coal field. The beds crop out to the west and dip to the east. The strata of coal amount to thirty, varying in thickness from six inches to eleven feet. The whole thickness of coal is stated by Mr. Bakewell as amounting to seventy-eight feet. The beds of slate clay and shale are numerous; those of sandstone amount to twenty, and some of them are very thick. The lowest of these beds is termed *millstone grit*, and below it no workable coal is found.

This field is traversed and dislocated by an immense *fault*, proceeding from near the termination of the magnesian limestone range on the south northwards in a zigzag direction, on the western side of that limestone, quite into Yorkshire. Respecting the size and contents of this *fault* we have no accurate information; but the beds of coal on the west side of it are so dislocated, that it is difficult to connect them with the intervening strata, so as to form an accurate conception of their number and relative position with respect to each other. The best account of this coal field that I have seen will be found in Mr. Farey's *Mineral Survey of Derbyshire.*

To the west of this great coal formation in North Staffordshire there are two detached coal fields, namely, that of Cheadle and that of Newcastle-under-Line where the potteries are situated.

The Cheadle coal field appears to consist of an insulated basin, reposing, according to Mr. Farey, upon millstone grit.

The Pottery coal field occupies a triangular area, the two sides of which are each about ten miles in length, and the base, in the middle of which Newcastle-under-Line is situated, about seven miles long. From the two sides the beds dip towards the centre of the area. The lowest bed is millstone grit, which seems to rest on mountain limestone.

The Manchester or South Lancashire field begins in the north-western parts of Derbyshire, and ranges thence to the south-western parts of Lancashire; forming a kind of crescent with Manchester nearly in the centre. The distance between the extremities of this crescent is about forty miles. Generally speaking, the beds crop out towards the south, where they may be seen lying over the millstone grit. But great disturbances interrupt the regularity of this disposition. In the first place, what may be called the south-eastern horn of the crescent, forming the portion of the coal field which lies within Derbyshire and Cheshire, bifurcates at the village of Disley in the latter county, being divided into two branches by an intermediate ridge or saddle of millstone grit. The eastern branch forms a trough of which the strata crop out on both sides against the millstone grit. This has been called the Goyle trough, from a small river of that name which runs through it. The extent of it is about fifteen miles from Disley to near Mearbrook in Staffordshire.

The western branch of the bifurcation is not so regular, owing to numerous *faults* which have altered its position. These coal beds contain more than fifty seams of coal in a few hundred yards' sinking.

Respecting the northern and far more important part of this coal field, which occupies a considerable portion of the southern division of Lancashire, I am not aware that any accurate details have been given to the public.

There is another coal field of small extent in the north of Lancashire, situated half way between Lancaster and Ingleton. It seems to form a small insulated basin reposing on, and surrounded by, millstone grit.

The last coal field connected with the Penine Alps that requires to be mentioned is that of Whitehaven. It lies on the sea shore, and extends from the promontory of St. Bees, where a good section of the coal beds and the superincumbent rocks may be seen, about twenty miles north. The number of beds cut through in this field is 117. Of these, seventeen are coal. The rest are sandstone, slate clay and ironstone. The greatest depth of the mines is 110 fathoms.

If we reckon the millstone grit and the mountain limestone as constituting a portion of the coal field, then we may say that a great coal formation extends without interruption from Berwick to Nottingham, from Nottingham to Liverpool, to the Solway Firth, and from that to Berwick, constituting a length of about 200 miles, and a breadth of about 90 miles. But as a great portion of this tract consists of millstone grit containing very little coal, and of mountain limestone containing none at all, it seemed better to notice the different coal fields separately.

The coal fields in the central districts of England come now to be noticed. Though of no great extent they are important on account of the manufacturing population which they supply with fuel. This part of England consists of new red sandstone, through which detached coal beds rise in different places like so many oases.

The first of these is the Ashby-de-la-Zouch coal field, which occupies an irregular area of 10 miles by 8, having the town of Ashby-de-la-Zouch nearly in its centre. It extends nearly to the transition country of Charnwood forest in Leicestershire. The deepest coal pit in this district is 123 fathoms. Six beds of coal are known, the lowest of which has a thickness of from 15 to 21 feet.

This coal field is flanked on the north-west by a line of detached mountain limestone of a remarkable character. This limestone contains magnesia, but is known to be mountain limestone by the fossils found in it. There are eight of these detached limestone points, each occupying but a few acres in extent, surrounded, and as it were, insulated by overlying masses of new red sandstone.

The second central English coal field is in Warwickshire. It extends from Tamworth, in Staffordshire, to about 3 miles east from Coventry, a length of about 16 miles. Its average breadth is about 3 miles. The beds crop out to the east north-east, the inclination becoming more and more rapid towards the eastern edge of the field, where it in several places exceeds an angle of 45° with the horizon. On the west side it decreases to one foot in five. The lowest bed exposed is mill-stone grit. The principal works are near the southern extremity of the field, at Griff and Bedworth. At Griff four beds of coal are worked; the depth of the first bed is 117 yards, and the principal seam is 9 feet in thickness. The Bedworth works are upon the same beds; but here the first and second coal seams run together, and constitute one 15 feet thick.

The third central coal field is the one which supplies the manufacturers of Birmingham and the immense iron works between Dudley and Wolverhampton, with fuel. In length it extends about 20 miles, from near Stourbridge on the south-west, over Cannock chase to Beverton, near Badgeley on the north-east. Its greatest breadth near Dudley, may be about 4 miles. Its superficial area has been found by actual survey, to equal 60 square miles. The northern portion from Cannock chase to near Darlaston and Bilston, affords many coal seams, of 8, 6, and 4 feet in thickness. The southern portion extending thence to near Stourbridge, is about seven or eight miles in length and four in breadth.

This field lies over transition limestone, no red sandstone, mountain limestone, or millstone grit, intervening between the coal beds and the transition rocks. The beds in this field amount to sixty-five, all of which have been cut through to a depth of 940 feet. There are eleven beds of coal, but only the one called *main coal*, 30 feet thick, and constituting the sixth bed, is worked. It lies 315 feet below the surface. The beds dip to the south and gradually crop out as we advance north. Hence it happens, that in the north part of this field the *main coal* is wanting, and those only are worked which lie below it.

Having described the coal fields in the north, east, and central parts of the island, let us attend to those in the western parts of Great Britain. They are disposed round the great transition district of North and South Wales, and may be conveniently distributed into three sets:—1. The north-western; 2. the western; and 3. the south-western.

1. *North-Western Coal Beds.*

Coal is wrought in a valley of the island of Anglesey, which runs parallel to the Menai straits; but I have no information respecting the extent or importance of this coal field.

The principal north-western coal formation is in Flintshire. It begins at Llanossa, near the western cape of the estuary of the Dee, and extends south to near Oswestry in Shropshire, a length of about thirty miles, but the breadth is not great. These coal measures repose upon mountain limestone, which rises to day on the west side of the coal basin, and consitutes a tract of some extent, skirting indeed (but with intervals) almost the whole transition rocks of Wales. Over this limestone lie beds of shale and sandstone, corresponding with the shale and millstone grit of Derbyshire. The coal is of different thickness, from three quarters to five yards. The beds dip from one yard in four to two in three. They sink below the estuary of the Dee, are discovered again on its opposite side on the south of the peninsula of Wiral in Cheshire, where they finally sink below the new red sandstone. Possibly they may continue under it to the Lancashire coal field.

2. *Western Coal Beds.*

The western coal fields are three in number; namely, 1. That in the plain of Shrewsbury; 2. Coalbrookdale coal field; and 3. the coal fields of the Cleehills and Billingsley.

1. The plain of Shrewsbury is skirted by transition hills; it is itself mostly covered with beds of new red sandstone, through which are scattered many small patches of coal beds.

2. The Wrekin, a very conspicuous hill in Shropshire, is composed of trap. It constitutes one of a series of low hills that run on the east side of the plain of Shrewsbury. A few miles to the eastward of this chain, lies the important coal field of Coalbrookdale. This field is about six miles long, from Wambridge to Coalport, on the Severn. Its greatest breadth is about two miles.

The coal measures rise west north-west, at an angle of about 6°. On the eastern side, to which they dip, they are succeeded by the great new red sandstone district. The beds are those which usually belong to the coal measures. Those which have been cut through are 86 in number. The deepest coal pit, namely, 729 feet, is at Madely. The sandstones, which make part of the thirty uppermost strata, are fine-grained, very micaceous, and often contain thin plates or minute fragments of coal. The 31st and 32d strata are coarse sandstones, entirely penetrated by petroleum. The thickness of both together amounts to 15½ feet, and they furnish the supply of petroleum that issues from the tar spring at Coalport. At the depth of 430 feet, occurs the first very coarse sandstone or grit. Its thickness is about 15 feet. The next bed of sandstone deserving notice, is at the depth of 576 feet. It is about 18 feet thick, fine-grained, and very hard, and is often mixed with a little petroleum. The colliers call it *big flint.* The lowest sandstone, called *little flint*, is the 85th bed, and is about 15 feet thick. The lowest portion of it is very coarse and full of quartz pebbles. The upper part is fine-grained, and sometimes is rendered very dense and hard by an intimate mixture of iron ore. It occurs at the depth of 705 feet.

One bed of clay porphyry occurs, 9 inches thick and 73 feet from the surface. It is an indurated clay of a liver-brown colour, with intermixed grains of quartz, hornblende, and felspar.

The clay beds are sometimes compact, dull, and smooth; they are then termed *clod*. Sometimes they are glossy, unctuous, and slaty, when they are called *clunch*. They contain compressed balls of clay ironstone.

The beds of iron ore are five or six in number. They all lie in the indurated clay, and consist of balls or broad flat masses. Essentially they consist of carbonate of iron.

The slate clay, called by the miners *basses*, is of a bluish black colour and slaty texture. It usually contains pyrites, and is always either mixed with coal or combined with petroleum.

The first bed of coal occurs at the depth of 102 feet from the surface. It is only 4 inches thick, and is very sulphureous. Nine other beds of the same nature, but somewhat thicker, lie between this and the depth of 396 feet. They are called *stinking coal*, and are employed only in the burning of lime. The first bed of coal that is worked, is 5 feet thick, and occurs at the depth of 496 feet. Between this bed and the *big flint*, are two beds of coal, one 10 inches, the other 3 feet thick. Between the *big* and the *little flint*, which are about 100 feet apart, lie nine beds of coal of the aggregate thickness of about 16 feet. Beneath this, and constituting the lowest bed of the whole formation, is a sulphureous 8 inch coal. Thus the whole beds of coal amount to 23, but only two or three of them are worth working.

3. A few miles south from the Coalbrookdale coal field, lie the hills of Brown Clee and Titterstone Clee. Upon these a number of small detached coal fields are distributed.

3. *South-Western Coal Fields.*

This division includes the three following important coal fields:—1. The grand south Welsh basin; 2. the Forest of Dean basin; and 3. the south Gloucester and Somerset basin. All these coal fields are close related, not merely by position, but by all resting on a common basis of old red sandstone and by the general analogies of their structure throughout. The strata near the edges of the basins are often highly inclined, and are partially covered and concealed on the south-east side of the great basin of South Wales, and throughout a great portion of that of South Gloucester and Somerset, by horizontal deposits of more recent formations.

1. The great coal field of South Wales, extending from Pontipool to St. Bride's bay, south of St. David's head on the west, is situated in a large limestone basin. The limestone crops out all round the coal, except where its continuity is interrupted by Swansea and Caermarthen bays. The deepest part of the basin is in the neighbourhood of Neath, which is near its centre. And below Neath, or a little to the west of it, the lowest strata of coal are nearly 700 fathoms lower than the out crop of some of the inferior strata, in the more hilly parts of the district. The bed of coal which is nearest the surface, lies (near Neath) about 60 fathoms beneath it, and rises to it about a mile north and south, and also a few miles east and west of the deepest part of the basin. We may imagine the inferior beds of coal rising to the surface all round the out crop of the superior stratum. If a line be drawn from Pontipool on the east, to St Bride's bay on the west, it may be said that all the beds of coal on the north side of that line crop out on the north of it; and so also those on the south, except near Pontipool, where they rise towards the east.

There are twelve beds of coal from 3 to 9 feet thick, making together 70½ feet; and eleven others, from 18 inches to 3 feet, making 24½ feet, amounting altogether to 95 feet of workable coal, besides numerous others from 6 to 18 inches thick. This coal field occupies about 100 square miles. It contains 100,000 tons of workable coal per acre, or 64,000,000 of tons per square mile; or, altogether, the enormous quantity of 6400,000,000 tons of coal. This at the rate 5,000,000 tons per annum, (which is much more than the consumption in the Newcastle coal field), would last little short of 1,500 years.

The coal on the north-western side of the basin is what is termed *stone coal*, a kind of anthracite. The small of this, called *culm*, is used by the iron smelters and for burning lime.

The *lower* part of the coal series, as worked at Merthyr Tydvil and the neighbourhood, is distinguished by the predominance of shale; the *upper* by the predominance of a coarse grit of loose texture, abounding with specks of coaly matter, and agreeing with the rock called *pennant*, in Somersetshire. These beds are often slaty, sometimes sufficiently so to be employed as tiles. A great thickness of them separates the lower from what may be called the upper coal series, and it is of this rock that the summits of all the principal *mountains in the interior* of the basin consist. The lower series contains numerous strata of coal and sixteen of ironstone. This ore exists both in continuous beds and in detached nodules. It is principally found in the lower series, and some of its most valuable beds occur beneath the lowest coal. The beds alternating with the coal and ironstone in the lower series consist almost exclusively of slate clay; between it and the limestone on which the coal formation rests, millstone grit is often, but not always, interposed. The upper coal series has not yet been accurately described.

The inclination of the strata is much more rapid on the south edge of the basin than on the north; being often at an angle of 45° or more, while that on the north is generally under 10°.

On the western termination of the basin in St. Bride's bay, the strata exhibit the most extraordinary marks of confusion and derangement, being vertical, and twisted into every possible form of contortion.

This coal field is traversed by *dykes* or *faults*, generally in a north and south direction, which throw all the strata from 50 to 100 fathoms up or down. They are usually filled with clay, but Mr. Townsend mentions an enormous fault, many fathoms thick, filled with fragments of the disrupted strata which traverses the colliery of Lansamlet, near Swansea, effecting a rise of 40 fathoms in the strata.

2. The coal basin in the forest of Dean occupies the whole of the forest tract. It ranges round Colford as a centre, and is about ten miles long from north north-east to south south-west, and about six miles broad. All the beds dip uniformly towards the centre of the basin. Exterior ridges of mountain lime and old red sandstone enclose the coal measures and doubtless pass under them.

The thickness of the coal measures is 500 fathoms, containing about 26 beds of coal.

3. The coal basin of Somersetshire and south Gloucestershire occupies an irregular area, of which the longest diameter, from near Iron Acton, on the north, to Coalford at the foot of the Mendip hills, on the south, is near 25 miles. The shorter from the Newton collieries, near Bath, to those of Bedminster, near Bristol, is about eleven miles. The course of the river Avon nearly coincides with this diameter, dividing the coal field into almost equal portions. At the north-east and west the strata dip towards the centre of the basin; but at Coleford, near Mells, on the south, where they abut against

the Mendip hills, the stratification is much deranged, becoming vertical, and frequently thrown backwards and bent into the form of the letter Z.

This coal basin is very interesting to the geologist, because it is covered by some of the newer formations, which have been penetrated and their unconformable position ascertained. Thus the relation between the coal beds and the newer formations has been determined. Several of the formations below the coal are also exposed to view. The order of the beds, beginning with the lowest, is as follows:

Greywacke,
Transition limestone,
Old red sandstone,
Mountain limestone,
Coal measures.

The formations above the coal measures, in the order of their position, are

New red sandstone,
  Dolomitic conglomerate.[*]
  Red sandstone.
  Red marl.
Lias,
Oolite.

The Mendip hills, which bound this coal basin on the south, are composed of mountain limestone.[†]

There is a small coal basin near Wells, as appears from Smith's map, but I have met with no description of it.

Having finished the account of the coal measures in Great Britain, let us now turn our attention to Ireland.

Ireland may be considered as an island, nearly surrounded by primary or transition mountains, including a great central area filled with red sandstone, mountain limestone, and coal measures. The Irish coal districts are four in number.

1. The Ulster coal district, in the north of Ireland, is small in extent, being almost limited to the trap mountain of Fairhead, under which it lies.

2. The Connaught coal district occupies an extensive tract in Leitrim, in the middle of which Loch Allen is situated.

3. The Leinster coal district is situated in the counties of Kilkenny, Queen's and Carlow. It also extends a short way into the county of Tipperary; namely, as far as Killenaul. This is the principal coal tract in Ireland; it is divided into

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[*] The substitute for the magnesian limestone inthe north of England.

[†] For a full and instructive account of this important coal basin the reader is referred to the description of it by Buckland and Conybeare, in the *Memoirs of the Geological Society* (second series), i.

three basins separated from each other by mountain limestone, which not only surrounds but underlies the whole formation.

4. The Munster coal district occupies a considerable portion of the counties of Limerick and Kerry, and a large part of the county of Cork. It is the most extensive in Ireland, though hitherto very little coal has been extracted from it. According to Mr. Weaver much of these coal measures are in the *transition* formations; a fact which, if confirmed, will overturn many of the theoretic opinions entertained about the state of the globe at the time when the coal beds were deposited. An accurate survey of this part of Ireland would be a valuable present to the science of geology.

We may now take a cursory view of the coal tracts on the continent.

1. There occurs a small coal tract at Helsingburg, at the Sound, not far from the southernmost point of Sweden. It extends about thirteen miles along the sea coast, and its greatest breadth may be about nine miles. This tract consists of the usual coal measures, sandstone, slate clay, shale and coal. There are two beds of coal, the uppermost is 1 foot thick, the undermost $2\frac{1}{2}$ feet. The coal mine which was worked at Höganäs in 1812, was 80 fathoms deep. It was mined for some time unsuccessfully by a Swedish company. Some years ago Mr. Bald was employed to survey it; he found the sandstone of so spongy a nature that it was impossible to drain the mine. By his advice the workings were abandoned.

From the fossils found in these coal measures, and from the description of the rocks of which they are composed, there can be no reasonable doubt that these coal deposits are situated in the *lias*, as is the case at Whitby and in Sutherland.*

Coal measures exist in the island of Bornholm, which is situated in the Baltic, on the east side of Scania. From the description of Hisinger and the fossils found in that part of the island, it is obvious the coal measures here also lie in the great oolitic formation.

2. Coal probably exists in considerable quantity in Spain, though no attempts have been made to work it. Eight different localities in Catalonia, three in Arragon and one in New Castile, are cited, where coal exists. But we know nothing of either the extent or depth of these coal basins.

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* *See* Köng. Vet. Acad. Handl., 1820, p. 108.

Since the absurd prohibition of mining, which existed so long in Spain in favour of America was removed by the Cortes in 1820, the inhabitants of the mining districts of that country have been roused into uncommon activity, and several collieries have been opened in different parts of the kingdom. In the neighbourhood of Oviedo, in the Asturias, very rich coal mines are worked, chiefly for the metallurgic establishments of Andalusia. Another coal mine near the river Avilis, and consequently more favourably situated for exportation, has been more lately opened. And the small coal field of Villa-Nueva-del-Rio, eight leagues above Seville, supplies fuel to the steam-boats which ply between Seville and Cadiz.*

3. France possesses many considerable coal tracts, and has of late years been fully aware of their importance. Great assiduity has been displayed in endeavouring to apply these mineral riches to the smelting of iron. But a circumstance, apparently trifling in itself, has hitherto prevented the French iron works from thriving. In France the coal and the iron ore do not occur together, as they do in Britain.† Hence they are obliged, at a great expense, either to carry the ore to the coal,or the coal to the ore.

There occurs a small coal field at Litry, on the south-west of Bayeux, in the western part of Normandy, just where the transition tract of the Cotentin terminates. This tract, in point of situation, is analogous to that of the south-western coal fields of England. The coal metals repose immediately on transition formation, but in an unconformable position. Somewhat farther south between Angiers and Nantes, where the Loire forces its way through the transition chain to the sea, another more extensive, though not large, coal field occurs.

In the centre and south of France several coal tracts occur in the valleys interspersed through that extensive primary country. These occupy chiefly the valleys of the Loire, the Allier, the Creuse, the Dordogne, the Aveyron and the Ardeche, between ridges proceeding from the primitive centre group, connected with the Cevenne; and also on the south-east, between the Cevenne and the Rhone. In these places the coal beds repose immediately on the primary formations.

In the north-east of France, and in Belgium, a very consi-

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* Ann. des Mines (third series), v. 184.

† The Newcastle coal beds constitute an exception. No ironstone is found in them. Hence the reason of the small number of iron works established in that great coal country.

derable coal tract exists. It extends from Hardinghen, near Boulogne, in nearly an eastern direction, as far as Eschweiler, beyond Aix-la-Chapelle, a length of about 200 miles. Indeed, several of the coal districts in the north of Germany may be considered as prolongations of it.

This coal field is covered by the green sand formation, and lies immediately on the transition formation, and is 8202 feet below the level of the sea.*

On the east and north, the great deposits of chalk, and the strata above the chalk, skirt and partially overlie this tract. On the south, it is bounded by the transition ridges which occupy the forest of Ardennes, overhang the magnificent defile of the Rhine, from Bergen to Bonn, and thence extend to the Westerwald. This tract does not consist of a single coal field, but of many isolated and basin-shaped deposits of coal measures, encircled by mountain limestone, and old red sandstone. It bears a striking resemblance to the coal districts in the south-west of England.

The most westerly point of this great chain of coal basins is at Hardinghen, in the great denudation exposing the beds below the chalk, which comprises the Boulonnais on the French side of the channel, and the Weald of Kent and Sussex on the English side. The coal mines and quarries of mountain limestone, which occur at Marguise, are situated at the very foot of the escarpment of the surrounding chain of chalk hills. For the outcrop of all the intermediate formations crosses this part of the denudation to the south, and, as it were, withdraws to expose the coal. Indeed, to the west the coal is worked at several places within the general limits of the overlying chalk formation.

The environs of Aniche, near Douay, and of Monchy le preux, near Arras, present deposits of this nature. The mines surrounding Valenciennes are still more extensive. In the neighbourhood of Mons, Charleroy, and Namur, in a tract surrounding Liege, and close to Eschweiler, on the east of Aix-la-Chapelle, very considerable coal fields are worked.

To the east of this place, the more recent formations intrude upon and conceal the coal, till you cross the Rhine a little to the north of Bonn. Then these newer formations again recede to the north, and an extensive coal field occurs along the small river Ruhr, a little above its junction with the Rhine. On

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* Brongniart, Tableau des Terrains, &c., p. 276.

the south, the beds of this coal field describe the segment of a circle, cropping out against alternations of limestone, shale, and old red sandstone, which separate them from the regular transition slate. On the north they are bounded by the overlying and more recent deposits.

Somewhat to the north of this district of transition rocks, coal fields again occur between the Rhine and the Moselle, in the northern parts of Lorrain; first between Sarrebruck and Sarrelouis, on the river Sarre; and, secondly, near Waldmohr, on the banks of the Glane. But I have never met with a good description of these coal fields. From Keferstein's account, the beds are extremely contorted and dislocated. Masses of unstratified trap rocks are interposed among the coal measures. Agates abound in the amygdaloid. Quicksilver occurs both in the porphyritic conglomerate, and in the coal sandstone.

Coal also occurs on the west side of the Vosges mountains, which form the limit between Alsace and Lorrain.

4. In the south-west and south of Hanover, there occurs an extensive coal district, between Osnabruch and Hildesheim. It is probably a continuation of the great coal tract in the Netherlands.

There is an extensive coal tract on the east side of the Hartz mountains, which has been described by Keferstein. The coal measures immediately succeed the slate mountains of the Hartz; near the east end of which they present themselves in three places; 1. The Opperode district; 2. The Ilefield district; 3. The Petersbirge district. The two first lie immediately on the slate, and form a portion of the Hartz chain. The third constitutes an insulated district in the Suale Kriese. The coal measures present the usual alternations of shale, sandstone, and some limestone beds, containing marine fossils. Three beds of coal are sometimes found. A good deal of porphyry occurs in the Ilefield and Petersbirge districts. Its relation to the coal beds has not been well made out. From Humboldt's account, it does not seem to form true beds; but to have been introduced in the same way as the trap rocks into our coal fields.

There occurs a small coal field between Dresden and Freiberg, near the Weisseritz river, which, from the nature of the country, would seem to rest on primary rocks, as is the case in France. But the principal Saxon coal district lies along the course of the Zwickau, between Leipsic and the Erzgebirge. In this district, porphyry prevails; and it would seem in some places to be associated with, and to alternate with, the coal beds. Coal occurs near Zwickau at Schonfeld, and at Planenschen grund near Dresden. This district is supposed to have a subterranean connexion with Petersbirge district, in the Hartz.

Coal occurs in two different parts of Bohemia, at Pilsen and Waldenburg.

There is an extensive coal district in upper Silesia, including the following towns:—Pless, Freystadt, Troppau, Jagerndorf, Kosel. It lies partly in Silesia, and partly in Poland. In the former country, it exhibits coal only; in the latter, coal and porphyry. The coal beds repose immediately upon the slate mountains of the Sudetergebirge. The strata are elevated on approaching that chain, but become more horizontal as they recede from it. The coal measures are covered by the porphyry, which in its turn supports the alpine or magnesian limestone. The coal measures pass by such gradual transition into the greywacke, on which they repose, that, according to Keferstein, it is difficult to ascertain the exact demarcation between them. Hence the position of this coal seems to be similar to that in the south-west of Ireland. The usual strata of the coal measures present *grits*, or coarse sandstones of various textures; millstone grit, shale, with nodules of clay ironstone, and mountain limestone. There are numerous beds of coal, and some of them of considerable thickness.

5. There is a coal district at Balligorod and Rosocky, near Sanok, in Austrian Poland, upon the north side of the Carpathian mountains.

6. Another coal tract is said to occur in Hungary, at Funfkirchen, on the borders of Sclavonia. The order of beds, beginning at the surface, is as follows:—

1. Red porphyry,
2. Red grit,
3. Greenstone,
4. Several varieties of grit,
5. Coal,
6. Carbonaceous grit,
7. Shale and fetid limestone,
8. Slaty coal grit,
9. Coarse coal grit,
10. Black limestone.

The uppermost of these beds evidently belong to the new red sandstone, which lies immediately over the coal measures.

7. In Russia, an extensive coal tract occurs at Toula, to the south of Moscow, where the great Russian iron works are established. About the year 1816, the Emperor Alexander gave a large salary to a gentleman from Whitehaven, a prac-

tical coal mining engineer, to superintend the working of this coal. The coal was worked successfully for some years; but at last suddenly abandoned, because it was found that the Russians could not be prevailed upon to purchase this coal, after it had been dug up.

8. Coal is said also to occur in the Crimea, and near the Uralian mountains, not far from the source of the Chusova.

9. There can be little doubt from the abundance of naphtha and petroleum in various parts of Turkey and Persia, that coal tracts of considerable extent exist in these countries; though no attempts have been made by the inhabitants to avail themselves of the mineral riches which their country is capable of furnishing.

10. There is a coal tract upon the Ganges, in Bengal, about two hundred miles above Calcutta. This coal is worked and supplies the manufactories in Calcutta with fuel. No description of these coal measures, so far as I know, has been published.

11. Coal has also been discovered in the district of Cutch, to the north of Bombay.

12. On the east coast of New Holland, about fifty miles north of Port Jackson, there is a coal field, the strata of which are laid open by the section of the cliffs at the sea shore. This coal has been worked for some time, and was carried to Calcutta till superseded by the discovery of coal on the banks of the Ganges. It supplies all our settlements in Australia with fuel. The bed of coal worked is about 40 inches in thickness, and is about 100 feet below the surface of the earth. It has been suspected, from the fossils found in these coal measures, that they belong rather to the lias than the independent coal formation; but the coal measures are traversed by trap dykes, in the same way as our own fields.

If we now turn our attention to the continent of America, we shall find that the inhabitants of the new world have been furnished with large quantities of this subterraneous fuel, which, in future ages, after the country has been fully peopled and stript of its superfluous timber, will be found of immense importance.

13. A remarkable coal district occurs in Pennsylvania, and extends about a hundred miles north by east, running parallel to the Blue Mountains, which traverse that country from the Susquehanna to the Lehigh mine, then bending north and

afterwards north-east. The tract of country in which it occurs is transition; but the coal measures, from the description of them by Mr. Cist, appear to be similar to those which occur in this country. The American coal is an anthracite, which burns without smoke and with little flame. It is used in America for a great variety of purposes. The annual consumption in 1821 was 2000 tons. There are two beds of coal: the uppermost varies in thickness from 12 to 18 feet, the lowest is 14 feet thick; the other beds are sandstone, slate clay and shale. The vegetable impressions are numerous, and, as far as can be judged from the imperfect account of Mr. Cist, they resemble those which occur in our own coal beds. All these vegetable impressions are in the slate clay above the coal; very few, if any, fossils have been observed under the coal.

14. A coal field occurs in the county of Chesterfield, in Virginia, just on the south side of James' river, and about a hundred miles west from the Atlantic Ocean. From Mr. Grammer's account of these mines* the country appears to be primitive, and the coal metals are considered as deposited directly over the granite, though the contact of the two has not been observed. Only one bed of coal has been worked the thickness of which varies from thirty to fifty feet. The coal is similar to our own slate coal. This bed has been burning for a great many years. The combustion goes on very slowly. Various attempts have been made to put out the fire by letting water into the pit, but they have not been attended with success. Advantage has been taken of this combustion to ventilate the mines; a level has been cut to an old abandoned pit in the vicinity of the burning part of the bed; a door is put on this adit; when the miners begin to be incommoded with foul air this door is opened, a rapid motion of the air immediately takes place towards the burning part of the bed, which cleans the pit of foul air.

15. In Nova Scotia, not far from the upper extremity of the bay of Fundy, and particularly round what is called *Mines basin*, coal fields have been discovered in fourteen different places. The most extensive coal tract is in the district of Pictou, near Northumberland straits, which separate Nova Scotia from the island of St. John, near a place called New

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* Silliman's Jour. vol. i.

Glasgow. Six or eight shafts have been sunk by Mr. Carr and excellent coal found, which is now exported in considerable quantities to the United States.

From the Geological Account of Nova Scotia, published in the *Memoirs of the American Academy*, by Messrs. Jackson and Alger, it appears that the country in which these coal metals occur is granite. No accurate description is given; but from the map, which they have published, it would appear that the basins filled by the coal beds are hollows in the granite. The granite is succeeded in that country by a clay slate, to which Messrs. Jackson and Alger (it does not appear for what reason) have given the name of *transition slate.*[*]

16. But the great coal country of North America is the immense basin of the Missouri, interposed between the Rocky Mountains on the west and the Alleghany mountains on the east, constituting a prodigious tract of fertile country not less than 1500 miles square. Mr. Maclure conjectures that the whole of this region was once a lake or inland sea, which was drained by the river St. Lawrence forcing its way to the Atlantic Ocean on the east and the Mississippi on the south. Immense tracts of coal occur in this basin, some of which, it is said, have been already worked; but they cannot come into general use till the country be sufficiently peopled and denuded of wood, to occasion a demand for that kind of fuel. There cannot be a doubt that this vast and fertile basin, so richly furnished with fuel and with soil, is destined one day to become one of the most powerful and flourishing countries in the world.

17. We know very little about the coal formations in South America, though it is well understood that various such exist. Humboldt mentions a coal field on the table land of Sta. Fe de Bagota, at the height nearly of 8,700 feet above the level of the sea. He informs us that coal beds exist also in the high Cordilleras of Huarocheri and of Contu. It is even said that

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[*] According to these gentlemen, a Geological Account, by whom, of Nova Scotia has been inserted in the *Memoirs of the American Academy*, for 1832, this country is composed chiefly of transition slate. The country contiguous to the sea is alluvial, except at Halifax, where the clay slate rocks come to the shore. Behind the alluvial deposits is a broad zone of transition slate, extending from near Cape Breton to St. Mary's bay on the west. A narrow zone along the Annapolis river is quartz rock; this is succeeded by a narrow zone of red sandstone, dipping under the trap rocks which surround the bay of Fundy.

they occur near Huanuco, mixed with magnesian limestone, very near the limit of perpetual snow, or at the height of 14,700 feet above the level of the sea. There are numerous coal tracts in New Mexico, in the central parts of the saline plains of Moqui and Nabajoa, and likewise near the sources of the Rio Sabina.

From the preceding history of the coal formations in different parts of the world, imperfect as it is, we see that the coal measures are sometimes mixed with the lias beds, sometimes with the magnesian limestone; sometimes they repose on millstone grit, sometimes on mountain limestone, sometimes on old red sandstone or greywacke, sometimes upon clay slate and sometimes upon granite. The coal in the *lias* is doubtless of a posterior date to that which lies below the magnesian limestone. But the era of the magnesian limestone and of the coal measures, though posterior, is not, perhaps, very different. The reason of the difference of the position of the other coal beds, with respect to the lower strata, must be the occasional absence of certain beds.

CHAP. XIII.

GREYWACKE AND OLD RED SANDSTONE FORMATION.

The term *transition* was applied by Werner to certain rocks, because he was of opinion that they were deposited when the earth was passing from an uninhabited to an inhabited state. The evidence of this opinion was, that they contained the fossil remains of vegetables and animals, while no such remains occur in any of the rocks situated below them. Werner affirmed that the fossil remains in the transition rocks belong exclusively to the lowest classes, both of the vegetable and animal kingdom. It is now known that these opinions were ill-founded; it can be proved that the earth was inhabited, at least, by fishes and plants before the transition rocks were deposited; and surely it would be too much to affirm that fishes and filices and equiseta belong to the very lowest classes of animals and vegetables.

The only one of the transition rocks of Werner which seems capable of coming under a general arrangement is the one which he distinguished by the name of *greywacke*. This rock alternates very frequently with a clay slate, which, on that account, has received the name of *transition* or *greywacke slate,* though it is impossible, in many cases, except from position, to distinguish between *primary* and *transition clay slate.* Large masses of limestone occur in the greywacke, or interposed transition slate. This limestone frequently constitutes whole mountains; from its situation it is known by the name of *transition limestone.* The greywacke is a sandstone the fragments of which are cemented together by clay slate; but sometimes it puts on the appearance of a conglomerate, and not unfrequently the grains become so fine that it assumes the form of a sandstone. Its colour in that case being usually *red* (though sometimes purple), it has been distinguished by the name of *old red sandstone.* As this sandstone cannot be distinguished from *new red sandstone* or *coal sandstone,* except by position, these three sandstones have frequently been mistaken for each other; this has introduced considerable confusion into the subject, which can only be cleared up by a greater attention to the position of the rocks submitted to description, or by attending carefully to their fossils, when they contain any.

The term *greywacke* (in German *grau wacke,*) was given by the Saxon miners to a rock near Freyberg, remarkable for the many metalliferous veins which it contains. It is a sandstone, composed of fragments of quartz, felspar, lydian stone and clay slate, often exceedingly hard, or much more siliceous than common. Or we may define it a siliceous clay slate containing numerous fragments of quartz, felspar, lydian stone and clay slate. The imbedded masses vary in size, but seldom exceed a few inches. When they are very small the sandstone appearance of the rock vanishes, it assumes a slaty structure and is then known by the name of greywacke slate or transition slate. Greywacke is termed by the French *traumate* and *psammite.*

Greywacke, like other sandstones, is stratified, and the stratification can be still better seen by its alternating with clay slate. Now, the remarkable circumstance is, that these beds (so far as I have seen) are never horizontal, but almost always very nearly perpendicular. It is clear from this that they have been exposed to some violent action since their original deposition, and this is partly accounted for by the fact that they are always, or at least generally, more or less mixed with trap rocks, to which, doubtless, they owe their position.

There is a range of transition mountains in Scotland which begins at St. Abb's Head, the southern termination of the Frith of Forth, and extends with little interruption till it terminates in the Irish sea, on the north side of Loch Ryan in Galloway. This range extends in length about one hundred and twenty miles, and includes the mountains of Galloway, Dumfries, Lanark, Peebles, Mid Lothian, and Berwick. The highest part of the tract is near Moffat, where Hartfell rises to the height of 3300 feet above the level of the sea. Lowther, near Leadhills, which is in the same range, is 3130 feet high. This mountainous tract is composed of transition rocks; but from the abundance of greenstone found in it, the whole has been thrown into such inextricable confusion, that it would be a difficult task to determine the relative position of each rock. The kind of rocks found in the range, so far as I have observed, are greenstone, clay stone, porphyry, greywacke, clay slate, alum slate, and sandstone. The sandstone constitutes the principal part of some of the Pentlands west from Edinburgh, and I think it probable, from the situation, that this sandstone belongs to the coal beds, though this is merely a conjecture.

About five miles south of Edinburgh, in the Pentlands, which constitute a part of this chain, there occurs a romantic valley, and Mr. Playfair, who used to visit it occasionally, distinguished it by the name of the *Valley of the Pentlands.* It was formerly a favourite resort of the inhabitants of Edinburgh during the summer months, being marked by tradition as the *Habby's Howe,* which constitutes the site of Allan Ramsay's *Gentle Shepherd.* The lower part of this valley is composed of alternate strata of greywacke and clay slate. The soil has been removed on the north side, and the rock laid bare, by the action of a rivulet for about 100 yards. The beds are in general thin, sometimes only a few inches. These beds are standing almost perpendicular to the horizon. I have observed the same beds in nearly the same position to the east of Soutra Hill, one of the Lammermuir chain, which terminates at St. Abb's Head, and indeed in various other spots of the hilly part of Berwickshire. Indeed, if we traverse the country from the Tweed to the Lammermuirs, we will find the red sandstone, which at the Tweed distinctly covers the coal measures, gradually and insensibly passing into greywacke. The same greywacke rocks are visible at Moffat, where they have been used as a building stone; but I had not an opportunity of determining the relative position of the beds.

Good sections of greywacke may be also seen in the mountains north from Loch Ryan. The road from Glasgow to Port Patrick crosses these mountains. It is steep and inconvenient for the traveller, but admirably contrived to furnish the geologist with sections of transition rocks. The hill behind General Wallace's house, at Carn, is composed of clay slate, and this slate alternating with greywacke, may be traced for several miles north, till the mountainous country suddenly terminates a little to the south of Girvan.

The greywacke slate which lies over the granite and gneiss district at Loch Ken, in Galloway, is probably a continuation of, or at least connected with the great transition tract just mentioned.

There is another extensive transition series of rocks in Cumberland, which have been gradually investigated by Otley, Phillips, and Professor Sedgwick. It constitutes the country round the lakes, so frequently visited on account of the romantic nature of the scenery.

The undermost portion of this tract consists of primary rocks. The lowest bed of all is granite. Skiddaw, and the neighbouring region, consist of gneiss and hornblende slate, over which lies a formation of clay slate which is considered to be transition slate. Over this lies an enormous formation of green slate, intimately associated with a porphyry very similar to that which constitutes the summit of Ben Nevis.

Next comes the greywacke system of rocks, containing calcareous beds with organic remains. Towards the south side of a line drawn from Skiddaw to Egremont, there is a group of mountains composed almost entirely of diallage rock. It is in precisely the same position with the rocks of the district as a similar rock in the peninsula of the Lizard, Cornwall.

The greatest part of North Wales consists of transition beds. These beds consist chiefly of three sorts of rocks: 1. An extensive porphyry district. 2. Clay slate, exceedingly abundant, and often capable of being split into very thin roofing slates. The greatest part of England is supplied with slate from Wales, which forms a lighter roof, but not so durable as the Scottish slate. 3. Greywacke containing in its upper part organic remains, and gradually passing into slate.

There is a variety of slate at Snowdon, seemingly approaching very closely to the slate in the Cotentin, which Brongniart has distinguished by the name of *steashist.*

In the neighbourhood of Plymouth, alternations of clay slate occur with limestone containing conchiferous and coralline fossils, and therefore considered as transition limestone. The clay slate possesses all the characters of primary slate, except that it alternates with the transition limestone. No greywacke rocks can be discovered in the neighbourhood of Plymouth. But a little to the east of Truro, there was, about twenty years ago, a greywacke quarry near the road, the stone from which was employed in mending the roads. The clay slate, unchanged in its characters, continues to form the fundamental rock of Cornwall through the greater part of the county. In the peninsula of the Lizard it is interrupted by a deposit of greenstone, connected with which is a formation of diallage rock and serpentine, all of which, have doubtless been forced up from below. The granite rocks which run from the Landsend to Dartmoor, with certain interruptions on the surface, though probably united below, are most likely to be referred to a similar cause.

The Plymouth limestone rises into low hills near the seashore, and was employed in constructing the breakwater. It is a variegated compact limestone with a splintery fracture, most commonly reddish or blackish, and capable of taking a good polish, and is a variety of what is well known under the name of *Devonshire marble.* Shells and corallines are by no means uncommon in this limestone.

There is a *conglomerate rock* which occurs at Oban in Argyleshire, which has so many relations to greywacke, though I was unable to find in it any fossil remains, that I think its formation must be referred to the same period. The fundamental rock of the country is primary clay slate, over which the conglomerate lies in an unconformable position. It must therefore have been deposited and solidified after the clay slate and after the deposition of all the primary rocks in that country; because it is composed of fragments of these rocks.

This conglomerate makes its appearance about five miles to the north of Oban, constituting a range of low hills that run east and west a little to the north of the Connal Ferry over Loch Crerar. The little hill called Berigonium, considered as a vitrified fort, and fabled to have been the capital of Caledonia, is composed of this conglomerate. The low islands at the mouth of Loch Crerar consist of the same conglomerate. They serve to connect these hills with the one on which Dunstaffnage Castle is built, which is also composed of conglomerate. The rock continues along the sea shore to Donolly Castle, which is likewise built on a conglomerate rock, so steep on all sides but one, that Donolly must have been a place of great strength in olden times. About a furlong north of Donolly the upper part of the cliff retires back a good way from the sea, leaving a space not unlike the undercliff in the Isle of Wight. The rocks on the beach are still conglomerate above, but below they assume the form of a hard, purplish, slaty sandstone, intermixed with water-worn pebbles. This sandstone is stratified, the beds varying in thickness from an inch to some feet. It dips east below the conglomerate at a small angle, the dip not exceeding 1 foot in 24.

In like manner at Oban, where there is a beautiful bay constituting the harbour, the conglomerate rocks retire backwards, and form the high bank which protects the village on the east. This part of the rock is covered with grass, except at the south end, where a fine section presents itself to the view of the geologist.

The conglomerate continues along the sea shore to the ferry of Kerrera, about a mile and a half distant, where its continuity is interrupted by a broad basalt dyke. It may be followed four miles farther south, where it may be seen lying over the clay slate beds. How much farther south it proceeds I do not know, the encroachments of the sea rendering it inconvenient to proceed farther except in a boat.

The same conglomerate makes its appearance in the Island of Kerrera, situated to the west of Oban, about half a mile or three quarters of a mile from the main land, and thereby constituting a secure and spacious natural harbour. We can trace the rock from the north end of the island to the ferry, which is nearly half way between its two extremities. The south end of the island consists chiefly of clay slate.

How far inland these conglomerate rocks extend cannot easily be determined, the nature of the country presenting almost insurmountable obstacles to such an examination.

This conglomerate consists of a congeries of water-worn and rounded pebbles of very various sizes, united very firmly without any visible cement. Some are not larger than a grain of sand, while others constitute spherical or ellipsoidal masses 7 feet in length, and 5 feet in breadth and thickness. The most common size is from that of a human head to that of the two fists. These pebbles are all fragments of the primary rocks in the neighbourhood; granite, clay slate, felspar, quartz are common, but the most abundant constituent is the felspar porphyry, which constitutes the summit of Ben Nevis, which exists in Glenco, and in many other parts of the neighbourhood. These pebbles bear such characteristic marks of their original, that there can be no doubt about it. For example, there is a variety of clay slate conspicuous on the sea shore near Kerrera ferry. It is of a very dark blue colour, almost black, and full of quartz veins. At first sight it looks like basanite, though the slaty texture of the rock when viewed in situ leaves no doubt about its nature. Now this variety of clay slate is a common ingredient in the conglomerate rock.

The conglomerate rock in the island of Kerrera, immediately on the south side of the ferry, differs in its appearance from that on the main land. It consists chiefly of fragments of clay slate and mica; and these, though water-worn, are not rounded, but remain flat with rounded edges.

No appearance of stratification can be seen in the upper part of this conglomerate rock; but the lower portion is divided into regular beds, and consists of a soft sandstone, with interspersed water-worn pebbles, which, however, are few in number, compared with the sandstone in which they occur. This soft sandstone does not pass gradually into the conglomerate: the line of demarcation is quite distinct.

The dip of the conglomerate is variable, but every where it is to the north-east; while the dip of the clay slate on which it lies is south.

With respect to the origin of this conglomerate there can be no doubt. The primary rocks in the neighbourhood must have been fractured, and the fragments washed down into the sea by the violent action of water. They must have been long exposed to the action of the waves of the sea, since the pebbles are all rounded. After this process they must have been agglutinated together, and finally raised above the level of the sea to their present position.

How the agglutination was produced we may have some conception if we attend to the circumstance, that this conglomerate is every where intersected by trap dykes, which usually have a direction from south-west to north-east. These trap dykes doubtless made their way through the conglomerate while in a state of igneous fusion. Now this heat may have been so intense as to have softened the superficies of the pebbles, of which the conglomerate is composed, and thus have caused them to cohere together; for although no cement can any where be seen uniting the constituents together, yet the adhesion is so strong that it is often easier to fracture a pebble than to separate two pebbles from each other.

The probability is, that the consolidation took place under the sea, and that the elevation of the conglomerate was a subsequent, and probably a gradual process. The west coast of Lorn, from Dunstaffnage to Gallochin, an extent of about eight miles, bears unequivocal marks of having been elevated at no very remote period. A considerable portion of this coast consists of pretty steep rocks, the summits of which are elevated 300 or 400 feet above the level of the sea. Now these rocks show clearly that they have at no very remote period been washed by the sea at a height certainly more than 30 feet above the present high-water mark. Now, as we cannot suppose the sea to have subsided 30 feet in this place without producing a corresponding change upon the other parts of the coast, we have no other alternative but to admit that the conglomerate has been elevated at least to that amount; and if we admit an elevation of 30 feet, there can be no reason for refusing our assent to an elevation of 300 or 400 feet subsequent to the period of the consolidation of the conglomerate.

Thus the conglomerate of the coast of Lorn resembles greywacke, in being composed of the debris of primary rocks. We are able even to form some notions of the way in which it has been formed, consolidated, and elevated; nor can there be any good reason for refusing to apply the same principles to the formation and subsequent elevation of greywacke itself.

Parallel to the south-east flank of the Grampian mountains, there runs a chain of low hills. These hills are very irregular in their position, and are separated from each other, and from the Grampians, by intervening valleys, sometimes constituting plains of considerable extent. I have had an opportunity of examining these hills only at the west end of Strathearn. From the village of Crieff, which is situated upon the side of one of these hills, when we turn our eyes around, we see ourselves surrounded, on the south-west and north, by an amphitheatre of little hills, which, varying each in size and in shape, and being covered to the summits with wood, while the prospect is closed on the west by the Grampians, constitute one of the most lovely landscapes any where to be seen. The Earn and the Turret may be observed making their way between these fantastic little hills, and, after uniting their streams in the plain, making their way together through the extensive valley of Strathearn, till the view is closed by the distant hills beyond Perth.

These hills are composed of greywacke, which assumes various appearances in different places. Sometimes it has very nearly the appearance of common greywacke rock. Sometimes it is a very coarse red conglomerate, composed chiefly of a porphyry very like that of the rocks at Glenco. Sometimes it is a pretty fine-grained red sandstone, composed chiefly of grains of quartz; and the strata, which are very distinct, are nearly vertical. The cement of this sandstone is sometimes clay, sometimes clay slate. The grains are very fine, and it contains much mica. A similar stone occurs in Strathearn; but as it is deposited in strata perfectly horizontal, while those in the hilly tract are vertical, I am disposed to consider the sandstone of the flat country as belonging to the new sandstone series.

Dykes of greenstone occur here and there in this greywacke district. There is one at Monzie, on the south flank of one of these old red sandstone hills, which is extensively quarried for mending the roads.

The old red sandstone beds, described by Buckland and Conybeare, as lying under the south Gloucester and Somerset coal beds; and also the same rock lying under the South Welsh great coal formation, probably belong to the same formation as the red sandstone in Perthshire, or, more accurately speaking, skirting the Grampians on the south-east flank. For I have noticed the existence of similar deposits in the same situation, in Stirlingshire and Dumbartonshire.

The origin of the greywacke and old red sandstone, is obviously to be ascribed to the destruction of the older rocks; and doubtless the clay slate which is interposed between the beds of greywacke, and which, in fact, greatly exceeds it in quantity, owes its origin to the same cause, and consists of the debris of those rocks reduced by the action of water to an impalpable powder; which, after its deposition in regular strata, had been subsequently consolidated by pressure, heat, or some other unknown cause. But the origin of the transition limestone is not so easily explained. If we compare with each other the quantity of limestone which exists in the different formations, we shall find that it increases pretty regularly, according as the formations become newer. There is least of all in the primary formations, more in the greywacke series, still more in the coal beds; still more in the new red sandstone series; more still in the oolite, and most of all in the chalk. In consequence of this regular increase, and on account of the prodigious number of the remains of shells and corals which exist in these limestones, it has been supposed that these limestone beds owe the greatest part of their contents to the exuviæ of testaceous animals and polypifers. This explanation, however, can apply worst of all to the transition limestone, because it contains much fewer fossils than those which exist in the subsequent beds.

The fossil remains in the greywacke group are pretty numerous. The fullest catalogue of them which I have seen is given by De la Beche.[*] He enumerates 378 species, besides the trilobites, and the remains of fish, which, in general, have not been attempted to be classified; of these, 14 species belong to plants, 77 to zoophyta, 34 to radiaria, 4 to annulata, 201 are shells, and 48 crustacea.

The plants, employing the generic names of Brongniart, are

Fucoides, 3 species,
Calamites, 3 species,
Sphenopteris dissecta,
Cyclopteris flabellata,
Pecopteris aspera,
Sigillaria tesselata, Voltzii,
Lepidodendron,
Stigmaria ficoides,
Asterophyllites pygmæa.

In all 13 species.

The zoophyta include the following genera:—

Manon,
Scyphia,
Tragos,
Gorgonia,
Stromatopera,
Madrepora,
Cellepora,
Retepora,
Flustra,
Ceriopora,
Agaracia,
Lithodendron,
Caryophyllia,
Anthophyllum,
Turbinolia,
Cyathophyllum,
Strombodes,
Astrea,
Columnaria,
Coscinopera,
Catenipora,
Syringopora,
Tubipora,
Calamopora,
Aulopora,
Favosites,
Mastrema,
Amplexus.

The most abundant genera of shells are terebratula, producta, pecten, cardium, patella, orthoceratites. The most abundant genera of the crustacea are Calymene, Asaphus, paradoxites, &c.

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[*] Geological Manual, p. 455.

From the various forms of the fossils imbedded in the greywacke, we may infer, that the animals of which they constituted the solid parts, occupied situations as different as those of the present day: some preferring deep waters, while others were fitted for shallow waters; and not a few must have swam freely in the open ocean. The orthoceratites are found of a large size, a yard or more in length. If, therefore, they constituted a part of a swimming molusca, like the nautilus, their size must have greatly exceeded that of any similar animal at present known to exist. Productæ are common to the greywacke, coal, and new red sandstone group. Spinifers have been observed as high up as the lias; but they are much more abundant in the greywacke. The terebratulæ are much more copiously distributed through the mineral kingdom; for they exist in all the formations, from the greywacke to the very newest; and many species exist alive in the ocean at the present day. I need not observe that many of the greywacke fossils, especially the zoophyta and conchifera, exist in the transition limestone. Mr. Hennah has given a valuable account of those found in the Plymouth limestone. He found in it various species of zoophyta, belonging to the following genera:—

Polyparia,
Stylina,
Caryophyllia,
Turbinolia,
Crinoidea.

Besides a considerable number of shells.

The family of trilobites must have abounded in particular places during the deposition of the greywacke. In some parts of Wales the *Asophus Debuchii* is so abundant that the laminæ of the slates are charged with them, so that millions may be met with within a limited space. The trilobite long known under the name of the *Dudley fossil*, because so common in the neighbourhood of that town, is the *Calymene Blumenbachii* of Brongniart. The trilobite family is now entirely extinct, and it seems to have disappeared before the productæ. No traces of them have been discovered in the *lias*, nor *new red sandstone*, nor even in the *coal beds*.

Among the corals are found several genera now existing. It deserves notice that wherever there is an accumulation of polypifers in the fossiliferous rocks, such as would justify the accumulation of coral banks or reefs, the genera Astrea and Caryophyllia are present; genera which, according to the more recent observations of naturalists, are, joined with a few others, the principal architects of coral reefs at the present day.*

The fossil vegetables found in the greywacke beds are similar, though far less abundant, to those found in the coal measures.

Mr. Weaver has shown that greywacke is an abundant formation in the south of Ireland. It is found also abundantly in France and in Germany; though it would be inconsistent with the extent of this work to enter into a detail of the localities. But the transition rocks in Sweden are so peculiar in their situation that a short account of them ought not to be omitted.

In West Gothland constituting an extensive district in Sweden to the west of the lake Wenner, the country is flat, with twelve little hills rising insulated through it. The highest of these, Kinnekulle, is only 920 feet above the level of the lake Wenner. The province consists of beds of gneiss, alternating with granite, and stratified often almost horizontally. So much so that the country east of Trollhätta for an extent of eight or ten miles has exactly the appearance that it would have had if it had been artificially covered with flagstones. The twelve little hills consist of transition rocks seemingly reposing on the gneiss.

Kinnekulle for instance consists of five beds lying over each other in nearly a horizontal position. The lowest of these is a sandstone, doubtless a variety of greywacke. Over this is a thin bed of alum slate, from which an alum manufactory in the neighbourhood in 1812 was supplied with ore. This slate contains nodules of stinkstein, and contains fossil remains. The third bed is a compact limestone abounding in petrifactions, the most common of which are orthaceratites and echini. Over the limestone lies a bed of slate clay. The uppermost and smallest bed, constituting the conical summit of the hill, is a fine grained greenstone. It has probably made its way from below, and has acted as the consolidating agent of the other beds.

There are two little hills which lie at the southern extremity of the lake Wenner, and about a mile east from Wennersborg. These are called Halleberg and Hanneberg. The latter is southernmost, and is separated from the former by a

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* See De la Beche's Manual, p. 470.

narrow valley. The height of these hills does not much exceed 200 feet, but they are so steep on every side that it is no easy matter to ascend them. The summit is nearly flat, so that they constitute a table-land about seven miles in length, and nearly as much in breadth. These hills are composed of the following beds, beginning with the lowest which reposes on the gneiss, of which the flat country is composed:—

1. A white sandstone composed of rounded quartz grains.
2. Iron shot clay mixed with pyrites.
3. Alum slate, black, and much mixed with pyrites.
4. Fibrous limestone containing petrifactions.
5. Alum slate with nodules of stinkstein as at Kinnekulle.
6. A very fine grained greenstone constituting three-fourths of the hill and crowning it.

In these hills the sandstone is the substitute for greywacke or old red sandstone, and the alum slate for the clay slate which usually alternates with that rock. The structure of the remaining nine little hills is similar. The reason why the sandstone constituting the base of these hills is so different in its appearance from greywacke seems to be this: From the constituents of greywacke it is evident that it is composed of the debris of the rocks on which it rests. And these rocks in this country and in Germany where greywacke abounds, are chiefly clay slate. But clay slate being altogether wanting in Scandinavia, the sandstone formed from the disintegration of gneiss (the fundamental rock in Scandinavia) could not possibly resemble greywacke, which consists chiefly of the debris of clay slate.

When greywacke lies immediately contiguous to primary rocks it sometimes seems to alternate with them. Thus Dr. M'Culloch describes greywacke and quartz rock as alternating in the gneiss beds which constitute the eastern portion of the Isle of Skye. Such appearances are doubtless owing to alterations produced in the relative situation of rocks by the agents to which these rocks were indebted for their consolidation.

CHAP. XIV.

STRATIFIED PRIMARY FORMATIONS.

THE greywacke group is the lowest series of beds that contain petrifactions. Those which lie below them (with a few trifling exceptions) are entirely destitute of the remains of animals or vegetables. On that account they have been usually denominated *primary* or *primitive* formations, indicating by the term that they are still in the same state as when they came from the hands of the Creator. But as a considerable number of these formations are in beds deposited regularly above each other, we have the same evidence that they were formed under the surface of the sea, that we have for the similar deposition of the secondary strata. The absence of fossil remains undoubtedly constitutes an important distinction between primary and secondary rocks, but it does not destroy the evidence derived from stratification. It may be that the unfossiliferous stratified rocks were deposited and solidified before the earth was inhabited by animals or vegetables. Or, as is more likely, they may have contained fossils at the time of their deposition, but all remains of them may have been obliterated by the agent by means of which they were consolidated.

The relative position of the stratified unfossiliferous formations is not quite uniform, but in general they occur in the following order, beginning with the uppermost rock:—

1. Clay slate.
2. Mica slate.
3. Gneiss.

Beds of hornblende slate, chlorite slate, quartz, and granular limestone, occasionally occur interspersed through the three preceding rocks, and these sometimes become so considerable as to constitute whole mountains.

1. *Clay Slate.*

Clay slate, the uppermost of the unfossiliferous stratified formations, is a rock well known in this country, being the substance commonly used for roofing houses.

The colour of clay slate is very various, grey, blue, red, yellow, but by far the commonest colour is blue of various shades.

Its texture, as the name implies, is *slaty*, and there is a great difference in the degree of thinness into which these slates can be split. The texture of the rock then is slaty, and sometimes the foliæ are straight, sometimes curved. It is only in the former case that the rock answers for making roofing slates. Very often the slates in the rock alternate with quartz, and constitute a rock slaty to the eye, but incapable of being split, because the clay slate and the quartz cohere very firmly. Indeed, in such cases the slaty portion of the rock is so thin, that if it could be separated from the quartz it would not be of any service as a roofing material.

The lustre of clay slate is more or less pearly, or at least silky.

Its specific gravity is about 2·7.

Its constituents, determined by analysis in my laboratory, are as follows:—

Silica,	49·232	59·11
Alumina,	14·560	19·41
Lime,	5·540	1·12
Protoxide of iron,	20·776	11·45
Magnesia,	2·248	4·51
Soda,	—	—
Moisture and volatile matter,	8·200	4·35
	100·556*	99·95†

Clay slate almost always contains cubic crystals of iron pyrites interspersed through it. These have a yellow colour, the metallic lustre and a considerable degree of hardness. When clay slate alternates with greywacke it contains abundance of petrifactions, and is known by the name of *transition slate.* Pyrites is much less common in transition clay slate than in what is called primary slate.

Beds of granular limestone, of chlorite slate, and of quartz, are common in clay slate mountains.

Clay slate usually occurs in mountainous districts, seldom in plains. The mountains composed of it are sometimes round backed, but they much more frequently rise into sharp cliffs, sometimes quite precipitous on one side to a very considerable depth. Ben Lomond, which is rather an elegant shaped mountain, is composed of clay slate, and from the

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* A green coloured slate from Ireland. Specific gravity 2·531.

† A bluish grey slate, with darker spots, from Germany. Specific gravity 2·761.

summit on the north-east side there is a perpendicular cliff that cannot be under 1000 feet high.

A considerable portion of the Grampian mountains in Scotland is composed of clay slate. For example, Glen Almond, a romantic ravine through these mountains, through which the road passes from Crieff to Kenmore, exhibits on both sides a majestic section of clay slate mountains. The same remark applies to Glen Queach, which may be considered as a continuation of Glen Almond. The mountain to the south of Kenmore is composed of clay slate. About four miles west of Kenmore, on the north bank of Loch Tay, mica slate rocks make their appearance, and Ben Lawers is composed of mica slate. But as we approach Killin, at the west end of Loch Tay, clay slate rocks again make their appearance. From this section of the Grampians to the extremity of the Mull of Kintyre, where the range may be said finally to terminate, a distance of about one hundred and twenty miles, and more than half the length of the Grampians, they consist almost entirely of clay slate. Clay slate beds may be seen also on the north side of the Grampians, in Aberdeenshire, and on its south side, in Kincardineshire. Hence it probably extends along the whole course of these mountains.

It has been already observed, that the clay slate in Wales contains abundance of fossils, particularly the *Asaphus Debuchii.* On that account, and because it alternates with greywacke, it is considered as *transition slate.*

The clay slate in the neighbourhood of Plymouth alternates with the limestone of that neighbourhood, which contains fossil remains. On that account it is considered also as transition slate. Now this clay slate is continued with little interval from Plymouth through the whole of Cornwall, and no good reason can be assigned for considering the age of the Cornish *killas* (the name in that county for *slate*) as different from that of Plymouth. This clay slate in general contains no fossils, yet they have been met with in the clay slate of Tintagel in Cornwall. Perhaps therefore there is no very valid reason for considering the age of the *primary* clay slate as very different from that of the transition. The shells from Tintagel are figured in the *Geological Transactions*, iv. 25. Those from Snowdon are figured in the *Annals of Philosophy* (second series), iv. pl. 17.

Clay slate rocks occur on the coast of France opposite to

Cornwall, in Britanny, mixed with granite, and also with greywacke; and Brongniart has given it as his opinion that these beds are fossiliferous; but I am not aware that this opinion has been verified by the discovery of any fossil remains in them.

2. *Mica Slate.*

When a mountain mass is granitic, it was the opinion of Werner that the central and highest portion of it consisted of granite; that this central portion was enveloped on all sides in beds of gneiss wrapt round it mantlewise, and that these beds thinned out and disappeared before we reached the upper part of the mountain. Still lower down, beds of mica slate were wrapt round the gneiss as it had been about the granite, and thinned out and disappeared before they reached the height of the summit of the gneiss beds. Still lower down clay slate beds wrapt round the mica slate beds, and thinned out in their turn before they reached the upper summit of the mica slate. Though this description is certainly very far from holding good in all cases, yet it must be admitted that an approximation to it may be frequently observed. Thus in the southern part of Aberdeenshire the central portion of the Grampians consists of granite. Whether this granite central mass be wrapt round by gneiss I do not know from personal inspection, but have been told that it is. Mica slate rocks may be seen both to the north and the south of the granite chain. The beds of these rocks are very much elevated, and they obviously lean against the granite central mass just as would have happened had the mica slate been originally deposited in horizontal beds, and the granite had forced its way upwards through these beds in a state of fusion.

Mica slate is a stratified rock composed of mica crystallized in plates, and quartz. The mica being usually in thin leaves is much more bulky than the quartz, which it frequently conceals so effectually that its presence can only be recognised by breaking the mineral into small fragments. Sometimes, indeed, the quantity of quartz is so small that in hand specimens it cannot be recognised. In such cases the grains of mica become very small; it begins to assume the silky lustre of clay slate, and gradually passes into that rock. So that in a congeries of beds consisting partly of mica slate and partly of clay slate, it is difficult to determine where the one rock *terminates and* the other begins.

Crystals of *garnet* (the variety called *precious garnet*) are almost always interspersed through mica slate, often in great numbers and of all sizes. They of course serve to characterize this rock. In clay slate they are very rare, and though they occur in gneiss yet they are uncommon in that formation.

In the Grampians the mica slate rocks begin about Ben Lawers, which is composed of it, and it seems to proceed with little interruption from that place to the south-eastern extremity of the range.

Mica slate contains in it a considerable number of subordinate beds. The most common of these is *chlorite slate*, which occurs near Inverary, in Argyleshire, where the rocks are composed of mica slate. The Duke of Argyle's house at Inverary is built of chlorite slate, from quarries in the neighbourhood.

Dolomite, or magnesian limestone, containing crystals of tremolite, epidote, tourmaline, lepidolite, amphibole, corundum and magnetic iron ore, is said to constitute a bed in mica slate in the Alps, but this is doubtful; for many of the localities in the Alps, which Brochant described as composed of transition or primary rocks, have been since ascertained to be of much later origin, and to belong to the new red sandstone, the oolite, or even the chalk series.

Beds of quartz rock, usually white, with thin plates of mica interspersed through it, are rather common in the mica slate, as well as in the clay slate formation; such beds are frequent in our Grampians. Hornblende and hornblende slate occur also in beds, both in clay slate and mica slate mountains; such beds are abundant in the Grampians. In the pass of Larikeely, between Loch Earn Head and Killin, an enormous bed of this kind may be seen cut through by the road. The country is composed of clay slate.

Emeralds occur usually in mica slate, though those at Muzo, in New Grenada, are found, according to Humboldt, in a bed of hornblende slate, which, however, is subordinate to mica slate; syenite also occurs in mica slate. This at least is the case in the Shetland islands, a portion of which is composed of mica slate. We have an interesting geological account of these islands by Dr. Hibbert, in the first and second volumes of the *Edinburgh Philosophical Journal*. They consist entirely of primary rocks, and are composed chiefly of granite and gneiss; but beds also of mica slate are met with, remarkable for the syenite which they contain. There appears a striking analogy between the structure of the Shetlands and Sweden; while the Orkneys, which consist chiefly of new red sandstone, are geologically connected with Caithness, which consists partly of new red sandstone and partly of lias.

In Europe mica slate constitutes a very extensive and wide spreading formation. In America it is less common; and in that country, according to Humboldt, it never contains beds of porphyry, nor does it pass into porphyry; while, according to Von Buch, this happens in the Splügen Alps, between the village of Splügen and the valley of Schams.

Humboldt informs us that mica slate is almost wanting in the Cordilleras of Mexico and South America. The primary rocks in these districts, he says, consist of alternate beds of granite and gneiss mixed with syenite.

3. *Gneiss.*

The unfossiliferous stratified rock, which commonly lies contiguous to granite, when the two formations occur together is *gneiss.* Now gneiss is a schistose rock, composed of *felspar, quartz* and *mica.* These constituents are deposited in alternate layers. Hence the slaty structure so conspicuous in this rock, from the difference in the colour of the felspar and mica, which generally enter most abundantly into the composition of gneiss. In the gneiss rocks most approaching to the granite in situation, or what is usually called the *oldest gneiss,* the quantity of mica is comparatively small, the rock being chiefly composed of felspar; but it increases very much as we approach the mica slate rocks, and becomes at last so abundant, that we can scarcely distinguish it from this last rock, into which it gradually passes.

The word gneiss *(gneuss)* is German, and was given by the Freyberg miners to the rock in which most of the mineral veins of Saxony occur. When this rock was constituted by Werner into a particular formation, he naturally adopted the name by which it had been already distinguished. In this way it made its way into geology, and has long been current in all European languages.

It is but rare to find gneiss for any great space quite pure; it almost always alternates with other rocks, and the most common of these is *granite.* The greatest part of the vast peninsula of Scandinavia consists of gneiss, in this way alternating with granite. In the Scandinavian gneiss, mica is very little abundant; it consists chiefly of felspar and quartz, though to this there are many exceptions. When it loses the slaty fracture, and becomes granular, then it cannot be distinguished from granite, into which, of course, it passes. Adam's peak, a celebrated mountain in Ceylon, between 6000 and 7000 feet above the level of the sea, is composed of gneiss, as we are informed by Dr. Davy.

Gneiss rocks were thought to be richer in gold and silver ores than any other formation. The gneiss of Germany, of France, of Greece and of Asia Minor yields silver, for the silver mines worked by the ancients in the two last countries, and so much celebrated for their riches, were situated in gneiss. It is now known, however, that the greatest silver mines are situated in newer rocks. This is the case with the Mexican mines, which supply more silver than all the rest of the globe put together.

The only part of Great Britain where gneiss rocks occur in any quantity, is the granite tract which runs along the Dee, in Aberdeenshire. On both sides of that tract gneiss rocks recline against and cover the sides of the granite. There is also a tract of gneiss which begins at the Coran ferry, nine miles south of Fort William, in Inverness-shire. The range of mountains constituting the north side of Glen Tarbert, which runs in a westerly direction from the Coran ferry to Strontian, in Argyleshire, are gneiss. The range would appear to terminate at Strontian, about twelve miles from the ferry; for half the mountain in which the lead mine of Strontian is situated is gneiss, and the other half granite. The lead ore lies in a vein which separates the gneiss and granite from each other.

Gneiss frequently alternates with mica slate. When this is the case, the gneiss contains much mica, and gradually passes into mica slate. The other beds occurring in gneiss are quartz, often containing garnets; felspar, generally in a soft state, and destitute of potash, or nearly so, constituting in fact kaoline or porcelain clay; porphyry, generally reddish, and having a base of hornstone; granular limestone, though this kind of bed is rare; serpentine, which is said by Cordier to constitute an immense bed in the central gneiss of France; hornblende slate; and greenstone.

Humboldt assures us that he has never seen gneiss at a greater height above the sea than 8900 feet; but this observation can apply only to America, for the central culminating point of the Alps consists of gneiss alternating with granite, and rises to the height of 12,201 feet. This point is called the Grosse Glockner, and is situated a little to the west of Carinthia and Salzburg.

A considerable number of the western islands of Scotland consist of gneiss. This is the case with Long Island, Teree and Coll. There is also a considerable deposit of gneiss on the main land of Scotland, beginning at the south-east point of Morven, opposite to the Isle of Mull, and extending at least as far north as Loch Carron, situated to the north of the Isle of Skye. This tract has been very well described by Dr. Macculloch, in his *Geological Account of the Western Islands of Scotland.* It is evident from the sections which Dr. Macculloch has given, that the gneiss in the north of Scotland lies over quartz rock and *primary sandstone,* if such a name can be given to the granular quartz rocks, which Macculloch considers as sandstone.

Cape Wrath, a most conspicuous promontory at the north-west extremity of Sutherland, contains abundance of gneiss and granite veins. Gneiss also occurs to the north of Loch Broom, in Ross-shire, evidently lying over the quartz rock and primary sandstone of Dr. Macculloch.

Garnets, octahedral iron ore, fluor spar, zircon, tourmaline, epidote, molybdena and iron pyrites occur pretty frequently interspersed through gneiss rocks.

There is a circumstance of almost constant occurrence in gneiss rocks, which deserves to be pointed out. The beds of which the rock is composed are frequently found incurvated in a most extraordinary manner. Some idea may be formed of the nature of these incurvations by supposing the gneiss beds to have been in a plastic state, either from the action of heat or of some other unknown cause, and, while in this state, to have been subjected to pressure at the two extremities, or in some other parts, according to the nature of the curvatures. But even this hypothesis (though the best that has been thought of) will scarcely enable us to explain all the contortions which not merely the beds of gneiss, but likewise of mica slate and clay slate and even greywacke slate, exhibit. There is a bed of clay slate near the ferry to Kerrera, a few miles south of Oban, in Argyleshire. This bed has been partly wasted away by the sea and its structure exposed to view. It contains a central cylindrical nucleus of unknown length (but certainly considerable), round which six beds of clay slate are wrapt, the one within the other, so as to form six concentric cylinders. Now, however plastic the clay slate may have been, there is no kind of pressure which will account for this structure; the central cylinder would have required to have been rolled six times in succession (allowing an interval for solidification between each) in the plastic clay slate.

When gneiss, mica slate or clay slate lie incumbent on, or in contact with granite, we frequently observe veins of granite penetrating through these rocks, and sometimes passing a considerable way. These veins are not more than a few inches wide; they were observed by Dr. Hutton in Glen Tilt, and have been recognised since as so exceedingly common, that hardly any extensive junction of granite with other rocks is to be met with in which granite veins may not be traced. One of the most remarkable of these localities is St. Michael's Mount, Cornwall. This mount consists of a cone of granite, wrapt round by clay slate, of which the neighbouring country consists. Veins of granite not less than 124 feet in length, and becoming gradually less than an inch in thickness, may be perceived running into the clay slate, especially on the east side of the Mount.

CHAP. XV.

GRANITE.

Granite, from the beauty of the stone and from the majestic elegance which in general characterizes the mountains composed of it, has always occupied a prominent place in geological descriptions of the earth. It was long a controversial subject whether or not granite rocks be stratified, but the point has at last been decided in the negative; what has been called *stratified granite* is, in reality, *gneiss*. Both rocks, indeed, are composed of the same constituents, but the former is granular while the latter is schistose.

The term *granite* is supposed to be derived from the Latin word *granum*, and to have been given to this rock from its granular structure. Werner used to affirm that it was first used by Tournefort in his *Voyage to the Levant;* this book did not make its appearance till after Tournefort's death, an event which took place during the year 1708. Tournefort uses the word in his account of Mount Cynthus, in the island of Delos, which he says is nothing else than a block of *granite* of the ordinary sort, common in Europe. He says that there is scarcely an island in the Archipelago that does not abound in granite, and that the Romans used to fetch great quantities of it from the island of Elba, on the coast of Tuscany, and also from the quarries of Upper Egypt. It is obvious from all this that the word *granite* was in common use in Tournefort's time, at least in France, and that it was by no means first used by him. I have looked into several older writers without finding any trace of the term. To Pliny it was unknown. It does not occur in Agricola, nor is any trace of it to be found in the early volumes of the *Philosophical Transactions*, or the *Memoirs of the French Academy*. In the first volume of *Birch's History of the Royal Society*, p. 80, the following passage occurs, copied by him from the registers of the Society for 1662.

"Mr. Winthrop produced malleable mineral lead and a piece of a rock of *granite*."

Upon turning up this passage in the original register of the Royal Society, still preserved in their apartments, I found that the word was not written *granite* but *granate*. Now, this was the usual expression at the time for what we now call *garnet*, but in the English translation of Tournefort's voyage, published in 1742, the word is also spelt *granate*. I think it probable that the term *granate*, in the passage above quoted, referred to the rock which we at present distinguish by the name of *granite;* had it referred to a garnet, it is not likely that the term *rock* would have been applied to it. If this be admitted it is the oldest example that I have met with of the application of the term in its modern acceptation.

Granite is a granular rock composed of three ingredients; namely, *quartz*, *felspar* and *mica*. These three constituents are in crystals more or less regular, and are mixed together and cohere without any visible cement and without any thing like regularity in the proportion of the constituents. The felspar is usually the most abundant ingredient, and as it occurs of various colours and of very various sizes, it is to it, chiefly, that the great diversity in the appearance of granite is owing. Instead of felspar, albite is often substituted, and in many varieties of granite, both felspar and albite occur together. The colour of the mica in granite is most commonly dark brown, almost black; but it occurs also colourless, in beautiful silky scales. Sometimes hornblende assumes the place of the mica; the rock is then called syenite from Syena, in Egypt, where this kind of mineral was quarried by the ancients and employed for ornamental purposes. It is not uncommon to meet with syenite containing both hornblende and mica, and therefore composed of four instead of three ingredients.

It was the opinion of Werner that syenite was distinguished from granite by its position, being considerably higher in the series of rocky formations; but this opinion does not seem likely to be verified by more extended observations. In this country syenite occurs in Galloway in three places nearly in a line with each other, and with the granite tract in the island of Arran. The first of these is the Criffle, a very conspicuous mountain to the south of Dumfries, and at the eastern extremity of the County of Kirkcudbright. The second locality is called the *Dee tract;* it begins at Loch Ken and extends about nine miles west, with a breadth of about four miles. The third tract is at Loch Doon, on the borders of Ayrshire; it is of the same extent as the Dee tract and similarly situated. These three syenitic deposits are partially covered by clay slate rocks, which lie over the syenite in an inclined position. I am not sure that any fossil remains have been found in this slate, yet it has been generally referred to the transition series.

There is a syenitic hill, called Mount Sorrel, which occurs in the tract in Leicestershire called Charnwood forest. This tract consists of clay slate rocks, rising through a new red sandstone country. These slates resemble exactly the Welsh slates, and, like them, are employed for roofing. It is probably transition slate, and the beds of it recline against the sides of the syenitic hill of Mount Sorrel. This remarkable tract constitutes a kind of triangle, the three sides of which are, respectively, nine miles, nine miles and six miles.

But the granite which constitutes the base of Ben Nevis seems also to be a syenite. Now, there can be no doubt that gneiss, mica slate and clay slate follow in regular order of position over this rock.

The constituents of granite are sometimes of a very small size, so that we can just distinguish them from each other by the naked eye. The rock is then called *small-grained granite.* This is pretty much the case with the granite found in the neighbourhood of Aberdeen, and employed in that part of the country as a building stone. The principal quarries from which the stone is taken, are the *Dancing cairn*, about three miles north-west from Aberdeen, near the Don and Inverury canal, and Rubislaw, about a mile beyond the town on the great south road. The appearance of the blocks in situ, resembles very closely that of a basalt or greenstone quarry. In this granite, when the felspar is red, the grains are usually large, when white, small. The red grains are *felspar*, but I have not been able to procure the white grains in a state fit for analysis. They are probably *albite*. The Aberdeen granite constitutes a very durable and beautiful building stone; but in consequence of its extreme hardness, the masons were long unable to carve out of it the usual architectural ornaments. Hence, in Aberdeen, the doors and the windows were long destitute of every thing ornamental, being mere holes in the wall. But they have gradually acquired the requisite skill, and in the new houses, granite pillars, pilasters, and columns, are beginning to make their appearance.

When large crystals of felspar are interspersed through small-grained or medium-sized granite, the stone is said to be porphyritic. This is the case with that portion of Cornish granite which occurs in the neighbourhood of Redruth. The foot pavement of Westminster bridge consists of this granite. The slabs are long and have been worn quite smooth by the feet of passengers. When this pavement has been washed clean by a shower of rain, these large crystals of felspar of a flesh colour, and from 3 to 6 inches long, may be very distinctly seen in the granite.

One of the most beautiful varieties of granite that I have seen, occurs at the south-west end of the island of Mull, large blocks of which may be seen on the contiguous island of Icolmkill. The felspar is flesh-red, the quartz white, and the mica not abundant. Nearly the same kind of granite occurs at Balechulish, on the south side of Loch Linné, at the northern extremity of Argyleshire. The granite of Strontian and Ben Nevis approaches more in appearance to the Aberdeen granite, except that the grains are larger.

The great granite tract in Scotland is in the neighbourhood of Aberdeen. The primary country begins in Kincardineshire soon after passing the river at Stonehaven. Gneiss first makes its appearance; but before we come to the Dee the gneiss passes into granite. The granite tract extends from the Dee to the Don, where gneiss occurs intermixed with mica slate, and somewhat farther north, the mica slate passes into clay slate. The Aberdeen granite stretches along the Dee at least sixty-five miles west, as far as Brae Mar, at which place it is occasionally mixed with gneiss and beds of an impure limestone. I do not know, from personal inspection, that the granite continues beyond Castleton; but it probably does, as the lower part of Ben Nevis, which is in a line with the Aberdeen granite, consists of granite. Here it extends over a space at least twelve miles in breadth, and with alternations of gneiss, continues to the west coast of Scotland.

There is another granite tract, which begins at Portsoy on the Murray Frith, and extends as far as Banff. Probably, indeed, it proceeds without interruption to Kinnaird's Head, which constitutes the north-east extremity of Aberdeenshire; but I did not myself trace it farther than Banff.

Another extensive granite tract in Scotland, is in the county of Sutherland. Caithness, the farthest north county in Scotland, is exceedingly flat, and composed chiefly of sandstone and slate clay. It is separated from Sutherland by a high mountainous tract, distinguished by the name of the *Ord of Caithness*. It is about ten miles in breadth, and its greatest height above the level of the sea is not under 1400 feet. The basis of the Ord seems to be granite, but sandstone beds (doubtless connected with the greywacke series) may be seen covering this granite in many places. The east coast of Sutherland, from the Ord to the Dornoch frith, is alluvial, and consists of soil mixed with an immense number of granitic boulders, many of them of great size. Beyond this alluvial portion, sandstone beds occur, recognisable by their fossils for a part of the lias formation. About three miles inland from the coast, granite rocks commence, at first constituting only the under part of the mountains, while their summits consist of sandstone. But as we advance westwards the whole hills become granitic. These granite mountains are in general low, round backed, and barren. How far west the granite of Sutherland extends has not been determined. The westside of the county consists of quartz rocks and a red sandstone, which seems connected with the greywacke series.

A considerable tract of granite exists in the island of Arran, the centre of which is Goatfield. The granite is skirted all round with mica and clay slate. At Loch Ranza, on the north-west side of the island, occurs the celebrated junction of the granite and clay slate, which was so often visited during the controversy between the Neptunists and Plutonists. It was brought into notice by Dr. Hutton, who observed that the clay slate in the neighbourhood of the granite was harder than at a distance from it. This he considered as a proof of the indurating effect of the granite while in a state of fusion upon the clay slate. The granite of Galloway has been noticed already.

Granite occurs in the mountainous tract in the south of Roxburghshire, which separates England from Scotland. I have seen specimens of the granite, but never having visited the spot, can give no account of its extent and situation.

Granite constitutes a very conspicuous rock in Cornwall and Devonshire, and makes its way to the surface in certain isolated places. The Land's End consists of granite cliffs about 230 feet in height. The rock extends, without interruption, to Penzance, a distance of about ten miles. It appears in two other places, in a line between the Land's End and Dartmoor. This table land, which constitutes the mountainous part of Devonshire, consists of it. The highest of the Dartmoor hills is Rippontor, which rises to the height of 1,549 feet above the level of the sea. Brown Willie, the next in height, is 1,368 feet high.

I shall not attempt to describe the granite formation as it appears in different parts of Europe, Asia, and America. Such a description would occupy a great deal of room without adding much to our information. I may merely mention the Simplon, the lower half of Table Mountain at the Cape of Good Hope, and the neighbourhood of Canton in China, as well known examples of its occurrence.

It was long believed that granite constitutes the lowest of all the formations hitherto met with on the globe. Hence it was considered as the oldest and the fundamental formation. But after a great deal of discussion and observation, it is now generally admitted that this point cannot be maintained. It is true that granite occasionally appears under every other rock; but when we examine the rocks in contact with it, we generally find granite veins making their way through them, and not unfrequently proceeding a very considerable way. We find beds of granite often interspersed through gneiss, mica slate, and even clay slate. And in the neighbourhood of *Christiania*, in Norway, Von Buch observed granite lying over fossiliferous limestone. It is therefore incontestible that it must have been deposited after this limestone.

The opinion now generally adopted respecting granite, is the one originally proposed by Dr. Hutton; namely, that granite has been forced up from below in a state of fusion, and that it has cooled more or less slowly under a great pressure. Hence the reason of its crystalline texture, of the great difference in the size of its grains, and of the beautiful crystals occasionally met with in cavities of the rock. Hence the reason of the granite veins. The forcing up of a fluid mass of matter would naturally alter the position of, and produce rents in, the strata through which it was forced. The liquid matter would of course enter these rents and fill them. When the quantity of fluid granite was large, it might force itself between two contiguous beds, or it might make its way to the surface and be deposited upon the uppermost formation which existed. Hence we may expect occasionally to find granite lying over every formation which existed at the time of its protrusion.

Granite differs very much in its appearance from modern lavas, or even from the lavas of extinct volcanoes of the remotest period. The reason of this cannot be assigned. The stony matter, by the fusion of which it was formed, may have been different. In lavas, we never, or at least very seldom, find quartz crystals. The silica is usually in combination with other constituents of the rock.

CHAP. XVI.

PORPHYRY AND TRAP ROCKS.

Besides the formations which have been already described, there is another set of rocks scattered in great profusion over the surface of the earth. These, so far as is known at present, never contain any fossil remains, either of vegetable or animal bodies. They often constitute the highest portion of the country where they occur, though frequently also they are interposed between the layers of stratified rocks. These rocks have a striking analogy to those of volcanoes; and, after a violent controversy, which lasted for upwards of half a century, it has *been finally decided* by geologists that they are of igneous origin. These rocks have been c classes of *porphyry* and *trap*. Let us tal succession.

I. PORPHYRY.

The term *porphyry* literally signifies r ally applied to certain stones capable of distinguished by a red colour. Thus Pli *porphyrites* as common in Egypt. B present apply the term to all rocks havi through which are scattered crystals, or g mineral. The nature of the base give porphyry. This basis is either

Felspar,	Ho sto
Pitchstone,	Cl st

The crystals are usually felspar or qua or hornblende.

Felspar porphyry and claystone porphy among the transition rocks. Whether th primary rocks is not so clear; I am not authenticated example of it. There is porphyry in the valley of Magdalena, be Truxillo, in Peru, which reposes upon gra by a secondary quartz rock.

Transition porphyry constitutes one of rocks in South America. There can be li phyry, like trap, has made its way from bel and has, in that way, insinuated itself thro it occurs. It would therefore be an object est to determine the lowest rock over which i nes, because the knowledge of this would give us some idea respecting the era of its eruption.

It constitutes the uppermost conical summit of Ben Nevis, and seems to have been forced up in a state of fusion through the granite of which the inferior portion of that mountain is composed. Hence it may be inferred that it is of posterior formation to granite, and many other circumstances lead to the same conclusion. The Ben Nevis porphyry spreads itself a good way to the south and caps the summit of many mountains in the neighbourhood. Whether it constitutes the summit of Ben Cruachan I do not know, having been disappointed by the weather in my attempt to ascend that mountain.

Claystone porphyry is very common in our mountain ranges in Scotland, which are connected with the secondary and transition formations. It constitutes the summit of all the eastern part of the Pentlands, on the south and south-east of Edinburgh; it is also pretty common in the Ochils. No transition beds have been observed in this chain of hills, but they rise up from under the coal beds, and therefore have been elevated after the deposition of the great coal basin in the middle portion of Scotland.

The mineral called *pitchstone*, so far as I know, has been hitherto met with only in veins. There are two remarkable localities of it in Scotland, namely, the Islands of Egg and Arran.

Egg is a small island situated a little to the south of the Isle of Skye. It is composed chiefly of amygdaloid, according to Dr. Macculloch; but towards the south end of the island, there is a high ridge or dyke, which traverses it from west to east. This ridge is known by the name of the *Skune of Egg*. This dyke, or wall, is about 300 feet high on the east side, and so precipitous as to be inaccessible. It is composed of pitchstone, or rather pitchstone porphyry, for it contains occasional crystals.

At Brodic Bay, in the Island of Arran, which is the usual landing place, the beds exposed on the surface are composed of red sandstone, similar to what constitutes the neighbouring Cumbraes, and which appears on the opposite west coast of Ayrshire. Through this red sandstone run some pretty thick veins or dykes, of leek-green pitchstone. The uppermost bed in the south of Arran, is a clay stone porphyry. It is probable that the pitchstone dykes, notwithstanding the great difference in their appearance, are nearly of the same era as the claystone porphyry.

I am not aware of the existence of hornstone porphyry in any part of Great Britain; it is obviously rare.

II. TRAP ROCKS.

The word *trap* was first applied to rocks by Rinman, in a paper *On Stones containing Iron*, inserted in the *Memoirs of the Stockholm Academy* for 1754. He imposed the name, he says, because the rocks alluded to broke in rectangular fragments like *sandstone*.* Werner afterwards limited the

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* The Swedish word *trappa*, signifies a stair. The name was doubtless

signification to certain rocks distinguished by the hornblende which they contain. At present the term is applied to all the rocks which penetrate through others in the form of dykes, and to those which cover the summits of the other rocks as lava does. The most important of these rocks are the following:

1. Greenstone,
2. Serpentine,
3. Diallage rock,
4. Amygdaloid,
5. Basalt,
6. Porphyry slate,
7. Wacke,
8. Trap tuff.*

1. *Greenstone*, called by the French *diabase*, is a mixture of felspar and hornblende, or sometimes of felspar and augite. It is granular, and differs much in the size of its constituents. Sometimes they are so small as hardly to be distinguished by the eye, and sometimes in large, and almost regular crystals. The hornblende predominates, and usually gives the stone a greenish shade. Hence the reason of the name *greenstone* imposed on it by Werner.†

This rock is exceedingly common in the coal district of Scotland. Many hills in the neighbourhood of Edinburgh, as the Castle hill, Salisbury Crags, Arthur's Seat, Inchkeith, &c. contain masses of it not stratified, but frequently split into columns, sometimes of great size. The most remarkable of these are the columns in Fingal's Cave, in the Island of Staffa, and the Giant's Causeway, in the north of Ireland. Dykes of greenstone are abundant on the west coast of Ayrshire, and also in Lorn, near Oban. In England it is not so abundant, yet it occurs in the transition formation in Cumberland as well as in the range of Scottish mountains, from St. Abb's Head to Loch Ryan. In the neighbourhood of Birmingham a number of little hills of greenstone and basalt occur, which are employed in that country in paving the roads. The streets of Birmingham itself are paved with stones from these quarries. Indeed greenstone and basalt constitute the very best materials for mending roads, and last so much longer than the flints employed for that purpose in the neighbour-

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imposed from the *stair-like* appearance which some of the most remarkable of the Swedish trap rocks exhibit.

* Of these, *serpentine* and *diallage* rocks are not usually reckoned trap rocks. But I place them here from their analogy with the others, and because I conceive that they owe their origin to the same cause as the traps, namely, *heat*.

† Beudant has shown that greenstone is usually a mixture of felspar, albite, amphibole, and sometimes of pyroxene, and even of other minerals. See his analyses, Ann. des Mines (second series), v. 300.

hood of London, that Mr. Macadam is of opinion, they are worth three times the price of these latter materials.

2. *Serpentine*, called *ophites* and *variolites* by the French, is a well characterized mineral, which has been described in a preceding part of this work. Serpentine rocks are all massive without the least indication of stratification. We have two localities of serpentine rock in Great Britain; namely, the peninsula of the Lizard, in Cornwall, where it is associated with greenstone, and occurs in clay slate rocks; and Portsoy, in Banffshire, where it occurs in granite. It is a common rock in various parts of Italy, particularly near Genoa and Turin. In France it is rare, but it is found at Abeille, near Limoges, and in the Pyrenees. In Germany it occurs at Zöblitz. In the United States of America, it is found near New Haven in Connecticut; but the most celebrated locality is Hoboken in New Jersey, not far from New-York.

3. *Diallage rock*, is a mixture of diallage and Saussurite. It is called *gabbro* by the Italians. It is a beautiful rock, usually associated with serpentine. Accordingly, it occurs in the Lizard in the serpentine of that district, and in the serpentine rocks in the north of Italy. From the circumstance that diallage usually occurs in serpentine, it has been considered by some as crystallized serpentine; but the constitution of the two minerals is incompatible with that supposition.

4. *Amygdaloid*, is a name given to a rock consisting of a compact basis, and containing numerous almond-shaped cavities, usually filled up with minerals, differing in their nature from the rock in which they occur, and these minerals usually form groups of crystals more or less perfect; and, what is curious, water is a very common constituent of these crystals. The basis is sometimes claystone, sometimes wacke, and sometimes greenstone. The minerals contained in the cavities are calcareous spar, chalcedony, agate, quartz, green earth, and the whole tribe of zeolites, amounting to not fewer than twenty-four species. The zeolites always contain water as a constituent, but the calcareous spar and quartz are anhydrous.

Amygdaloid is a very common rock in Scotland, in that part of the country where trap abounds. The hill of Kinnoul at Perth, is an amygdaloidal rock. It abounds in the Ochils, and is very common in the Campsie and Kilpatrick hills, and also in the high country to the south of Greenock.

5. *Basalt*, is a black compact rock of considerable hardness and weight. It almost always contains imbedded grains of

olivine and augite, and frequently other crystals. It is tough, and answers admirably for mending the roads. Its constituents, as determined by the analysis of Dr. Kennedy,* are

Silica,	48
Alumina,	16
Lime,	9
Soda,	4
Protoxide of iron,	16
Muriatic acid,	1
Water,	5
	99

Basalt and greenstone are usually associated together, and appear in fact to be little else than two different states of the same mineral. They have both a strong tendency to assume a columnar form. Many of the columns at the Giant's Causeway and Staffa, approach nearer basalt than greenstone. These columns are usually hexagonal or pentagonal, and the regularity of the jointing is often surprising. Columns of basalt are not uncommon in Fife, and a tendency to the same form may be seen in the Castle Hill of Stirling. The southern declivity of Arthur's Seat, near Edinburgh, exhibits the columnar form in considerable perfection.

6. *Porphyry slate*, has for its basis the mineral named *clinkstone*,† (*eurite* of the French) from the metallic sound which it emits when struck with a hammer. It has usually a greenish-grey colour, though sometimes it is brownish-red. The cross fracture is dull and splintery, principal fracture glimmering and slaty. This characterizes clinkstone. This rock contains in it crystals of glassy felspar, which gives it a porphyritic structure.

Porphyry slate is common in East Lothian, which is the only part of Great Britain where I am aware of its existence. The county in general is composed of new red sandstone, through which a number of conical or round backed hills make their way, and these hills are either composed of porphyry slate, or at least contain it as one of their constituents.

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* Edin. Phil. Trans. v. 89.

† M. C. G. Gmelin has shown that clinkstone is a mixture of felspar and a zeolite, usually mezotype. Muriatic acid decomposes the zeolite and leaves the felspar, which may be afterwards analyzed separately. Four of these analyses may be seen in the Annales des Mines (second series), v. 298.

The most conspicuous of these hills is North Berwick Law, constituting so remarkable an object from Edinburgh. This hill rises from the sea-shore about twenty-two miles east from Edinburgh, it is conical, and probably 800 or 900 feet high. It seems composed entirely of clinkstone and porphyry slate, which sometimes assumes the aspect of claystone porphyry and sometimes of compact felspar.

Trapren Law is a low round-backed hill situated about eight miles south of North Berwick Law. It is about 360 feet high, very steep on the south and west sides, but much less so and covered with grass on the north and east sides. It is composed of clinkstone, generally porphyritic. It has a slaty structure, and the position of the slabs is nearly perpendicular. The slates are thick, and from their splitting in blocks the south side of the hill has a columnar appearance. The old castle of Dunbar is situated upon a rock surrounded by the sea, and about six miles east from Trapren Law. It is a hard rock, having the aspect and the metallic sound of clinkstone, but is so much injured on the surface by the continued action of the sea, that it is difficult to make out the species of rock of which it was originally composed. The old pier of Dunbar is built upon a red coloured stone split into five-sided columns, and doubtless also a variety of porphyry slate. At North Berwick the porphyry slate is obviously associated with amygdaloid, greenstone, and claystone porphyry. The Girleton hills, situated between North Berwick and Haddington, are said to be composed also of porphyry slate. But I have not had an opportunity of examining them.

The constituents of clinkstone, as determined by Klaproth,[*] are

Silica, . . .	57·25
Alumina, . . .	23·50
Lime, . . .	2·75
Soda, . . .	8·10
Protoxide of iron, .	3·25
Protoxide of manganese,	0·25
Water, . . .	3·00
	98·10

7. *Wacke* is a soft mineral intermediate between basalt and clay. It has a greenish grey colour, and becomes harder

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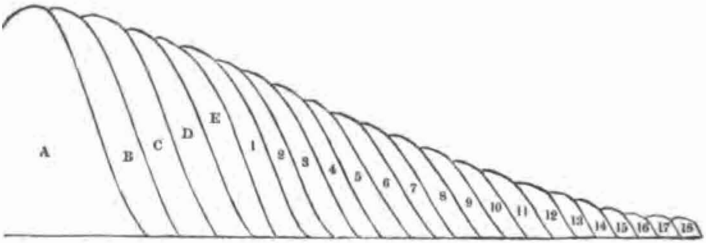
[*] Beiträge, iii. 229.

when long exposed to the air. It has no lustre, but before the blowpipe melts like basalt, showing that in its composition it bears a considerable resemblance to that mineral. It often contains crystals of hornblende and mica. When this is the case it is harder than usual, and approaches somewhat to basalt in its appearance. One of the localities where wacke could be best seen was the Calton Hill at Edinburgh, after it had been cut through for the new London road, and before the rock was concealed as it now is by the buildings of the High School.

The Calton consists of alternate beds of claystone porphyry, and of trap tuff. It is steep and almost precipitous on the south, north-west, and north sides, but the east side extends a considerable way, and slopes gradually down into the plain. This sloping portion is composed of alternate beds of wacke and shale. The following ideal section of the hill will convey some idea of its structure :—



A. Claystone porphyry,
B. Trap tuff,
C. Claystone porphyry,
D. Trap tuff,
E. Claystone porphyry,
1. Shale,
2. Wacke,
3. Sandstone,
4. Shale,
5. Wacke,
6. Shale,
7. Wacke,
8. Shale,
9. Wacke,
10. Shale,
11. Wacke,
12. Shale,
13. Wacke,
14. Shale,
15. Wacke,
16. Shale,
17. Wacke,
18. Shale.

From this alternation of wacke and shale I think it not unlikely that wacke will be ultimately found one of the constituents of the coal metals rather than be associated with the trap rocks, to which however it is obviously also related.

8. *Trap tuff* as a rock may be considered as a kind of coarse sandstone made of portions of the other trap rocks, basalt, amygdaloid, sandstone, cemented together by a loose spongy clayey basis often much iron-shot. The masses vary much in size, and are often enormous, so that the rock cannot be well studied except in situ.

Beds of trap tuff occur in the Calton Hill at Edinburgh. The highest part of Arthur's Seat, and a considerable portion of the south shoulder of that hill are composed of it, also one of the farthest west of the Ochil hills is likewise partly composed of it, and a fine section of trap tuff is laid open by the road which passes on the west side of Airthrey to the Sheriff Moor.

These trap rocks seldom appear in the formations which lie over the coal measures. There are indeed a few examples of these rocks in the new red sandstone. Along a line of from five miles north to five miles south of Exeter, many points occur in which masses of amygdaloidal trap are found interposed between the beds of the new red sandstone. They are near the lowest part of the sandstone, but decidedly in it, and in a conformable position, and not in the transition beds which lie immediately below. This rock is granular, has a purplish brown colour, and contains imbedded in it great quantities of fragments of calcareous spar and mica slate, sometimes tinged by copper and sometimes by manganese. The amygdaloidal cells are filled with oxide of manganese, calcareous spar, and coarse jasper. The compact portions of this rock fuse before the blowpipe, sometimes into a black glass, and sometimes into a white enamel.

There occurs also a basaltic dyke near Cleveland, extending from the coal across the oolitic chains. The great greenstone dyke in Strathearn, which crosses the road between Muthil and Crieff passes through new red sandstone.

The great body of trap occurs in dykes which intersect the coal measures, and have obviously produced great alterations in the position of the beds. It must therefore have been of posterior origin, and the example of the Cleveland and Strathearn dykes proves that sometimes at least the difference of age is very considerable. In the western islands of Scotland, Dr. Macculloch has shown that the trap occupies a position superior to the lias; and on the north-east coast of Ireland we find it lying over chalk. From all this it is evident that the irruption of trap rocks must have taken place during a vast series of ages. Yet, the greatest quantity seems to have made its appearance after the deposition of the coal measures, and before that of the new red sandstone.

No organic remains, either mineral or vegetable, have yet been observed in the trap rocks of Great Britain. But Dr. Richardson discovered ammonites in a black rock about four miles from the Giant's Causeway, which he considered as basalt, but which in fact has more the appearance of an indurated clay. Mr. Weaver informs us that he has discovered shells of the terebratula in the greenstone associated with the mountain limestone of the centre of Ireland. It would appear from these discoveries, that though petrifactions are very rare in trap rocks, yet they are not absolutely wanting.

The trap rocks connected with the coal measures occur in three distinct modes of position. Two of these appear to indicate an origin distinct from that of the strata with which they are associated, while the third countenances the opposite inference of contemporaneous formation.

1. They occur as overlying masses resting unconformably on the subjacent strata. This is a common occurrence in the counties of Edinburgh, Stirling, and Fife, and indeed in the whole coal country of Scotland.

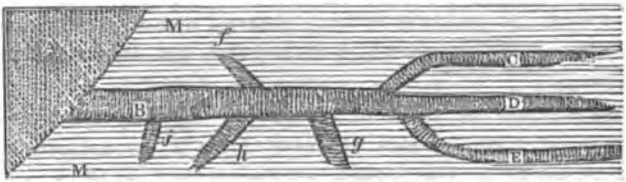
2. As dykes irregularly intersecting and traversing the strata. Numerous examples of this occur in all our coal fields. And in the same way are they found traversing formations older than the coal. Thus, on the south of Oban they traverse the transition conglomerate of that country, and probably also the clay slate, though that is not so satisfactorily established. A little to the south of Aberdeen there is a greenstone dyke which cuts through the granite, and may be traced a considerable way west. A similar greenstone dyke traverses the granite at Newry, in Ireland.

3. As beds conformably interstratified, and regularly alternating with the other strata. The great whynsill of Northumberland and the toadstone strata of Derbyshire illustrate this case. The whynsill is 120 feet thick, and is said to consist of a basaltic greenstone. It is the 192d bed from the surface, and is 840 yards below the level of the height of the Northumberland beds.

Between the trap rocks occurring in these three so different positions, no mineralogical or external features of distinction have been shown to exist. The same varieties seem to occur indiscriminately in each.

When trap exists in beds alternating with, and conformable to, the beds in which it is placed, it has been asserted that it is subject to much greater alterations in thickness than is the case with the other beds. It has also been said that the metalliferous veins traversing the other strata are themselves cut off by the trap beds. Hence it has been inferred that they are of subsequent formation to the beds in which they occur. But the metalliferous veins themselves are subject to such alterations in width when they pass through different strata, that it would not be safe to rely upon these disappearances as a proof of posterior formation. It may be, as it has been affirmed, that in these cases the metalliferous veins are not completely annihilated, but merely reduced to very minute strings.

But Dr. Macculloch has shown in his account of the coast of Trotternich, in the Isle of Skye, that trap in the same place may appear in all these three states, and of course that no conclusion relative to its origin can be drawn from its position. He noticed a large mass of trap rising through, and on one side overlying the sandstone strata. From this mass a horizontal bed was detached running conformably through the midst of the strata. This was ultimately divided into three beds, also conformable, and alternating with the sandstone. Dykes also proceed in several places from the single bed of trap. The following diagram exhibits a section of this appearance :—



A, mass of trap lying over the sandstone, M. B, a bed of trap proceeding from A, passing in a conformable position through the sandstone, and finally splitting into the three subordinate beds, C, D, E; *f*, *g*, *h*, *i*, dykes of trap proceeding from the bed, B.

The general opinion of mineralogists is, that trap rocks have been forced up from below in a state of fusion, and that they have thus made their way through the beds with which they are connected. Several circumstances have been pointed out which strongly corroborate this opinion. The strata through *which trap rocks pass* are generally found indurated in the immediate neighbourhood of the trap dyke; loose grits pass into compact quartz rock, and shale into flinty slate. Coal, under similar circumstances, is converted into coke, as if by the volatilization of its bituminous matter.

The most remarkable trap bed known, is the whynstonesill, in the Northumberland coal measures. It may be seen near the lead mines on Dufton fell, upon the great western escarpment of the mountain range connected with Cross fell. It is a greenstone bed, composed of white felspar and greenish-black hornblende, and from the prevalence of the latter it has a greenish colour. Its thickness is very irregular, being only 6 fathoms in some places, and 20 or even 30 in others. This trap bed is believed to be the same which is laid open to view in the valley of the Tees. Here it extends from near the source of the Tees to Eggleston, so that its breadth cannot be less than fifteen miles. There are several other basaltic or trap beds in the Tees, which occasion cascades, but it would be tedious to enumerate them.

A bed of basalt is penetrated at the depth of 159 fathoms in the Alston Moor mines. This is referred by the miners to the whynsill, but whether correctly or not, is doubtful.

At Wratch cliff crag, near Alnwick, basalt occurs conformably interstratified with the other rocks. The effects produced by this basalt upon the contiguous strata are striking. Limestone is rendered highly crystalline, and unfit for lime; slate clay is converted into a substance like flinty slate or porcelain jasper, and the coal is invariably charred when in contact with it. The sandstone on which it reposes has assumed a brick red colour.

The number of veins or dykes passing through the coal measures is very considerable, and there is no uniformity in their direction. The circumstances attending them are in many cases very extraordinary. The most considerable basaltic dyke in the neighbourhood of Newcastle is that which passes through Coleyhill, about four miles west of the town. A long range of quarries has here been opened upon it, in some places to the depth of 50 feet, and laying bare the entire width of the dyke, which is 24 feet. The dyke in this place is vertical; the basalt of which it is composed is in detached masses, coated with yellow ochre. The removal of these brings into view thin layers of indurated clay, with which the fissure is lined, and which, breaking into small quadrangular prisms, are used by the country people for whetstones. In this substance clay ironstone, impressed by the figures of ferns, is very abundant.

The upper seam of coal is here found at about 35 feet from the surface, and where in contact with the dyke is completely charred, forming an ash-grey porous mass, which breaks into small columnar concretions, exactly like the coke obtained by baking coal in close iron cylinders in the process of distilling coal tar. Calcareous spar and sulphur are disseminated through the pores of this substance.

The basalt itself, when broken, is of a greenish-black colour, and a coarse-grained fracture. It contains quartz, calcareous spar, and a peculiar mineral not yet examined chemically.

Passing to the east-south-east of the Coleyhill dyke in the line of its direction, a vein is found traversing Walker's colliery, and crossing the Tyne at Walker. This dyke is well defined. It occasions no alteration in the level of the coal strata, and the depth at which it intersects them is unknown. It has been cut through by horizontal drifts in four places. On each side of it the coal is converted into coke, to a depth which on the one side was found to be 18 feet, and on the other upwards of 9 feet. A firm, hard and unbroken vein of basalt, on an average about 13 feet thick, was in immediate contact with the coke on each side; and between these two veins lay nodules of basalt and sandstone, upwards of 9 feet in thickness, imbedded in a cement of blue slate.

At Walbottle Dean, five and a half miles west of Newcastle, below the bridge on the western road, a double vein of basalt crosses the ravine in a diagonal direction, passing nearly due east and west. It underlies at an angle of 78°, and cuts the coal strata without altering their dip. On the eastern bank of the ravine it is laid bare from the level of the brook to the height of about 60 feet. The northern and southern basaltic portions of this vein, the one 5 and the other 6 feet in thickness, are here 13 feet apart, and are separated from each other by a confused heap of fragments of shale and sandstone, broken from the coal strata. With these fragments are found balls of basaltic tufa, parting into concentric layers, and of a light brown colour. The balls are most abundant on the sides of the rubble near the basalt. In a neighbouring colliery both portions of the vein hold their course through the seam of coal, which is charred by their influence. This basalt contains nodules of quartz and chalcedony, but no *adularia*, which is *abundant in the basalt* of Coleyhill.

A dyke, called the Cockfield dyke, underlies to the south, and throws up the coal measures on that side 18 feet. The low main coal contiguous to the basalt is only 9 inches thick, but enlarges to 6 feet at the distance of 150 feet from it. The coal is reduced to a cinder, and the sulphur is sublimed from the pyrites near the dyke.

A dyke is seen on the banks of the Tees, a little below Yarm. It there passes into the new red sandstone, and continuing its course in the same direction is well known to traverse the north-eastern part of Yorkshire, near the still more recent formations of lias, and the sandstone of the inferior oolite in the eastern Moorlands, on its way to the German Ocean. This dyke is rendered highly interesting by its great length, and the proof it affords, by thus penetrating later rocks, that it must have owed its origin to causes in action long subsequent to the formation of the coal. Analogy leads to the conclusion that the other dykes in the coal are likewise of subsequent origin. It is a dark greyish brown basalt, which turns brown on exposure to the atmosphere. It is the principal material for the roads in the district called Cleveland.

In Derbyshire the trap rocks occur in a bed alternating with the mountain limestone, which, by their interposition, they divide into four separate beds. But other masses of trap, of more limited extent, are occasionally found contained within the limestone beds, especially in what is called the third limestone.* An instance of a dyke is also mentioned by Whitehurst. It has not been ascertained whether these occasional masses of trap be in any way connected with the principal strata. The upper *toadstone* exhibits in Hockley lime quarry, south of Ashover, portions of limestone imbedded in its mass, and some other probable examples of the same kind are cited by Mr. Farey; and Professor Buckland observed the nodules of limestone thus imbedded to be occasionally surrounded by a thin crust of fibrous calcareous spar, exactly resembling that produced in the instances of incipient fusion under pressure, in Sir James Hall's experiments.

The Derbyshire toadstone is an amygdaloid consisting of a compact reddish-brown coloured paste, containing nodules of various sizes, from small granular dots to the size of a hazel nut, or larger. They consist of whitish calcareous spar and of green earth. Agates occur sparingly, affording specimens

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* They are reckoned from the surface.

of onyx, chalcedony, jasper and quartz crystals, usually called *Derbyshire diamonds;* zeolites also occasionally occur. The decomposition of the imbedded nodules causes the toadstone frequently to assume a vesicular lava-like character. This amygdaloid occasionally passes into ordinary basalt, which is sometimes columnar, as at Cavedale, near Castleton.

Mr. Whitehurst maintained that the metalliferous veins of the limestone strata were universally cut through by those of the toadstone, and produced this as a conclusive proof of its subsequent origin. Mr. Farey admits this to be the general fact, but adduces several exceptions, mentioning no fewer than nineteen instances in which the toadstone beds carried ore; usually, however, only in thin strings. More lately the veins of the Seven Rokes mine, near Matlock, which had before been worked in the second and third limestone, have been pursued with success in the intervening toadstone.*

The average thickness of the first or upper toadstone is about 60 feet; of the two lower 75 feet each. This, however, is subject to very great variations.

The district is described by Mr. Farey as bounded on three sides (south, west and north) by an extensive fault, the effect of which is in these directions to place the fourth or lowest limestone on the same level with the shale, the true place of which, as ascertained on the eastern side, is above the whole limestone series. Hence, while the three toadstone strata form nearly parallel bands along the eastern side, where the beds crop out in regular succession, we must not look for any repetition of them on the western side, where the lowest bed is abruptly brought into contact with the shale, necessarily excluding the intervening beds.

The third toadstone bed occurs on the north-western border of the district, where it is repeated with an opposite or north-western dip, underlying the insulated portions of the third limestone. Of these portions one extends from Dolehole, about a mile and a half to the eastward, to Sparrow pip, near the celebrated ebbing and flowing spring. The other includes the villages of Buxton and Fairfield.

In the north-east the third toadstone commences on the border of the limestone tract near Castleton, where it is first

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* Mr. John Taylor, in a late communication to the British Scientific Association, affirms that the veins constantly pass through the toadstone, but that they generally contain no ore. This was the reason why they were considered as interrupted by these toadstone beds.

seen in Cowler hills, and then crosses the ravine called Cavedale. Hence it ranges in a sinuous line south-west towards the river Wye, thence along the country in a south-west direction to the extremity of the limestone district. The two other beds of limestone have nearly a similar direction; but, of course, are lower in the series. A minute description would not be understood without a map of the district; it will be sufficient to refer to Mr. Farey's *Survey of Derbyshire*, where the whole course of these beds is particularly detailed. The subject is highly worth the attention of future observers, because the assertions of Mr. Whitehurst, if verified, would go far to demonstrate the igneous origin of trap.

Several trap dykes occur in the neighbourhood of Glasgow, one in particular about five miles east on the Stirling road, which alters the dip of the beds on the east of it. After the particulars given respecting the dykes in the Newcastle coal measures it would be tedious to enter into the same details about the Glasgow dykes and those on the west coast of Ayrshire and near Oban, where, however, the nature and effects of these dykes may be studied with great advantage.

Dykes of trap are uncommon in granite though they sometimes occur in it. I have already mentioned the greenstone dyke passing through the granite a little to the south of Aberdeen. It disappears, or, at least, cannot be traced beyond the *Brig of ae hair*, though probably it extends a considerable way inland.

Thus, it appears that the trap rocks cut through or overlie all the formations, from the granite to the chalk; they must, therefore, have been of posterior formation to all of these beds. It is obvious, from the facts stated, respecting the trap dykes cutting through the coal measures, and being covered by the magnesian limestone, that many of these dykes must have assumed their present situation before the deposition of the magnesian limestone; others not only cut through the magnesian limestone, but even penetrate through the lias and the sandstone of the inferior oolite. It is clear, therefore, that all the trap rocks were not formed at once, but that the formation of them was continued at intervals through an immense series of ages. The porphyries, in general, are probably older than the great proportion of the trap rocks, though we have no good data to determine the point.

Trap dykes are not the only foreign matter that may be seen passing through the regular stratified rocks in a direction unconformable to their stratification. Almost all the stratified rocks, owing, probably, to a force applied to them from below, and by which they have been elevated from the bottom of the sea to their present height above its surface, have been subjected to *cracks* or *clefts*, the two portions having separated to a greater or less distance and left an open space. When this space continues empty it is called simply a *cleft*, but when it is filled with extraneous matter, as it frequently is, it is called a *vein*. Veins then are merely clefts of the strata afterwards filled up with extraneous matter. Hence it cuts through the strata of the rock in which it occurs, and it may assume every possible direction according to circumstances; it may be perpendicular, or it may approach the horizontal, or it may dip at any angle. In general, veins are widest above and become gradually narrower as they proceed downwards, though the very contrary of this sometimes happens, veins being occasionally met with widest below and gradually narrowing as they approach the surface.

Sometimes two or more veins cut through the same stratified rock at the same time. Thus, in the lead mine district of the north of England, which is situated in the coal formation, or at least in the millstone grit and mountain limestone situated below these measures, the lead ore exists in a set of veins which run east and west. These veins are commonly very narrow while they pass through the sandstone beds, but in the limestone they swell out frequently to a very considerable breadth. These veins are filled with galena, blende, fluor spar, and occasionally carbonate of iron and calcareous spar, &c. There is another set of veins running through the same beds, but their direction is north and south. Now the north and south veins cut through those that run east and west; of course they are the newest of the two sets; they are very seldom filled with lead ore, but often with iron pyrites, quartz, &c. There is a remarkable north and south vein, which appears very conspicuous a little way to the east of the summit of Cross fell. It is filled with quartz through which a good deal of iron pyrites is interspersed; on that account this vein is known to the miners of the country by the name of the sulphur vein. In consequence of its great hardness it has stood the action of the weather better than the beds through which it passes. Hence it rises conspicuously, forming a low wall extending a great way in length.

Sometimes the new veins not only cut through the old ones, but occasion a subsidence of the strata on the one side or an elevation on the other; or, in other words, they constitute what is called a fault. Now as in these cases the old vein, with all its contents, is elevated or depressed as well as the strata in which it occurs, it is clear that the old vein must have been filled and brought into the very state in which it is at present before the new vein was formed.

A great many opinions have been advanced respecting the way in which these veins have been formed. An enumeration of a considerable number of these opinions may be seen in the second chapter of Werner's well known book, entitled *New Theory of the Formation of Veins.* But it is needless to enter into the consideration of these opinions, as they can scarcely be considered as any thing else than conjectures, unsupported by proof. It must be admitted by every person that veins were originally clefts in the strata in which they occur, though it does not appear so evident whether these clefts remained long open, or whether they were filled and formed almost at the same time.

If we were to suppose that a cleft was formed through a series of strata while still under the surface of the sea, it is clear that this cleft would be gradually filled up by the action of the waters carrying to it the loose matter which existed at the time at the bottom of the ocean, under which the cleft was formed. In such cases the vein would naturally be filled by rolled masses or water-worn stones. Now Werner describes a vein of this kind in Danielstollen at Joachimsthal; it was in continuing to work out the vein Elias and carrying on the operation towards the vein Schweizer, that this vein, consisting of rolled pieces, was discovered at the depth of 180 fathoms. This vein was 14 inches thick, accompanied the vein Elias for some time, and was almost entirely composed of rolled pieces of gneiss of different sizes, some of which had acquired a shape almost spherical. Werner afterwards met with a similar occurrence in the *Stoll-Resser*, near *Riegelsdorf* in Hesse, where a vein of cobalt, having a direction nearly vertical, was intercepted by another vein almost entirely composed of sand and rolled pieces. According to the observations made by Mr. Schreiber, veins occur in the mountains of Chalanches near Allemont, in Dauphiné, which are entirely filled with rolled pieces.*

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* Werner on Veins (Engl. Transl.), p. 65.

When veins have been formed by fused matter forced into them, it is obvious that they must have been filled at once, and almost always from below. In this way the granite veins so common in gneiss, mica slate, clay slate, &c., have been formed. To the same origin we must ascribe the dykes or veins of trap so common in the coal beds, and of which so many details have been given in a former part of this chapter. In such dykes it is no uncommon thing to meet with fragments of the stratified rock, which constitutes the walls of the vein, isolated in the midst of the trap. It must have been forced out of its place by the projecting force of the melted matter, and afterwards enveloped in it.

But the most important veins are those which contain the ores of metals. Almost all the metals are found in veins; though there are some, as iron, manganese and chromium, that occur in beds, while the ores of others which are scarce metals, as those of cerium, titanium, columbium, molybdenum, occur in grains or patches in the older rocks. The ores of lead, copper, tin, antimony, zinc, cadmium, bismuth, and even of silver, usually occur in veins, which traverse sometimes the older and sometimes the newer rocks. Now these metals rarely occur in the metallic state, but in combination either with sulphur, or oxygen, or acids. The veins containing these ores, when they are of any considerable size, are not all filled with the metallic portion, but with some other mineral, such as fluor spar, calcareous spar, quartz, &c., through which the metallic ore is interspersed in grains or strings. But sometimes the structure of these veins is of a more complicated nature, being composed of beds arranged in a direction parallel to their sides; these beds are often crystallized more or less regularly, showing that they have been deposited in succession, and very slowly. Now it deserves attention that, when veins are stratified, the same minerals occur on both sides, at equal distances from the walls of the vein.

Werner gives as an example of this structure the mine of *Segen-Gottes* in *Gregorius*, in the district of Freyberg. In it, reckoning from the middle, which is composed of two beds of calcareous spar in which small druses occur here and there, thirteen beds of different minerals are arranged in the same order on each side of the vein; these are fluor spar, calcareous spar, sulphate of barytes, galena, &c. In the southern vein Gregorius, the two beds which adhere to the sides of the vein are composed of crystallized quartz; next to that, on each side, is a bed of black blende, mixed with iron pyrites; this is followed by galena, brown spar, galena, grey silver ore, red silver ore, sulphuret of silver. The central part, which, of course, has been last filled up, is composed of calcareous spar. It sometimes happens that one or more of the different beds are wanting.*

We are not perhaps capable, in the present state of our knowledge, of forming any very accurate conception of the way in which these veins were filled up. It is obvious, from the appearance of the different beds in the vein, that the filling up has been a very slow process, and that it probably occupied a long series of ages. It may be conjectured, perhaps, that the process took place while the beds in which the vein exists were still under the ocean, that the upper surface of the vein either never had been open, or that it had been closed by some unknown means, and that the successive deposition of the beds on the walls of the vein was owing to a succession of galvanic actions, by means of which the materials were gradually brought from a distance, united together and deposited as we now find them. Hence, perhaps, the reason why the nature of veins differ so much, according to the rock through which they pass. This is admirably exemplified in the galena veins in the north of England, which are so rich in ore in the limestone beds, and so poor when they pass through the sandstone and slate clay beds.

The same thing is observed in Cornwall; when a vein passes through the killas it is rich, but it becomes poor on entering the granite, and *vice versa.* In a part of the parish of Gwenap there exists a bank of reddish killas very considerably inclined. The copper veins regularly traverse this bank and are always unproductive; but they resume their richness in passing through the common killas. At Godolphin the veins are rich in the light blue killas and poor in the dark blue. At Poldice and Huel Fortune the veins become poor in the hard blue killas. At Huel Squire the veins of copper are very rich in the soft blue killas, but when they pass through two beds of hard dark killas, the one at the depth of 44 fathoms, the other of 120 fathoms, they become poor.

Some idea may be formed of these galvanic actions by recollecting, that whenever any agents whatever act unequally upon a metallic body, as many piles are formed as there are

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* Werner on Veins, p. 83.

points unequally attached. Suppose a particle of metal and charcoal in contact in a vein, while an acid of any kind is present, or even any imperfect conductor, as water, action would take place, the compounds within reach of this action would undergo decomposition according to the usual law; acids, oxygen, chlorine, &c., would be collected round the positive pole, while alkalies, and metals, and bases would be deposited round the negative. These depositions might give origin to the formation of calcareous spar, fluor spar, carbonate of iron, &c., on the one hand, and of sulphuret of lead, sulphuret of zinc, iron pyrites, &c., on the other.

Mr. Robert Fox has lately made some interesting observations on the electro-magnetic properties of veins. His galvanometer consisted of a magnetic needle contained in a box 4 inches square and 1 in depth, round which a copper wire, covered with silk, was passed twenty-five times; small copper discs were placed in contact with the minerals in the mine, and these, by means of copper wires (sometimes several hundred feet long), were brought in contact with the two poles of the galvanometer. The following are the general results of his observations:—

1. In a vein running east and west, the direction of the current of electricity was usually from east to west when the vein dipt to the north, and from west to east when the vein dipt to the south.

2. In the same vein the current generally flows from more elevated stations to those which are situated at a lower level; but the contrary takes place when a cross vein of quartz or clay interrupts the continuity of the vein between the two stations.

3. When we compare two veins parallel to each other, the current flows from north to south more frequently than the contrary way.

4. At the mine of Huel Jewel a current was established between a disc placed at the surface of the mine upon a mass of ore extracted, and another disc applied to the vein at a lower level. The upper disc was positive, and the deviation of the needle increased as the vertical distance of the two discs was increased.*

Another way in which these stratified veins may be conceived to have been filled up is by the filtration of water

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* Phil. Trans. 1830, p. 399.

through them, containing in solution the substances constituting the beds of the vein. In this way we may account for the deposition of beds of quartz, calcareous spar, and even of carbonate of iron.

Whether some of the metallic ores may have been forced up from below in a liquid state we have no means of determining at present, though this has been a favourite opinion of geologists in all ages. It is clear that this cannot be the case with stratified veins, nor with veins filled with fragments of rocks or water-worn pebbles. Veins forced up from below in a state of fusion must fill the cavity with matter of the same kind, or if there be any difference it must proceed from subsequent crystallization. Now there are very few metalliferous veins that coincide with these necessary appearances. Some veins of hematite, of galena and of copper pyrites, when very narrow, may be homogeneous, but I suspect not for any great length.

CHAP. XVII.

VOLCANIC ROCKS.

The term *volcano* is applied to certain mountains which emit smoke from their summits, and occasionally discharge ashes, or stones, or melted stony matter, to which the name *lava* has been given. Such mountains obviously contain an immense quantity of matter in a state of active ignition at an unknown depth below the surface of the earth.

At what time volcanoes first made their appearance on the surface of the globe we have no means of determining; but that it was at a very remote period is evident from the numerous extinct volcanoes which must have ceased to burn before the commencement of history, since no allusion whatever has been made to them in the writings of the most ancient authors with which we are acquainted. The extinct volcanoes in Italy, in France, in Spain, and on the Rhine, may be mentioned as examples.

The two most celebrated volcanoes in Europe are Vesuvius and Ætna, and there is every reason for believing that both these mountains had been in a burning state at a very remote period; but no notice is taken of Vesuvius as a burning mountain, by any ancient writer, prior to the great eruption on the 24th of August of the year 79 of the Christian era, so minutely described by the younger Pliny.* It must, therefore, at that time have renewed its eruptions after having continued for many ages in a dormant state. Mount Ætna must have been a burning mountain at a very remote period of the history of the earth, yet no allusion whatever to Ætna as a burning mountain is made by Homer. This could scarcely have been the case had this mountain been in a state of activity in his time. An inspection of the mountain leaves no doubt that eruptions of lava had taken place from Ætna long before the time of Homer, who is usually supposed to have flourished about nine hundred years before the Christian era. But it is probable that for a long period before the age of Homer it had remained in a quiescent state. The consequence of this would be that in that rude state of society all recollection of former eruptions would be lost; and hence, doubtless, the reason of the silence of Homer. The earliest writer by whom the volcano of Ætna is mentioned is Thucydides, who says, that up to the date of the Peloponnesian war, which began in the year 431 B.C., three eruptions of Mount Ætna had taken place since Sicily was peopled by the Greeks.†

The earliest volcanic eruption upon record is that by which the cities of Sodom and Gomorrah were destroyed, if we admit with Dr. Daubeny the very probable conjecture, strengthened by the present aspect of the country, that the destruction of these cities was occasioned by a volcanic eruption.‡ Now, this happened about 1960 years before the commencement of the Christian era. How far the state of Mount Sinai, thus described in Exodus—

"And it came to pass on the third day, in the morning, that there were thunders and lightnings, and a thick cloud upon the Mount ......, and Mount Sinai was altogether on a smoke, because the Lord descended upon it in fire: and the smoke thereof ascended as the smoke of a furnace, and the whole Mount quaked greatly."§—

How far this state of the Mount was connected with volcanic eruptions, it would be presumptuous to conjecture; but it is

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* Plinii Epist. lib. vi. epist. 16 and 20.

† Thucydides Hist. lib. iii. 6, 116.

‡ *Daubeny, on Volcanoes*, p. 279.

§ Exodus, xix. 16, 18.

certain, from the observations of Burkhardt, that abundance of extinct volcanoes exist in the Peninsula of Mount Sinai.

The number of volcanoes at present in a state of activity is very considerable, and shows how great an influence volcanic agency has had in elevating the mountains. The number of volcanoes at present or very lately in a state of activity, amounts to about 220. Of these an interesting account may be found in Von Buch's Memoir *On the Nature of the Volcanic Appearances in the Canary Islands, and their Connexion with the other Volcanoes on the Surface of the Earth.** I shall satisfy myself here with a bare enumeration of the active volcanoes, with the existence of which we are at present acquainted.

In Europe there are thirteen volcanoes, viz.:—

1. Ætna,
2. Vesuvius,
3. Stromboli,
4. Volcano,
5. Volcanello,
6. Santorino, in the Archipelago,
12. Hecla, and other five volcanoes in Iceland,
13. Jan Mayer, in Greenland.

The volcanoes in the islands connected with Africa (for none have been observed on that continent itself), amount only to five; though, if we were to include the extinct volcanoes, they would be much more numerous. These five exist in Teneriffe, the Canaries, Azores, Cape de Verde, and the Isle of Bourbon. Their names are

1. Teneriffe, in the Canaries.
2. Lanzerote, in the Canaries.
3. Fogo, in the Cape de Verde Islands.
4. El Pico, in the Azores.
5. Solazes, in the Isle de Bourbon.

The volcanoes in Asia, and the many islands connected with that continent, are very numerous, upwards of 130 having been observed, though many of these are very imperfectly known.

From Bruce's account, it would appear that two volcanoes exist in islands in the Red Sea. It is said also that two active volcanoes exist in central Tartary, and a third in the Himalaya mountains; but the exact situation of these volcanoes has not yet been pointed out.

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* *Poggendorff's* Annalen, x. 1, 169, 345 and 514, for the year 1827.

Three volcanoes exist in Kamtschatka, and eleven are enumerated by Von Buch as existing in the Aleutian islands, which lie between Northern Asia and America. There are thirty-seven volcanoes in the Kurile and Japanese islands, and one in the Island of Formosa. Ten volcanoes are enumerated as occurring in the Australian islands; thirteen in the Island of Sunda; twenty-nine in Java; six in Sumatra; sixteen in the Philippines, and five in other islands scattered over the surface of the Pacific Ocean.

The volcanoes connected with the American continent in activity amount to about seventy-four. Of these, ten exist in the West India islands, to which the name of Antilles has been given; sixteen are in Chili; sixteen in the province of Quito; twenty-seven in Guatimala; and five in Mexico.

South Shetland, about 10° nearer the pole than Cape Horn, appears to be a volcanic country. No actual eruptions have been observed; but Mr. Webster informs us that several of the peaks still smoke, and that it abounds in hot springs.*

No doubt this number, great as it may appear, will be augmented when the interior parts of Africa and of New Holland become known. The preceding list is made out chiefly from Von Buch's Memoir, formerly mentioned, and from Dr. Daubeny's excellent work on Volcanoes.† Probably some of the volcanoes enumerated, especially in Java and some other of the Asiatic islands, may not at present be in a state of activity, as that circumstance is not always noticed by Horsfield and Raffles, from whom chiefly the list drawn up by Von Buch is derived.

Numerous as are the volcanoes at present in activity, those which have been extinct for many ages, or which in all probability had finished their eruptions before the earth became fit for the habitation of man, are not less so. One of the first districts containing these extinct volcanoes noticed by geologists is situated on the left bank of the Rhine, not far from Coblentz. A pretty keen controversy respecting the nature of this district, occupied the German geologists for more than half a century, and has been at last decided in favour of those who ascribed the origin of the rocks which constitute the peculiarities of the district to the action of extinct volcanoes.

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* Webster's Narrative, vol. i. p. 152.

† A description of active and extinct Volcanoes, published in 1826.

As many as five distinct craters have been observed, most of which are now filled with water, and constitute lakes. There are two volcanic districts, called the upper Eisel and the lower Eisel; the former is at some distance from the Rhine, but the latter is upon the left bank of that river, between the Mozelle and the Ahr. The volcanic rocks of this district cover a greywacke bed, which occasionally alternates with limestone. The lavas consist of scoriæ, trachyte and basalt, together with abundance of a matter called in that country *trass*. Its basis is composed of pumice, in which are included fragments of basalt and other lavas, pieces of burnt shale, slate and sandstone, and numerous trunks and branches of trees. These lavas are deposited on rocks containing lignite, in which five different species of extinct fish, and an extinct species of frog, have been discovered. Hence the age of these extinct volcanoes is uncertain, but Mr. Lyell is inclined to consider them as belonging to the eocene period.*

The extinct volcanoes of Auvergne have acquired still greater celebrity than those on the Rhine. The volcanic appearances in that country are so obvious that they have been generally admitted by all geologists who visited it, and denied only by those who never had an opportunity of examining them. Desmarest, Dolomieu, Von Buch, D'Aubuisson, Lyell, Scrope, have described them in succession, and proved incontrovertibly the existence of extinct volcanoes in that country. The volcanoes exist in three different places, namely, Auvergne, Cantal and Velay. Auvergne contains two distinct volcanic tracts, namely, Monts-Dômes and Monts-Dores. The Cantal lies south from Mont D'Or, and Velay east from Cantal, and separated from it by the river Allier. The following table exhibits the heights of the principal volcanic rocks of that country, determined barometrically by M. Ramond:—†

Cap de Prudelles, . .	2,293 English feet.
Montrodeix, . . .	3,041
Lafont de l'Arbre, . .	2,641
St. Genès Champanelle, .	2,907
La Serre de Fontfrede, .	3,461
Le Puy Girou, . .	2,792
Gergovia, . . .	2,497

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* Lyell's Geology, iii. 200.

† *Jour. des Mines*, xxiv. 249.

Mont Rognon, . . .	2,339 English feet.
Les Côtes de Clermont, .	2,090
Champturgues de Clermont,	1,854
Puy de Cornon, . .	1,765
Montaudou, . . .	1,965
Le Puy de Charade, .	3,018
Gravenère, . . .	2,723
Le Puy de la Vache, .	3,894
Le petit Puy de Dôme, .	4,190
Puy de Pariou, . .	4,009
Puy de Goules, . .	3,803
Le Grand Sarcouy, .	3,793
Le Puy de Dôme, . .	4,846

The volcanic matter so abundant in these countries consists partly of scoriæ, and partly of basalt and felspar porphyry. The basis of the whole tract is granite. The volcanic matter was probably situated below the granite, and forced up through it by the action of fire.

The volcanic country in the neighbourhood of Olot, in Catalonia, has not acquired so much celebrity as the two preceding tracts, though not less entitled to attention. It was first noticed by Mr. Maclure, and has been accurately described by Mr. Lyell.[*] It extends about fifteen miles from north to south, and about six miles from east to west; Castle Follet and the river Fluvia being at the north end, while it extends south nearly to Amer on the river Ter.

The eruptions have burst entirely through secondary rocks, consisting of sandstone and conglomerate, with some thick beds of limestone. At the southern boundary of the volcanic country, rocks of gneiss, mica slate and clay slate occur. There are about fourteen distinct cones with craters, besides several points whence lavas may have issued. The volcanic matter consists of scoriæ and lavas, which frequently put on the appearance of columnar basalt.

The extinct volcanoes in Hungary have also occupied the attention of geologists, and various notions were advanced respecting their origin. But the most complete and satisfactory account of them has been given by Beudant.[†] There are five different places in Hungary in which extinct volcanoes occur.

The first is the district of Schemnitz and Kremnitz, occu-

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[*] *Geology, iii. 181.* [†] *Voyage en Hongrie*, 3 vols. 4to. Paris, 1822.

pying an elliptical space of about twenty leagues in its greatest diameter, and fifteen in its smallest. The second is a smaller group on the south of the preceding one, constituting the mountains of Dregeley, near Gran, on the Danube. The third is the mountain group, known by the name of Matra, situated in the heart of Hungary, and east from the preceding groups. The fourth is a chain which commences at Tokai, and extends north to the heights of Eperies, in length from twenty-five to thirty leagues, and in breadth about five or six. The fifth or last region of extinct volcanoes in Hungary is that of Vihorlet to the east of the preceding, and connected with the trachytic mountains of Marmorosch, on the borders of Transylvania.

These several groups are quite unconnected with each other, and every particular mountain appears to have been separately formed, for their escarpments rarely correspond, so that they cannot be viewed as detached portions of one general bed cut away by the operation of subsequent causes. The lavas from these extinct volcanoes consist of trachyte, of which Beudant distinguishes and minutely describes five different varieties. These are trachyte, trachytic porphyry, pearlstone, millstone porphyry, and trachytic conglomerate.

Extinct volcanoes occur also in Transylvania, which have been described in considerable detail by Dr. Boué. Those in Styria have been described by Von Buch.*

In Italy a great number of tracts occur where volcanoes now extinct have once existed. Of these tracts an interesting account will be found in Dr. Daubeny's work on Volcanoes.† I shall satisfy myself here with barely enumerating the names of the principal districts. These are,

1. The Euganian hills, south of Padua, exhibiting a trachytic tract not unlike that of Hungary.

2. The Vicentin, north of Vicenza, partly trap, but also exhibiting volcanic rocks.

3. Monte Cimini, Monte Amiata, the former near Viterbo, and the latter near Radicofani.

4. The lagunes of Tuscany.

5. The neighbourhood of Rome. The Capitol, Mount Aventine, and Mount Celius, are capped with a volcanic rock, to which the Italian geologists have given the name of stonetuff, while the Mons Esquilinus, Mons Viminalis, Mons

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* *Transactions* of the Berlin Academy, 1818—21.

† P. 113, &c.

Quirinalis, and Mons Hincius, consist of earthy tuff. The rest of the formations of Rome consist of marl, sandstone, and travertin; the two former of which have been formed under the sea, and the latter in a fresh water lake.*

6. Rocca Monsina, south-west of Mola de Gaieta, near the river Garigliano, the ancient Liris.

7. The Ponza islands on the coast of Italy, opposite Terracina and Gaieta.†

8. Mount Vultur, near Melfi.

9. Lago di Ansanto, between Mount Vultur and Rocca Monsina.‡

10. Solfatara between Monte Nuovo and Puzzuoli, near Naples.

11. Lake Agnano and Grotto del Cane, the Lake Avernus.

12. Monte Barbara, the Gaurus of the ancients.

13. Islands of Procida and Ischia.

In the Grecian Archipelago abundant remains of extinct volcanoes occur. Santorino has been already enumerated among the active volcanoes of the present day, because about the beginning of the last century an actual eruption took place. The island of Milo is generally admitted to show unequivocal proofs of being an extinct volcano. The same remark applies to Cerigo and Lemnos.

Extinct volcanoes exist also on the western coast of Sardinia, for an account of which we are indebted to Captain Smyth. The volcanic matter has been deposited on tertiary beds, and the cones and lavas seem to be very fresh.

The Canary Islands, Madeira, the Cape de Verde Islands, and the Azores, exhibit abundance of extinct volcanoes, for an account of which we refer the reader to Von Buch, Daubeny, and Lyell.

The islands of Ascension, St. Helena, and Tristan d'Acunha, are extinct volcanoes.

The mountains of the Isle of France consist of extinct volcanic matter, and the same remark applies to a portion of the Isle de Bourbon, while in another portion of that island an active volcano exists.

It would be tedious to enumerate the numerous traces of

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* The reader will find an excellent account of the geological structure of Rome, chiefly by Von Buch, in Poggendorff's Annalen, xvi. 1.

† See Poulett Scrope, Annals of Philosophy (second series), viii. 65.

‡ This is the valley or lake of Amsanctus of Virgil, Æneis, lib. vii. l. 563.

extinct volcanoes which have been observed in Arabia, Palestine, Syria, Asia Minor, and in the Andes of South America, where also abundance of active volcanoes exist. Indeed, if Humboldt's remark, that no mountain exists in America higher than 10,000 feet, which is not volcanic, be true, by far the greatest portion of the Andes must be ranked among extinct volcanoes.

The matter ejected from volcanoes is usually called *lava*, when it has issued in a melted state, and been consolidated either under the surface of the sea or by exposure to the atmosphere. When detached stony fragments are ejected, which are afterwards cemented together, the rock thus formed is called *tuff*. And when matter is ejected in the state of powder or dust, it is called *ashes*.

Lava, by modern geologists, has been recognised as consisting of two distinct substances, namely, *trachyte*, and *greenstone*, and *basalt*.

The name *trachyte*[*] was applied by Hauy to a kind of porphyritic lava, having for its basis a paste of felspar. And the term, of late years, chiefly in consequence of the writings of Von Buch, has been generally adopted by geologists. The name is obviously derived from the harsh and rough aspect of the lava to which it is applied.

Trachyte, as has been already observed, consists of a paste of felspar filled with crystals of glassy felspar, often cracked. It sometimes contains crystals of hornblende, mica, iron pyrites, and specular iron ore. More rarely augite, and magnetic, or titaniferous iron ores. Before the blowpipe it melts into a *white* enamel. This is characteristic of trachyte. The felspar paste is often white, but not always so, having sometimes a deep or almost black colour.

The most minute account of trachyte hitherto given to the world is by Beudant in his description of the extinct volcanoes of Hungary. Dr. Daubeny has given an excellent abridgment of this account in his work on Volcanoes.[†]

According to Beudant, there are five different varieties of trachyte, which he distinguishes by the names of *trachyte proper*, *trachytic porphyry*, *pearlstone*, *millstone porphyry*, and *trachytic conglomerate*.

Trachyte, properly so called, is distinguished by its porphyritic structure, by the scorified and cellular aspect which

[*] *From τϱαχυς, harsh.*

[†] Page 93.

it has a tendency to assume, by its harsh feel, and by the presence of crystals of glassy felspar, generally cracked, and sometimes passing into pumice. Crystals of mica and hornblende are often present; and all these crystals are either confusedly united without any cement, or by the intervention of a paste of felspar, sometimes compact and sometimes cellular. This paste is generally light coloured, though different shades of red and brown are sometimes communicated by iron, and there is one variety in which the paste is *black* and semi-vitreous, intermediate in its characters between pitchstone and basalt; but distinguished from both by melting before the blowpipe into a white enamel. Augite and titaniferous iron frequently occur in it, but olivine is very rarely, if ever, present.

Trachytic porphyry, is distinguished from the first variety by the absence of scorified substances. Neither hornblende, augite, nor titaniferous iron, enter into its composition; but quartz and chalcedony, which are wanting in the former, are commonly present in this species. According to Beudant, there are two varieties of trachytic porphyry, the one with and the other without quartz, and in both, specimens occur possessing a vesicular structure. Indeed the subspecies, which is without quartz, often passes into pumice. Many varieties of trachytic porphyry contain a number of very small globules, which seem to consist of melted felspar, having often in their centre a little crystal of quartz or mica. The assemblage of these globules, leaving minute cells between them, sometimes gives to the rock a scoriform appearance. The chalcedony often occurs in small geodes and sometimes intimately mixed with the paste in which the crystals are imbedded.

Pearlstone, is characterized by the vitreous aspect generally belonging to its component parts. Trachytic porphyry passes insensibly into it. Pearlstone, properly so called, and likewise obsidian and pitchstone belong to this variety. Pearlstone occurs usually in Hungary, while obsidian, as we learn from Sir George Mackenzie, is common in the Iceland lavas. Pearlstone, in its simplest form, presents an assemblage of globules, from the size of a nut to that of a grain of sand, which have usually a pearly lustre and scaly aspect, and are set as it were one upon another, without any substance intervening.

From this, which is the most characteristic variety, the rock passes through a number of gradations. In some the globules are destitute of lustre, and become more and more minute till they entirely disappear, and the whole mass puts on a stony appearance. Sometimes the pearlstone passes into pitchstone or obsidian. Sometimes globules consisting of felspar occur in the rock, which are either compact or radiated from the centre to the circumference, and these are sometimes so numerous that the whole mass is composed of them. All these varieties occasionally present a cellular, porous, spongy, and fibrous aspect, and pass into pumice.

The *millstone trachyte* is distinguished by its hardness and cellularity, qualities which have caused it to be employed all over Hungary for millstones. Hence the name given to it by Beudant. It abounds in quartz, or at least in some of the modifications of silica; and puts on either the appearance of hornstone or of claystone porphyry. The paste is always dull and coarse looking. Its colours vary from brick-red to greenish-yellow; its fracture is generally earthy, and its hardness variable, but usually considerable. It contains crystals of quartz, of felspar, lamellar, and sometimes glassy, and of black mica imbedded. Jasper and hornstone also occur in nests, or in small contemporaneous veins very abundantly disseminated, and siliceous infiltrations posterior to the formation of the rock, seem likewise to occur among the cells, which are every where distributed. By the assistance of a glass, many little globules, analogous to those in the pearlstone, seemingly of a felspathic nature, may be discovered. These, when broken, are found to contain in their centre a little crystal of quartz, or a speck of some siliceous substance. These globules in some cases compose the whole substance of the paste, in others they are held together by a sort of hardened clay, which here and there resembles porcelain jasper.

The fifth variety, called by Beudant *trachytic conglomerate*, consists of those heaps of pumice and other loose materials which occur agglutinated together on the slopes and at the base of the rocks belonging to the four preceding classes. Although the prevailing constituent is pumice, every rock existing in the neighbouring hills is met with among the fragments. These vary extremely in size as well as in the mode of aggregation. The cement which unites them is often of a porphyritic character, hardly distinguishable from the fragments themselves. Crystals of felspar, mica, and hornblende, and sometimes grains of titaniferous iron, are diffused through it, or it is coloured red by the peroxide of iron.

The fragments of pumice are united together, either immediately or by the intervention of a paste of a vitreous character resembling obsidian, into which the pumice passes insensibly. Sometimes the whole rock is decomposed and converted into an earthy matter, similar to the *trass* of the Eisel volcanoes, or the *tripoli* of those in Auvergne. By a still farther alteration, the mineral called *alumstone* is formed, which is employed in the manufactory of alum, both in Hungary and in the Roman states at Tolfa.*

Although trachyte be one of the commonest appearances which lavas put on, it is not the only one. Several of the streams of lava from Vesuvius, as those of 1760 and 1794, resemble *basalt* exactly in colour, fracture, hardness, and weight. I have specimens of lava from the same volcano, which cannot be distinguished from ordinary *greenstone*, being like that rock, composed of grains or crystals of hornblende and felspar. Amygdaloidal rocks are not wanting among these lavas, and the vast number of crystallized minerals found in such rocks has been long known to mineralogists.

Tuff, or *Tufo*, is an Italian name for a variety of volcanic rock, of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose matter ejected from a volcano. Tuff may be studied to great advantage in Rome and its environs. What occurs in that locality has been divided into *stone tuff* and *granular tuff*.

Stone tuff constitutes the summit of the Tarpeian rock of Mount Aventine and Mount Celius. Its colour is reddish-brown with orange streaks, proceeding from interspersed masses of pumice. It is earthy and almost conchoidal in its fracture, and hard enough to be employed as a building stone. It contains white mealy leucites, plates of brown mica, crys-

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* Trachyte being in fact a compound rock, little advantage can be expected to result from its analysis. The following table exhibits the analysis of two varieties of it from Puy de Dôme and Pertuis, by Berthier.†

Silica,	65·5	61·0
Alumina,	20·0	19·2
Potash,	9·1	11·5
Lime,	2·2	—
Magnesia,	—	1·6
Oxide of iron,	3·0	4·2
Water,	—	2·0
	99·8	99·5

† Ann. de Chim. et de Phys. xvii. 35.

tals of black and green pyroxene, and very rarely small grains of felspar. Here and there rounded and angular fragments of limestone occur in it. Sometimes the grains of which it is composed are so small, that it appears a homogeneous mass, excepting that fine scales of mica may still be distinguished in it.

The stone tuff occurs at Rome, in beds from 1 to 6 feet thick, penetrated by long, vertical, and sloping clefts, formed probably during the drying of the mass. The fine granular variety, in consequence of the position of the scales of mica, has commonly a slaty structure. The ancient Elvacæ are chiefly composed of stone tuff, probably quarried from the Capitol. It occurs also in the walls of the theatre of Marcellus and in other buildings.

Granular tuff, differs much in its appearance from stone tuff. It has a blackish-brown or yellowish-brown colour, is light, friable, and is composed of thick grains slightly agglutinated together, intermixed with scales of mealy leucite, fragments of augite, scales of mica, and occasionally pieces of blackish-grey lava. Sometimes it puts on the appearance of a porous pumice lava, to which the Italians gave the name of *lapillo*. The degree of hardness, and the colour of granular tuff vary very much, according to the degree of decomposition which it has undergone. Sometimes it has quite the character of lapillo, being only a little less dry and meagre to the feel, or it is exceedingly friable, loses its porous texture, and assumes an earthy aspect. When much acted on by rain water it assumes the aspect of clay, which adheres to the tongue and becomes plastic when moistened. In such cases the leucite disappears, but the augite and mica may still be distinguished. It is of this earth that bricks are made at Velletri, at the foot of Mount Artemisio. At St. Agatha in Campania it is employed for making stoneware vessels.

When this tuff is decomposed in a very great degree it constitutes a peculiar variety, to which Brocchi has given the name of *earthy tuff*, *tufa terrosa*. It is of a yellow colour, extremely light, and so friable that it readily crumbles to dust, which absorbs water with a hissing noise and gives out a strong earthy smell. This tuff constitutes the whole of Mounts Pincius, Quirinalis, Viminalis, Esquilinus, and the greatest part of Mount Celius and Aventinus.

What is called *ashes* consists of a very fine powder, which is *emitted* frequently during volcanic eruptions in immense quantities, and sometimes it is carried by the wind to an immense distance. I have a quantity of *ashes* which covered a ship at the distance of two hundred miles, during the great eruption in St. Vincents, in the year 1812. The nature of these ashes is not always the same; it doubtless varies according to the nature of the rocks in which the volcanic energy exists.

Volcanic eruptions most commonly proceed from the summits of conical mountains, composed entirely of lava, and therefore formed by successive eruptions. Hence, at the commencement, the probability is that no mountain existed, but that the eruption originated from level ground. The indications of an approaching eruption are earthquakes, frequently very severe, subterraneous noises, and violent bellowings. And in the neighbourhood of Vesuvius, an approaching eruption is always indicated by the wells becoming dry. Soon after, the smoke, which issues continually from the crater of a volcano, increases in intensity, and rises in the form of a vertical column, the upper part of which, in consequence of its weight, spreads out into a top, which has been compared to the head of a gigantic pine-tree. This tree agitated by the wind, assumes the form of a thick cloud, which transported to a great distance, leaves here and there large masses of smoke.

The progress of the combustion is announced by the projection of ashes, scoriæ, and red hot stones, which rise to a great height and fall back again either into the crater or on the sides of the mountain. At last a quantity of melted lava rises to the top of the crater, and flows down the sides of the mountain like a melted metal. Before the eruption, the lava fills the crater, having a vast quantity of scoriæ floating on its surface, and as it alternately rises and falls, the scoriæ appear and disappear at intervals.

The lava at last passes over the brim of the crater, runs down the side of the mountain to the bottom; there it spreads out assuming a progressive motion. In general, it flows from under a kind of crust formed by the portion at the surface becoming consolidated. As it advances, it destroys and envelopes every thing which it meets with on its passage, passes over the obstacles which it cannot remove, spreads over the cultivated fields, frequently for leagues in extent, and carries desolation and destruction wherever it goes.

When the lava confined in the crater is too compact and heavy to make its way to the summit, one or more ruptures frequently take place on the sides of the mountain, whence it issues with phenomena similar to those already described.

Nothing approaching to regularity has been observed in the intervals between the eruptions of the same volcano. Ætna and Vesuvius are the only two with whose eruptions, for a long series of ages, we are acquainted. From the description of Vesuvius given us by the ancients, and from the observations of Diodorus Siculus, there can be no doubt that it had been in an active volcanic state at a very remote period. And Vitruvius, when speaking of the Puzzolana near Naples, which he supposes to have been formed by heat, notices a tradition, that Vesuvius also in former times emitted flames.* But it had remained quiet for so long a period, that no idea of its volcanic nature seems to have been entertained by the Romans previous to the tremendous eruption of the year 79, which proved fatal to the elder Pliny, and which has been so minutely described by the younger Pliny.

The earliest eruption of Mount Ætna is that mentioned by Thucydides, which must have taken place about 480 years before the commencement of the Christian era. The following table exhibits the different eruptions of these two mountains which have taken place since these remote periods.†

<table>
<tr><th>Ætna.</th><th>Vesuvius.</th></tr>
<tr><td>B.C.</td><td></td></tr>
<tr><td>480, or thereabouts.</td><td></td></tr>
<tr><td>427</td><td></td></tr>
<tr><td>396</td><td></td></tr>
<tr><td colspan="2">185 eruptions between the Eolian islands, according to Pliny, 200 B.C.</td></tr>
<tr><td>140</td><td></td></tr>
<tr><td>135</td><td></td></tr>
<tr><td>126 or 125</td><td></td></tr>
<tr><td colspan="2">91 eruptions in Ischia.</td></tr>
<tr><td>56</td><td></td></tr>
<tr><td>45 or 44</td><td></td></tr>
<tr><td>A.D.</td><td></td></tr>
<tr><td>40</td><td></td></tr>
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* See Daubeny on Volcanoes, p. 149.

† The table is taken from Dr. Daubeny on Volcanoes, p. 214, who extracted it with some few additions, from Hoff's *Geschichte der Veranderungen der Erdoberflache.*

Ætna.		*Vesuvius.*
A.D.		A.D.
		79
		203
251		
		512
		685
812		
		983
		993
		1036
		1049
		1138, or 1139
1169, February 4		
Between 1198 and 1250		
1198, the Solfatara inflamed.		
1284		
1302, eruption of Epomeo in Ischia.		
		1306
1329, June 28		
1333		
1408, November 9		
1445		
1446		
1447, September		
		1500
1535, March till 1537		
1538, 29th September, formation of Monte Nuovo near Puzzuoli.		
1566	Continuance of small eruptions during this interval.	
1578		
1603, July		
1607		
1610, Feb.		
1614, July 2		
1619		
1624		
		1631, December 16
1633, February 22		
1645, November		
1654		
		1660, July
1669, March 8		

Ætna.	*Vesuvius.*
A.D.	A.D.
1682, December	1682 August 12
1688	
1689, March 14	
1694, March to December, (only ashes)	1694, March 12, with feeble recurrence of action till 1698
	1701, July 2 till 15
1702, March 8	
	1707, May 20 till August
	1712 Feb. 18, eruption continued till the following year
	1717, June 6, continued as before
1723, November, beginning of the month	
	1727, July 26
	1730, February 27
1735, October, beginning of the month	
	1737, May 14
1747, Sept., volcanic action continued for some years	
	1751, October 25
	1754, December 2
1755, March 2	
1759	
	1760, December 23
1763, June 19	
1766, April 27	1766, March 25
	1767, October 23
	1770
	1778, September 22
	1779, August 3
1780, May 18	
1781, April 24	
	1783, August 18
	1784, October 12 and Dec.
	1786, October 31
1787, July 28	1787, December 21
	1788, July 19

Ætna.	*Vesuvius.*
A.D.	A.D.
	1789, September 6
1792, March	
	1794, June 15
1798, June	
1799, June	1799, February
1800, February 27	
1802	
	1804, Aug. 12 and Nov. 22
	1805, July
	1806, May
1809, March 27	
	1809, December 10
	1811, October 12
1811, October 28	
	1811, December 31
	1813, May to December
	1817, December 22 to 26
	1818
	1819, April 17
1819, May 29	
	1819, November 25
	1822, February 13 to 24
	1822, October 22
	1828, March 14 to 22
1830, May 20	
	1834
	1835, March 13

With respect to the origin of volcanoes, no theory even entitled to the name of plausible has been hitherto offered. Lemery ascribed the commencement of the combustion to the action of water upon iron pyrites, or upon a mixture of sulphur and iron. But the phenomena of volcanoes are utterly inconsistent with such an hypothesis. It is true that sulphur is pretty frequently emitted from the craters of volcanoes, showing that some combination of it exists under the earth at the place where the volcanic fire rages. But the evolution of sal ammoniac, boracic acid, and of prodigious quantities of carbonic acid, shows that the combustible materials are different from iron and sulphur.

Breislac's hypothesis is merely a modification of that of Werner. He suggests that volcanoes may arise from masses of petroleum collected in underground caverns, and set on fire by some third substance. In his opinion, certain combinations of phosphorus, or even of sulphuric acid, may occasion the commencement of the combustion. And he considers the conflagrations which occasionally occur in the coal mines, as proving that such substances do in fact occasionally take fire. But the vastness of the phenomena, and the very great depth at which the burning matter is situated, are quite incompatible with such an origin.

Werner's hypothesis, ascribing volcanoes to the burning of coal, is not reconcileable to facts known respecting the great depth of the volcanic foci below the surface of the ground, though the nature of the gaseous matters given out from volcanoes rather favours the notion that carbon, in some state or other, is one of the substances subjected to combustion. Dr. Daubeny condensed a portion of the vapour given off round the crater of the Island of Volcano, and found it to contain sulphurous acid. The vapour from the Solfatara of Puzzuoli contained sulphuretted hydrogen. The vapour condensed from the spiracles on the exterior of the crater of Ætna consisted of water, with a trace merely of muriatic acid. M. Boussingault has examined the nature of the elastic fluids disengaged from the volcanoes in South America, situated near the equator, and found them the same in all: namely, vapour of water, carbonic acid gas and sulphuretted hydrogen. Sometimes azotic gas and sulphurous acid gas occur; but these two gases are accidental. The azotic gas comes from a mixture of common air, and the sulphurous acid from the combustion of the vapour of sulphur which abounds in all volcanoes. The following table shows the names of the volcanoes, their height above the sea, and their latitude and longitude from Greenwich:—

Names of Volcanoes.	Height above the Sea. Feet.	Latitude.	Longitude.
Tolima, . . .	18,045	4° 35′ N.	76° 30′ 40″ W.
Azufral of Quindiù,	At the base of Tolima.		
Puracé, . . .	17,008	2° 20′ N.	78° 50′ 40″ W.
Pasto, ...	13,452	1° N.	79° 34′ 40″ W.
Tuquères, . . .	12,821	0°	
Cumbal, . . .	15,620	0°	

The gaseous matter issuing out of Tolima contained 0·14 *of carbonic acid gas.* It contained about $\frac{1}{1000}$th of its volume of sulphuretted hydrogen. No other acid except sulphuretted hydrogen could be detected.

The gaseous matter issuing from the Soufrière of Quindiù consisted of 95 per cent. of carbonic acid gas, and only 5 per cent. of common air. The sulphuretted hydrogen amounted to about $\frac{1}{1000}$th part.

The gas from Puracé contained 85 per cent. of carbonic acid gas, and 15 per cent. of common air, with a trace of sulphuretted hydrogen.

The constitution of the gaseous matter from the other volcanoes was found quite similar to that from the three volcanic sources just mentioned.*

From these experiments, there can be no doubt that carbonic acid is evolved in considerable quantity, at least from the volcanoes in South America, which are situated in the neighbourhood of the equator. Another constant ingredient in the elastic matter given out by volcanoes is vapour of water. This seems to be a constant and even essential constituent. Doubtless the volcanic force which produces earthquakes, rumbling noise, eruptions of lava, and heaving up of the solid portions of the crust of the earth, owes its energy, at least to a considerable extent, to the high temperature to which the water in contact with the burning lava is raised. It has been a general opinion, that no volcano can exist in an active state unless it be situated in the neighbourhood of water. Most of the volcanoes with which we are familiar are not far from the sea; but if the report respecting the existence of two active volcanoes in central Tartary be true, it is obvious that a maritime situation cannot be essential, though it is not unlikely that these inland volcanoes may be near a lake, which might answer all the purposes of a proximity to the sea. I am disposed to ascribe the energy of volcanoes in a great measure to the action of steam, and so far to admit that the presence of water is essential to that energy.

In the year 1700, Lemery published a *Theory of Volcanoes*, which was long considered satisfactory. He mixed together equal quantities of iron filings and sulphur, moistened with water. Fifty pounds of this mixture contained in a large pot was put into a hole in the garden, covered with a linen cloth, and then with earth to the height of about a foot. After an interval of eight or nine hours the earth was observed

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* Ann. de Chim. et de Phys. lii. 5.

to swell, to become hot, and to crack; then sulphurous and hot vapours issued from it; finally flames made their appearance, which enlarged the opening, and scattered round the place a yellow and black vapour.* From this experiment Lemery concluded that volcanoes were owing to the heat produced by the action of moist sulphur and iron on each other. In such an action the water is decomposed, and the sulphur acidified, and the iron oxidized. Sulphuretted hydrogen would be emitted, and perhaps also vapour of water; but we would look in vain for the source of the carbonic acid, of the muriatic acid, and of the sal ammoniac, which are so frequently observed to accompany volcanic eruptions.

Sir H. Davy, after his discovery of the metallic nature of potassium and sodium, and of the great combustibility of these bodies, conceived that the phenomena of volcanoes might be accounted for by supposing that the internal parts of the earth are composed of potassium and sodium, and that violent combustions are produced when water comes in contact with these very combustible metals; and Gay-Lussac extended this plausible explanation still farther, by supposing that not only potassium and sodium, but calcium, magnesium, aluminum, and silicon, may all exist in the interior parts of the earth, and may also occasion violent combustions when they come in contact with water; but neither the specific gravity of the earth, nor the nature of the elastic fluids emitted by volcanoes, will permit us to adopt this hypothesis. We are too imperfectly acquainted with the phenomena of volcanoes, and with the nature of the gaseous matters which they exhale, to be in a condition to form even a plausible hypothesis respecting the origin and continuance of these very formidable objects.

CHAP. XVIII.

OF THE ELEVATION OF MOUNTAINS.

When mountain chains are composed of stratified rocks, as is frequently the case, these strata are usually very much inclined, and sometimes almost vertical. This has led modern geologists to adopt an opinion first advanced by Dr. Hutton, and

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* *Histoire* de l'Académie Royale. Mémoires, 1700, p. 103.

strenuously supported by Mr. Playfair, that these strata were originally horizontal, and that they owe their inclined or vertical position to their having been elevated by a force acting from below. Against the sides of these inclined strata it is usual to find other stratified rocks abutting, and which occupy a horizontal position. It is difficult to avoid concluding from these phenomena that the mountain chains so circumstanced were elevated and brought into their present position before the horizontal beds abutting against them had been deposited. Thus, for example, if a range of mountains composed of the different beds belonging to the oolitic formation, placed in an inclined or vertical position, be abutted against by horizontal beds of the green sand or chalk formations, it is inferred that the oolitic mountains were elevated before the deposition of the green sand or chalk. If mountains composed of inclined beds of red sandstone formation be abutted against by horizontal beds of the oolitic formation, it is concluded that the red sandstone mountains were elevated before the deposition of the oolitic beds. Humboldt, Von Buch and some others of our most eminent geologists, have examined the different mountain ranges of Europe, and have concluded that they may be separated into three or four different systems, distinguished by the nature of their constituents, and by the bearings of their component parts to any assumed meridian.

M. Elie de Beaumont has carried his generalization much farther, and has concluded that each of these great systems of mountain chains, marked on the map of Europe by given parallel lines of direction, has also a given period of elevation, limited and defined by direct geological observation. All those chains which have been elevated at the same time are parallel to each other. Hence by determining the parallelism of chains we ascertain those which were elevated together; while the nature of the horizontal beds leaning against these inclined strata, enables us to determine the relative age of the elevation of each of these chains, and thus to deduce the order in which these mountain chains were raised into their present position. It will be proper to give a view of these different systems of mountain chains, which amount to twelve in number.

1. The oldest mountain chains with which we are at present acquainted are those in the south of Scotland, the north-west of England, Wales and Cornwall. The lake mountains in Cumberland have been investigated with much skill and in-

dustry by Professor Sedgwick; he has shown that they run from N. E. $\frac{1}{4}$ E. to S. W. $\frac{1}{4}$ W. They consist of slate rocks, and obviously lie under the coal beds which abut against their sides. Sedgwick has shown that they were elevated before or during the period of the deposition of the old red sandstone. Other circumstances lead to the conclusion that they were elevated before the deposition of the newest of the transition, namely, the Trilobite limestone of Dudley and Tortsworth. The chain of mountains running, in Scotland, from St. Abb's Head to the Mull of Galloway, or rather to Loch Ryan, is parallel to the Westmoreland chain and of the same age. The greywacke chain in the Isle of Man, and the chains of slate rocks in Anglesea and North Wales, and even in Cornwall, run in a parallel direction, and are, doubtless, of the same period. On the continent the mountain chains of Hundsrück, of the Eifel, Nassau and several portions of the Vosges have the same direction and are of the same age.

2. The *second system* consists of the Belchen mountains in the Vosges and the Hügel in Calvados. It would appear from a careful examination of the Westmoreland mountains that they were elevated before the deposition of the newer members of the slaty series. The transition mountains in the south of Ireland, described by Weaver, appear to have been elevated at a somewhat later period than those in Westmoreland and Wales and the south of Scotland. Those of Hügel, in the Bocage, and those constituting the south-east corner of the Vosges appear to belong to the same era with those in the south of Ireland. The direction of these mountain chains is north-east and south-west.

3. The *third mountain chain* in the order of time is that which runs from the border of Scotland through the north of England, as far as Derbyshire and Yorkshire. This mountain chain, distinguished by the Romans by the name of the Penine Alps, consists of stratified rocks belonging to the lower part of the series of the coal beds, and is surrounded in almost every direction by the great coal formation of the north of England. This mountain chain runs very nearly due north and south, inclining a little, however, to the north-west and south-east direction.

It is not probable that this mountain chain is isolated. M. Elie de Beaumont is of opinion that the problematical rocks which cut through the coal formation of Shrewsbury and Coal*brookedale, the* Malvern hills and the rocks which traverse the coal formation of Bristol in a north and south direction belong to the same period.

4. The *fourth system of mountain chains* constitutes the mountains of South Wales and of the Netherlands. From the neighbourhood of Aix la Chapelle to the small islands in the Bay of St. Bride in Pembrokeshire, constituting a tract of nearly five hundred miles in length, we find the different beds of the coal formation in every place not covered by some of the newer formations. There are however parts, as at Lüttich, Mons, Valenciennes, Norotingen (in the Boulognais) and the foot of the Mendip hills, where the most wonderful contortions present themselves to our view. In a great part of this tract the same beds appear, which nowhere reach to any great height, and are covered with newer formations lying in a horizontal position. The direction of this low chain is nearly west by north; it consists chiefly of members of the coal formation. In the neighbourhood of Bristol the magnesian conglomerate covers, in a horizontal position, the inclined beds of the coal formation. At Saarbruck the sandstone of the Vosges is found in a similar position. Hence the elevation of the beds of this chain must have preceded the deposition of the magnesian conglomerate of Bristol, and the sandstone of the Vosges.

5. To the fifth system Von Buch has given the name of the *system of the Rhine.* It consists of two symmetrical mountain chains, the one constituting the Vosges mountains, and the other those in the Black Forest. The Rhine flows between these ranges, and they enclose the greatest part of the province of Alsace. They consist partly of the sandstone of the Vosges, and exhibit great rifts and dislocations, the beds having been forced out of their original position. The elevation of these mountain chains must have preceded the deposition of the new red sandstone, the muschelkalk and the keuper, which fill up the interval between them, constituting the flat country of Alsace.

6. The *sixth system* consists of elevations which run in a north-westerly and south-easterly direction, and which were elevated between the time of the deposition of the keuper, which belongs to the new red sandstone formation, and the Luxemburg sandstone, which belongs to the oolitic formation.

The great oolitic formation, known on the continent partly by the name of Jura limestone, and partly by that of roestone and oolite, from the granular structure of many of its beds, was deposited, originally, in almost horizontal beds. It follows the contour of the sixth class of mountain chains in which the variegated sandstone, the muschelkalk and the keuper, as well as all older beds, are obviously elevated out of their original position. The beds of the Jura formation, on the contrary, stretch out in a horizontal position till they abut against the acclivity of the hills belonging to the sixth class, and even cover the upper parts of their inclined beds.

In the interior parts of France, at Avallon and Autun, we see hills running from the north-west to the south-east, and consisting of granite rocks, of inclined beds of the coal formation, and of arkose beds of the same age with the keuper. Similar hills occur in Brittany and in La Vendée; in Germany, constituting the mountains between Bohemia and Bavaria, the Thuringerwalde and various other ranges of hills in Saxony and Westphalia, very well laid down in Hoffmann's fine map of the north-west of Germany. This sixth class of mountain chains has obviously been elevated between the time of the deposition of the keuper and that of the Luxemburg sandstone and lias.

7. Many appearances show that in the interval between the periods of rest which correspond with the deposition of the Jura formation and that of the green sand a sudden and important change in the nature of the deposits took place; this sudden alteration appears to correspond with the elevation of the beds of a system of mountains under which that of the Côte d'Or in Burgundy, of Mont Pilas in Forez, of the Cevennes, the heights of Larmac, and even the Erzegebirge, between Saxony and Bohemia, may be reckoned.

The Erzegebirge, the Côte d'Or, the Pilas and the Cevennes belong to a set of elevated beds which have a north-east and south-west direction, stretching from the mouth of the Elbe to the canal of Languedoc. A careful examination of these mountains leads to the opinion that they were elevated at once by the same convulsion of nature. In France the beds of the Jura formation correspond with the direction of these mountain chains, while in Saxony the beds of green sand which abut against the sides of the mountains have a horizontal position. Hence it follows that the Erzegebirge were elevated before the deposition of the green sand, while the mountains of the Côte d'Or must have been elevated after the deposition of the Jura formation. And if all these mountains were elevated at one and the same time, it is obvious that this elevation must have taken place between the deposition of the Jura formation and that of the green sand and chalk.

8. *System of Mont Viso.* The French Alps and the south-west end of Jura, from Antibes and Nizza to Pont d'Ain and Lons le Saulnier, exhibit a range of mountains and elevations running nearly in a north north-west and south south-east direction, and in which the older beds of the green sand formation and the chalk, as well as those of the Jura formation, have an inclined position. The primary mountain pyramid of Mont Viso is traversed by mighty dislocations, obviously produced at the time that these chains of mountains were elevated. At the foot of the eastern crest of Devolny, which exhibits elevated beds of green sand and chalk, there exist, near the Col de Bayard, north from Gap, horizontal beds of the same formation, distinguished from the older beds by the presence of a great number of nummulites, cerithia, ampullariæ and other shells, which must have been deposited long before the appearance of any of the tertiary formations. It is evident that the rocks, constituting the Mont Viso system, must have been elevated in the interval between the deposition of the oldest and newest of the green sand and chalk beds.

9. *System of the Pyrenees.* The mountain chain of the Pyrenees runs from Cape Ortegal in Gallicia, to Cape Cross in Catalonia, from the west north-west to east south-east. From the observations of several geologists, it appears that tertiary formations stretch themselves horizontally to the foot of these mountains without entering into their composition, as is the case with the chalk. It follows from this, that the Pyrenees acquired their present position, with reference to the neighbouring portions of the earth's surface, between the period of the deposition of the greensand and chalk, which according to the observations of M. Dufrenoy are found on the very summits of these mountains, and the deposition of the tertiary beds of different ages, which that geologist traced in a horizontal position to the foot of the mountains.

The mountain chain of the Apennines is parallel to that of the Pyrenees. We allude to the mountains between Modena and Florence, and between Bari and Tarentum. And the age of these mountains seems to be the same as that of the Pyrenees. The Julian Alps between Venice and Hungary, as likewise a part of the mountains of Croatia, Dalmatia, Bosnia, and even of Greece, seem to belong to the same era.

It deserves attention, that a line drawn from the neighbourhood of London to the mouth of the Danube constitutes the southern boundary of an immense tract of flat country, which is almost every where covered with new formations. This line is nearly parallel to the mountain chains of the Pyrenees and the Apennines. It perhaps marks the southern border of an extensive sea, which at the time of the deposition of the tertiary beds covered a great portion of Europe. Towards the south it was bounded by a continent, divided by various bays, of which the mountain chain of the Pyrenees constituted the highest summit. The fragments of tertiary beds which have been deposited in the hollows of this continent often run in lines parallel to the direction of the mountain chain of the Pyrenees.

M. Elie de Beaumont is of opinion that the elevation of the hills in the neighbourhood of Paris and London, and in the Isle of Wight, took place at the same period with that of the Pyrenees.

10. *System of Corsica and Sardinia.* The tertiary beds do not proceed to any great extent without interruptions. Various such may be observed, all of which correspond with a range of mountainous heights running in a north and south direction. M. Elie de Beaumont has concluded, from a careful examination of the tertiary formations in France, that they are divisible into two series; one of which, consisting of plastic clay, coarse limestone, and the whole gypsum beds, together with the uppermost marl, scarcely extends farther south than Paris; while the other, represented in the north by the sandstone of Fontainbleau, the upper fresh-water formation, and the *fahluns* of Touraine, constitutes almost the whole tertiary formations in the south of France and in Switzerland, especially the brown coal beds at Fuveau and Kopfnach. The sandstone of Fontainbleau, lying on the marl of the gypsum formation, constitutes the first bed of this system, just as the sandstone of the lias lying on the Keuper constitutes the first bed of the Jura formation. The first stands in the same relation to the Arkose of Auvergne that the second does to the Arkose of the Jura formation at Avallon.

These two tertiary formations are distinguished by the fossil remains of large animals which they contain. The bones of Anoplotherium and Palæotherium found at Montmartre characterize the first, while other species of Palæotherium, almost the whole species of the genus Lophiodon, the whole genus of Anthracotherium, and the oldest species of the genera mastodon, rhinoceros, hippopotamus, castor, &c. characterize the second.

It is the line dividing these two tertiary formations from each other, which constitutes the class of mountains which M. Elie de Beaumont considers as constituting his tenth system. These mountains run in a northerly and southerly direction. It is the beds of the second set of tertiary deposits that constitute the contour of these mountains.

To this system belong the heights of the Loire and the Allier, with their continuation by Clermont, and the volcanic rocks of Monts Dômes, so well described by M. Ramond. The broad valleys between these ranges of mountains constitute the fresh-water formations of Limagne, Auvergne, and the large valley of the Loire.

The valley of the Rhone runs likewise from north to south, and is to a certain level covered with tertiary formations, the lower beds of which have much resemblance to those of Auvergne, and are obviously fresh-water deposits, while the upper beds belong to a sea-water formation. Here the regularity of the tertiary formations is destroyed by the upheaving which the surface of the earth has undergone, in consequence of the elevation of the western Alps, and of the principal chain of the Alps.

The mountains in Corsica and Sardinia run in the same direction, and are of the same age. Mountains having the same direction occur also in the Apennines and in Istria, in Hungary, Servia, Macedonia, and Thessaly. A chain of the same kind seems to constitute the east coast of the Morea, and to appear in the island of Candia. The range of Mount Lebanon, and those heights which run along the Dead Sea to the borders of the Red Sea appear to belong to the same era, as may be concluded from the late observations of Botti.

11. *System of the Western Alps.* The elevation of the western chain of the Alps is manifestly subsequent to the deposition of that tertiary formation, to which the French geologists have given the name of *molasse coquillière.* This formation lies near Lyons in horizontal beds, and covers the primary rocks of Forez. But as it approaches the Alps it becomes elevated, and at Rigi reaches a height of 6152 feet above the level of the sea. Messrs. Sedgwick and Murchison observed that the chalk and the tertiary beds, which at the foot of the Bohemian mountains have a horizontal position, become elevated on the other side of the Danube, and appear

at considerable heights in the Alps. Messrs. Murchison and Lyell have observed that the tertiary formations in the Italian side of the Alps have assumed a similar position. And Messrs. Brongniart and Buckland observed similar formations in the Diablerets elevated to the limit of perpetual snow.

Though we are accustomed to consider the Alps as constituting a single and continued chain of mountains, there can be no doubt that in reality they constitute more than one system, differing from each other both in age and in the direction of the beds. Throughout almost their whole extent, and especially towards their eastern extremity, we meet with traces of several small chains which have the direction of the Pyrenees, and like them have been elevated before the deposition of the tertiary beds. But these ancient displacements are often covered by newer formations. The highest and most complicated part of the Alps, the portion in the neighbourhood of Mont Blanc, Mont Rosa, and the Finsteraarhorn, consists principally in the crossing of two of these newer systems, which meet at an angle of from 45° to 50°, and which are distinguished from the Pyreneo-Apennine system, both by their direction and their age. In consequence of the two systems crossing each other, they form at the summit of Mont Blanc a knee. From Austria to Wallis, the direction of the beds is E. ¼ N. E. to W. ¼ S. W. But at Mont Blanc they suddenly assume the direction N.N.E. to S.S.W.

In the innermost system of the mountain chain, of which the Western Alps are mostly composed, we perceive no newer beds than those of chalk, while these chains rise from a bottom which had already assumed an elevated position immediately before and immediately after the deposition of the chalk; that is to say, at the time of the elevation of Mont Viso and the Pyrenees. It is obvious from the appearance and position of the beds constituting the Western Alps, and of the formations resting on them, that they were elevated after the deposition of the newest tertiary formations in the neighbourhood.

The beds of *molasse coquillière* are found upon the hill of Superga, near Turin, and on the west side of the mountain of the great Chartreuse, near Grenoble. Many other similar examples might be given, showing clearly that the Western Alps have been elevated after the deposition of the *molasse coquillière.*

12. System of the high chain of the Alps, from Wallis to

Austria. The valley of the Isère, of the Rhone, of the Soane, and the Durance, exhibit two very different alluvial formations, which are well distinguished from each other by their position and their characters.

The inundations which brought the materials of the first of these formations, appear to have proceeded from the fresh water lakes which once covered the northern side of the departments of the Isère, and of other places situated in the departments of the Lower Alps. The materials of the second formation, on the other hand, appear to have been deposited from streams which rushed with violence into the Mediterranean. It is usually called a diluvial stream, though it must have existed before the creation of man, but when other animals which it destroyed existed on the earth. M. Elie de Beaumont is of opinion, that it was occasioned by the sudden melting of the snow on the summits of the western Alps, at the time when the elevation of the principal Alpine chain took place. M. de Beaumont deduces from a long series of observations, that the principal Alpine chain was elevated after the deposition of the former of these diluvial formations, and before that of the latter. This he deduces from the horizontality of the latter and the inclined position of the former, when they are in contact with the beds of this Alpine chain.

Such is a short outline of the opinions entertained by M. Elie de Beaumont, respecting the relative ages of the different mountain chains which occur in Europe; but sufficient, we trust, to give our readers an idea of his general views. There can be little hesitation in admitting, that the method of induction pursued is unexceptionable, and that, provided the observations on which this induction is founded be accurate, he has made out his positions, so far as the relative ages of the different mountain chains are concerned. His opinion, that all of these mountain chains which are parallel to each other, were raised at once and with violence, does not seem to me to rest upon such unexceptionable evidence. The induction proves only, that each mountain chain must have been elevated after the deposition of those beds that rest against it in a vertical or inclined position, and before the deposition of those beds which abut against it in a horizontal position; but it gives us no information respecting the time which may have elapsed between the deposition of the former and the latter. M. de Beaumont, not satisfied with the European chains, has applied his opinions to the elevation of mountains in general, and has indulged in a series of such bold conjectures, that in a work like this, the object of which is to lay facts rather than conjectures or speculations before the reader, we hesitate about venturing to pursue the subject farther. At the same time, we strongly recommend M. de Beaumont's views to the attention of all practical geologists in their future observations.*

CHAP. XIX.

CONCLUSIONS.

Thus we have taken a view of the structure of the whole surface of the earth, so far as we are acquainted with it. Before quitting the subject, it will be worth while to take a short review of the principal facts, in order to discover what theoretical conclusions respecting the alterations to which the earth has been subjected since its original formation, they may enable us to draw.

1. The first thing that strikes us is, that all the formations of which the crust of the earth is composed, from the very highest and most recent, down to the very lowest to which we have access, are composed of regular beds lying over each other, sometimes exceedingly thin, sometimes of enormous thickness; but proceeding unvaried for a considerable way. Such regular stratification can be accounted for only by the action of the sea. It follows, therefore, that the whole crust of the earth hitherto examined, is composed of strata, which have been arranged in beds under the surface of the ocean. Consequently the surface of the earth, and its crust to a certain depth, presents no rocks or formations identical with those that existed at the original formation of it. The whole has been disintegrated and new modelled under the waters of the ocean.

2. Besides the stratified rocks, constituting so great a proportion of the earth's crust, there exists another set of rocks which exhibit no traces of stratification, but which exhibit very strong indications of having been pushed upwards from below in a state of fusion, and of having afterwards

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* The reader will find a short but excellent view of the whole subject, in *a letter by M.* Elie de Beaumont to M. Von Humboldt, in Poggendorff's *Annalen, vol. xxv. p.* 1.

solidified and crystallized more or less slowly. These are granite, porphyry, serpentine, the trap rocks, and lavas. These rocks were not all formed at once, nor under the same circumstances. They seem to have been protruded occasionally at all times from the deposition of the gneiss, mica slate, and clay slate formations, to that of the chalk, and even of the fresh water formation—a period of immense extent, and to which, indeed, we have no means of assigning any limits.

The formation and protrusion of these plutonic rocks may have been connected with the solidification and elevation of the stratified rocks. This solidification and elevation must have taken place successively, and must have occupied a very long period, to which, like the last, we have no means of assigning any limits.

3. The gneiss, mica slate, and clay slate beds, contain no remains of vegetables or animals, though such remains are to be found in all the other formations, except the plutonic. Either no animals or plants existed on the earth at the time when these beds were deposited at the bottom of the sea; or if they did, and if their remains were mixed with these beds at the time when they were deposited, the agent, (probably *heat*) by means of which these beds were solidified and elevated above the surface of the sea, was powerful enough to obliterate all traces of fossil remains. The former of these opinions is much more probable than the latter; for we can hardly conceive any thing short of fusion to be capable of obliterating all remains of shells and bones. But fusion would, at the same time, have obliterated all traces of stratification, which still continues very evident in these rocks. Indeed, the line of demarcation between different beds in these rocks, is often very distinct. This may be seen in the beds of quartz and of limestone which occur in the clay slate mountains of the Grampians.

4. All the formations above the clay slate, contain fossils both of plants and animals, and from the nature of these fossils, they may be divided into several groups.

The first of these begins with the greywacke series, and consists of what are usually called the *transition formations*, the *coal measures*, and the *new red sandstone;* for the fossils in all these great formations approach very nearly to each other. The vegetable fossils are casts of trees, both monocotyledonous and dicotyledonous, equisetaceæ, filices, &c. not one of which is identical with those at present vegetating upon the earth. From the great size which these fossil plants attained, compared with the analogous species at present growing in the torrid zone, it has been concluded, that when these formations were deposited, the temperature was much milder than at present, higher indeed than that of the torrid zone at present. But nothing can be more hazardous than to draw such conclusions from premises so obviously defective. These plants, for any thing that we know to the contrary, though analogous to plants at present vegetating in the torrid zone, may have been adapted for a colder climate; just as the mammoth, as was evident from the immense quantity of hair with which the carcase found in Siberia was clothed, was intended by nature to live in the cold climate of the north of Europe, and Asia and America.

The animal fossils consist of remains of *fish*, hardly any of which have been determined, and certainly not agreeing with any species of fish at present known to exist. Zoophyta, radiaria, annulata, conchifera, mollusca, and crustacea, are the only other classes of animal fossils that have been observed. No remains of birds, amphibia, or quadrupeds, have ever occurred in any of the beds, from the greywacke to the new red sandstone inclusive. The deposition of this long suite of beds must have occupied a very long series of years, and during the whole of it we have no evidence that any land animals existed, since all the fossils hitherto discovered belong to sea animals, and, excepting a few fishes, to sea animals of the lowest class. It is certainly possible that land animals might have existed at the time of the deposition of these beds, though the remains of none of them have been detected; yet as such remains are found in the beds situated above the new red sandstone, though wanting in those below it, the probability lies in the supposition that at the deposition of the whole series of beds, from the greywacke to the new red sandstone inclusive, the earth was uninhabited by quadrupeds, amphibia, or birds, though it abounded in shell fish, and zoophites and crustaceous animals. Now, these are perhaps the very lowest tribes of animals at present inhabiting the earth. It has been already observed, that not a single species found fossil in these beds agrees with any animal at present inhabiting the sea or fresh water. Hence it is clear, that at the deposition of these beds *the inhabitants* of the ocean were entirely different from those which it contains at present. To what are we to ascribe this circumstance? Certainly to some alteration either in the temperature or the state of the ocean.

5. The second group of fossiliferous formations consists of the oolite, which in England is composed of so great a number of beds. In them the number of fossils is immense. The vegetable fossils are not so numerous as in the coal measures, but more varied. Besides algæ, equisetaceæ and filices, there are found in the oolite fifteen species of cycadeæ, five species of coniferæ, and one species belonging to the natural order of *lily*.

The zoophites, radiaria, and annulata, are exceedingly numerous, and consist in general of species different from those found in the coal beds, though some are common to both; even many of the genera are different. The shells are very numerous, amounting to about seven hundred and fifty species, the greater number of which differ from those in the coal measures. The ammonites and belemnites are particularly abundant. But the remarkable circumstance is, that amphibious animals first make their appearance in the oolite beds. The crocodile, the megalosaurus, geosaurus, plesiosaurus, ichthyosaurus, pterodactylus, &c., to the number of twenty-nine species, have been found, particularly in the lias and the Stonefield slate. It is unnecessary to observe that all these species are extinct. Finally, a species of didelphis or opossum has been found in the Stonefield slate. Remains of fish and even of insects have been also observed, but scarcely in a state of preservation sufficient to enable anatomists to make out the species.

The deposition of the oolite, then, marks a remarkable era in the history of the earth. When the beds of which it is composed were formed at the bottom of the sea, the earth was inhabited by amphibious animals, some of them of prodigious size, and at least one land quadruped of the opossum tribe existed. The vast size of these animals, similar only to those that exist at present in the torrid zone, would seem to indicate that the climate in England, and those parts of France and Germany where such fossils have been found, was much milder than it is at present.

6. The third group of fossiliferous formations is the chalk. In it the number of fossil plants hitherto observed is but small. The fossil shells are exceedingly numerous, and in general different from those in the oolite beds, and all of them belong

to extinct species. But the great tribe of fossils which distinguish the chalk are the *radiaria*, especially galerites and spatangi. No quadruped fossil has been hitherto met with, but several amphibious animals, particularly the Mososaurus Hoffmanni, a species of crocodile, and some other reptiles, whose genera have not been determined.

Thus the chalk formation was deposited at the bottom of the sea before any evidence can be produced that the earth was inhabited by quadrupeds, with the single exception of the didelphis found in the Stonefield slate. All the fossils found in the chalk, and in the formations below the chalk, belong to species of animals and plants no longer existing. Many of the genera even have perished, and all traces of these ancient inhabitants of the earth, except what are deducible from their fossil remains, are lost.

7. The formations above the chalk exhibit a new era in the history of the earth, as they contain abundance of the fossil remains of land animals, quadrupeds, and even birds. The formations above the chalk, usually called *tertiary*, have been divided, it will be recollected, into three groups; namely, the *eocene*, the *miocene*, and the *pliocene*.

In the eocene formations, which have been examined with so much care in the neighbourhood of Paris and of London, the number of fossil shells which occur is prodigious. Almost the whole of them belong to extinct species, though there are a very few which still continue to live in the adjacent seas.

It is in this formation that the fossil remains of two new genera of quadrupeds have been found, namely, the *palæotherium* and *anoplotherium;* the former of which resembles the tapir, and the latter the camel. Ten species of the former genus, and five of the latter, have been discovered by Cuvier in the gypsum beds near Paris. Three carnivorous animals have also been found in the same beds. An account has been already given (p. 85) of the 78 different fossil quadrupeds discovered by Cuvier in these beds. To this account the reader is referred to save repetition. It is almost unnecessary to mention, that not one of these species at present exists. All the fossils belong to extinct species of quadrupeds.

Thus when the eocene beds were deposited at the bottom of the sea, the earth contained quadrupeds as it does at present, and several of these animals were of enormous size. But as *all the species* at that time existing, and even some of the genera, were different from those at present inhabiting the earth, and as almost all the inhabitants of the sea have changed since that period, it is obvious that it must be exceedingly remote; though we have no data to enable us to form even a conjecture respecting the length of time which has elapsed since the deposition of these beds. Their elevation, though long preceding the commencement of history, must of necessity have taken place at a later period.

8. The miocene beds lie over the eocene when both occur together, and therefore are newer. Like the eocene beds they abound in fossil shells, about one-sixth of which still exist in the neighbouring seas. They contain also abundance of fossil bones of quadrupeds, some of which are the same as those that occur in the eocene beds, but by far the greater portion are different. They all belong to extinct species. Thus after the deposition of the eocene beds, a prodigious interval must have taken place before the deposition of the miocene, since almost the whole inhabitants of the earth had during it changed their type.

9. The pliocene beds lie over the miocene when both occur together. They also contain a vast number of fossil shells, about one half of which belong to extinct species, and one half to species still living in the neighbouring seas. Mr. Lyell is of opinion that many of the extinct volcanoes may be referred to the pliocene period. It is therefore referrible to a time much posterior to the miocene, though we have no data to conjecture about dates. Fossil quadrupeds have not yet been much met with in these beds. Doubtless they will in general belong to extinct genera. But the investigation of the pliocene beds is still very imperfect, except as far as relates to the shells which they contain.

10. Above the pliocene beds, or at least in caverns filled with mud and stalagmite, occur fossil bones of animals, the species of which is now extinct, though all referrible to existing genera. The deposition of these bones is, therefore, referrible to a period of very ancient date, though probably posterior to the deposition of the pliocene beds. These depositions, to which the term *diluvial* has been applied, constitute a tenth era in the history of the earth. The deposition of the alluvial beds, which is still going on, and in which are found the remains of the vegetables and animals at present inhabiting the earth, constitutes an eleventh era, to which the name of *modern* may be applied.

We may now sum up the facts which seem to have been ascertained respecting the history of the earth in a few sentences.

When it came originally out of the hands of the Creator it was in a liquid state, and it assumed its present shape before it became solid. Hence the axis can have undergone no change since the original solidification, and the old notion entertained by Halley and others about the interior of the globe being hollow, cannot be correct. The mean specific gravity of the earth is even incompatible with the idea that any great portion of the interior is filled with water.

What was the original structure of the earth after its solidification we have no means of knowing, because all the rocks which at present constitute its crust have been evidently formed at the bottom of the sea by the destruction of former rocks, or have been forced up from below in a state of fusion.

Ten different eras may be distinguished during the formation and deposition of the beds constituting the crust of the earth at the bottom of the sea, during each of which the nature of the vegetables and animals inhabiting the earth underwent great changes. An immense number of ages must have elapsed during these successive depositions of strata.

These beds, after having been thus deposited at the bottom of the sea, must have been elevated by some mighty agent, and gradually raised to their present height above it. For the phenomena are inconsistent with the notion of any great subsidence of the surface of the sea.

There is one other topic to which it may be proper barely to allude, before bringing this part of the work to a conclusion. It has been affirmed by some that the discoveries made by geologists are inconsistent with the Mosaic account of the creation; and, on this account, attempts have been made by well-meaning, but ill-advised individuals, to prevent the cultivation of geological science. Nothing can be worse judged than such an attempt; it is a kind of acknowledgment that improvement in science is inconsistent with the prosperity of the Christian religion, and that ignorance is the mother of devotion.

These opinions on both sides proceed entirely from mistaken views. It never was the intention of revelation to teach science to mankind. Such a proceeding would have been inconsistent with the obvious intention of the Deity—that scientific investigations should occupy mankind, and that progress in them should be rewarded by a feeling of happiness of no ordinary kind, resulting from their successful pursuit.

The object of revelation was obviously to teach mankind their duties to their God, their neighbour and themselves. Had it displayed more science than existed at the time when it was made, it would not only have defeated the very object in view, but it would have been necessarily unintelligible to those for whom it was intended.

The cosmogony of Moses is nothing more than this: "In the beginning God created the heavens and the earth;" a proposition which no man of science can refuse to admit, and with which all true geological knowledge is perfectly compatible. To attempt to deduce geological theories from the writings of Moses, is to apply these writings to a purpose for which they were never intended, and to which they can never apply.

The following table exhibits a view of the fossil plants hitherto found and classified, arranged according to the formations in which they occur.

I. FOSSIL PLANTS IN TRANSITION FORMATIONS.

1. *Dicotyledones.*

Genus I. Sigillaria tesselata.
Voltzii.
II. Stigmaria ficoides.
III. Asterophyllites pygmæa.

2. *Filices.*

Genus I. Cyclopteris flabellata, Br. lxi. 4, 5, 6.
II. Sphenopteris dissecta.
III. Neuropteris Soretii, Br. lxx. 2.
IV. Pecopteris aspera.

3. *Lycopodiaceæ.*

Genus I. Calamites radiatus, Br. xxvi. 1, 2.
Voltzii, Br. xxv.

4. *Algæ.*

Genus I. Fucoides antiquus, Br. iv. 1.
circinatus, Br. iii. 5.
dentatus, Br. vi. 9 to 12.
Serra, Br. vi. 7, 8.

II. FOSSIL PLANTS IN COAL.

1. *Dycotyledones.*

Genus I. Sigillaria alveolaris.
appendiculata.
Boblayi.
Brardii.
Candollii.
canaliculata.
Cortei.
cuspidata.
Davreuxii.
Dournaisii.
elegans.
elliptica.
elongata.
hexagona.
Hippocrepis.
Knorrii.
lævigata.
lævis.
mammillaris.
monostachya, L. and H. lxxii.
notata.
oculata, L. and H. lix.
orbicularis.
organum, L. and H. lxx.
pachyderma, L. and H. liv.
peltigera.
punctata.
reniformis, L. and H. lxxi.
Serlii.
subrotunda.
tesselata.
transversalis.
trigona.
II. Favularia tesselata, L. and H. lxxiii. lxxiv. lxxv.
III. Stigmaria ficoides.
fucoides, L. and H. xxxi. to xxxvi.
intermedia.
minima.
reticulata.
rigida.
tuberculosa.

Stigmaria Weltheimiana.
Genus IV. Bothrodendron punctatum, L. and H. lxxx. lxxxi.
V. Pinites Brandlingi, L. and H. i.
Eggensis, L. and H. iii.
medullaris, L. and H. iii.
Withami, L. and H. ii.
VI. Knorria taxina, L. and H. xcv.
sellonii, L. and H. xcvii.
VII. Sphenophyllum dentatum.
dissectum.
emarginatum.
erosum, L. and H. xiii.
quadrifidum.
Schlotheimii.
truncatum.
VIII. Peuce Withami, L. and H. xxiii. xxiv. and xxv.
vii. viii.
IX. Asterophyllites Brardii.
comosa.
delicatula.
diffusa.
equisetiformis, L. and H. cxxiv.
foliosa.
galioides.
grandis, L. and H. xvii.
hippuroides.
longifolia.
rigida.
tenuifolia.
tuberculata, L. and H. xiv.
X. Pinnularia capillacea, L. and H. cxi.
XI. Hippurites gigantea, L. and H. cxiv.
XII. Megaphyton approximatum, L. and H. cxvi.
distans, L. and H. cxvii.
XIII. Halonia tortuosa, L. and H. lxxxv.
gracilis, L. and H. lxxxvi.
XIV. Phyllotheca.
XV. Annularia brevifolia.
fertilis.
floribunda.
longifolia.
minuta.
radiata.
spinulosa.

Genus XVI. Bechera grandis.

2. *Monocotyledones.*

Genus I. Nœggerathia flabellata, L. and H. xxviii. xxix.
foliosa.
II. Flabellaria borassifolia.
III. Cannophyllites Virletii.
IV. Cyperites bicarinata, L. and H. xliii.
V. Poacites æqualis.
striata.
VI. Sternbergia angulosa.
approximata.
distans.

3. *Filices.*

Genus I. Cyclopteris dilatata, L. and H. xci. B.
obliqua, L. and H. xc. Br. lxi.
orbicularis, Br. lxi. 1, 2.
reniformis, Br. lxi. bis. i.
trichomanoides, Br. lxi. bis. iv.
II. Glossopteris angustifolia, Br. lxiii. 1.
Browniana, Br. lxii.
III. Schizopteris adnascens, L. and H. ci.
anomala.
IV. Caulopteris primeva, L. and H. xlii.
V. Sphenopteris acuta, Br. lvii, 6, 7.
adiantoides, L. and H. cxv.
affinis, L. and H. xlv.
alata, Br. xlviii. 4.
artemisiæfolia, Br. lvi. and lvii. 1, 2.
asplenioides, Sternb. xvi.
bifida, L. and H. liii.
Brardii.
caudata, L. and H. xlviii.
conferta, Sternb. vi. 16.
crenata, L. and H. xxxix. c.
crithmifolia, L. and H. xlvi.
delicatula, Br. lviii. 4.
dilatata, L. and H. xlvii.
dissecta, Br. xlix. 2, 3.
distans, Br. liv. 3.
Dubuissonis, Br. liv. 4.
elegans, Br. liii. 1, 2.
fragilis.

Sphenopteris furcata, Br. xlix. 4, 5.
gracilis, Br. liv. 2.
Gravenhorstii, Br. lv. 3.
Hœninghausi, Br. lii.
latifolia, Br. lvii. 1, 2, 3, 4, 5.
linearis, Br. liv. 1.
Loshii.
nervosa, Br. lvi. 2.
obovata, L. and H. cix.
obtusiloba, Br. liii. 2.
rigida, Br. liii. 4.
Schlotheimii, Br. li.
stricta, Br. xlviii. 2.
tenella, Br. xlix. 1.
tenuifolia, Br. xlviii. 1.
trichomanoides, Br. xlviii. 3.
tridactylites, Br. l.
trifoliata, Br. liii. 3.
Virletii, Br. lviii. 1, 2.
multifida, L. and H. cxxiii.
Genus VI. Neuropteris acuminata, L. and H. li. Br. lxiii. 4.
acutifolia, Br. lxiv. 6, 7.
angustifolia, Br. lxiv. 3, 4.
auriculata, Br. lxvi.
Cistii, Br. lxx. 3.
conferta, Sternb. xvii.
cordata, L. and H. xli. Br. lxiv. 5.
crenulata, Br. lxiv. 2.
decurrens, Sternb. xvii.
elongata, Sternb. xvii.
flexuosa, Br. lxv. 2, 3, and lxviii. 2.
gigantea, L. and H. lii. Br. lxix.
Grangeri, Br. lxviii. 1.
heterophylla, Br. lxxi. and lxxii. 2.
Loshii, L. and H. xlix. Br. lxxii. 1, and lxxiii.
macrophylla, Br. lxv. 1.
microphylla, Br. lxxiv. 6.
oblongata.
obovata, Sternb. xvi.
plicata, Sternb. xvi.
rotundifolia, Br. lxx. 1.
Scheuchzeri, Br. lxiii. 5.

Neuropteris Soretii, L. and H. l.
tenuifolia, Br. lxxii. 3.
Villiersii, Br. lxiv. 1.
Genus VII. Pecopteris abbreviata.
adiantoides, L. and H. xxxvii.
affinis, Br. c. 2, 3.
aquilina, Br. xc.
arborescens, Br. cii. and ciii. 1.
arguta, Br. cviii. 3.
aspera.
aspidoides, Br. cxii. 2.
blechnoides.
Brardii.
Bucklandi, Br. xcix. 2.
Candolliana, Br. c. 1.
cistii, Br. ciii.
conchitica.
crenulata, Br. lxxxvii. 1.
cristata.
cyathea, Br. ci. 1, 2, 3, 4.
Davreuxii, Br. lxxxix.
Defrancii, Br. cxi. and cxii. 1.
gigantea.
Grandini, Br. xci. 1—4.
hemitelioides, Br. cviii. 1, 2.
heterophylla, L. and H. xxxviii.
Lepidorachis, Br. ciii. 1, 5.
lonchitis, Br. lxxxiv. 1—7.
longifolia, Br. lxxxiii. 2.
Mantelli, Br. lxxxiii. 3, 4.
marginata.
Miltoni, Br. cxiv.
nervosa, L. and H. xciv., Br. xciv. and xcv. 1, 2.
Nestleriana, Br. cxii. iv.
obliqua, Br. cxvi. 1—4.
oreopteridis, Br. civ. 1, 2, and cv. 1, 2, 3.
ovata, Br. cvii. 4.
platyrachis, Br. ciii. 4, 5.
Pluchenetii, Br. cvii. 1, 2, 3.
Polymorpha, Br. cxiii.
pteroides, Br. cv.

Pecopteris repanda, L. and H. lxxxiv.
Sauveurii, Br. xcv. v.
Schlotheimii.
Serlii.
Serra, L. and H. cvii.
sinuata, Br. xciii. 3.
laciniata, L. and H. cxxii.

VIII. Odontopteris Brardii, Br. lxxv. and lxxvi.
crenulata, Br. lxxviii. 1, 2.
minor, Br. lxxvii.
obtusa, L. and H. xl.
Schlotheimii, Br. lxxviii. 5.

4. *Lycopodiaceæ.*

Genus I. Lycopodites affinis.
filiciformis.
Gravenhorstii.
Hœninghausii.
imbricatus.
phlegmarioides.
piniformis.
tenuifolius.

II. Selaginites erectus.
patens.

III. Ulodendron majus, L. and H. v.
minus, L. and H. vi.

IV. Lepidophyllum, 5 species.

V. Lepidodendron acerosum, L. and H. vii.
aculeatum.
Bobleyi.
Bucklandi.
cælatum.
carinatum.
confluens.
cordatum.
crenatum.
distans.
dubium.
elegans, L. and H. cxviii.
emarginatum.
gracile, L. and H. ix.
Harcourtii, L. and H. xcviii.
xcix.

Lepidodendron imbricatum.
insigne.
lanceolatum.
læve.
laricinum.
lineare.
longifolium.
majus.
obovatum.
Ophiurus.
ornatissimum.
ornatum.
pulchellum.
Rhodianum.
rimosum.
rugosum.
selaginoides.
Sternbergii.
taxifolium.
tetragonum.
transversum.
trinerve.
Underwodii.
undulatum.
varians.
venosum.
Volkmannianum.

5. *Equisetaceæ*.

Genus I.* Equisetum dubium, Br. xii. 17, 18.
infundibuliforme, Br. xii. 16.
II. Calamites approximatus, Br. xxiv. xxv. 7, 8.
cannæformis, L. and H. lxxix. Br. xxi.
cistii, Br. xx.
cruciatus, Br. xix.
decoratus, Br. xiv. 1 to 5.
dubius, Br. xviii. 1 to 3.
Mougeotii, Br. xxv. 4, 5.
nodosus, L. and H. xv. xvi. Br. xxiii. 2 to 4.
pachyderma, Br. xxii.
ramosus, Br. xvii. 5, 6.
Steinhaueri, Br. xviii. 4.

Suckowii, Br. xiv. 6, and xv. 1—6, and xvi.
undulatus, Br. xvii. 1—4.

6. *Confervaceæ.*

Genus I. Confervites thoreæformis, Br. ix bis. 3, 4.

7. *Fucaceæ.*

Genus I. Fucoides.
Only the one I found in Ayrshire.

III. PLANTS IN NEW RED SANDSTONE.

1. *Bicotyledones.*

Genus I. *Juglans.
II. Æthophyllum stipulare.
III. Echynostachys oblongus.
IV. Cupressites Ullmanni.
V. Voltzia acutifolia.
brevifolia.
elegans.
heterophylla.
rigida.

2. *Monocotyledones.*

Genus I. Convallarites erecta.
nutans.
II. Paleoxyris regularis.

3. *Filices.*

Genus I. Sphenopteris myriophyllum, Br. lv. 2.
Palmetta, Br. lv. 1.
II. Neuropteris Dufresnoii, Br. lxxiv. 4, 5.
elegans, Br. lxxiv. 1, 2.
Gaillardoti, Br. lxxiv. 3.
Voltzii, Br. lxvii.
III. Pecopteris Sulziana, Br. cv. 4.
IV. Anomopteris Mougeotii, Br. lxxix. lxxx. lxxxi.
V. Filicites scolopendroides.
VI. Calamites arenaceus, Br. xxv. 1 and xxvi, 3, 4, 5.

4. *Fucaceæ.*

Genus *I.* *Fucoides* Brardii.

Fucoides digitatus.
frumentarius.
lycopodioides.
pectinatus.

IV. PLANTS IN OOLITE.

1. *Bicotyledones.*

Genus I. Stigmaria. Mammillaria Desnoyersii.
II. Peuce, several species.
III. Taxites podocarpoides.
IV. Thuytes acutifolia.
cupressiformis.
divaricata.
expansa.
V. Zamia acuta.
elegans.
Feneonis.
Goldiæi.
lævis.
longifolia.
Mantelli.
patens.
pectinata.
pennæformis.
Youngii.
VI. Zamites Bechii.
Bucklandii.
hastata.
Lagotis.
VII. Pterophyllum comptum, L. and H. lxiii.
minus, L. and H. lxvii.
Pecten, L. and H. cii.
Williamsonis.
VIII. Nilsonia. Two species in the sandstone of the lias.
IX. Cycadeoides. Two species in the Portland stone.
X. Araucaria peregrina, L. and H. lxxxviii.
XI. Dictyophyllum rugosum, L. and H. civ.

2. *Monocotyledones.*

Genus I. Zosterites. One? species in lias.

II. Bucklandia squamosa.
III. Ctenis foliata.

3. *Filices*.

Genus I. Cyclopteris Beanii, L. and H. xliv.
digitata, L. and H. lxiv. Br. lxi bis. 2, 3.
II. Glossopteris Nilsoniana, Br. lxiii. 3.
Phillipsii, L. and H. lxiii.
III. Sphenopteris crenulata, Br. lvi. 3.
denticulata, Br. lvi. 1.
hymenophylloides, Br. lvi. 4.
Williamsonis, Br. xlix. 6, 7, 8.
IV. Pecopteris Beaumontii, Br. cxii. 3.
denticulata, Br. xcviii. 1, 2.
Desnoyersii.
insignis, L. and H. cvi.
Meriani, Br. xci. 5.
nebbensis, Br. xcviii. 3.
polypodioides, L. and H. lx.
Phillipsii, Br. cix. 1.
Reglei.
tenuis, Br. c. 3, 4.
Whitbiensis, Br. cix. 2, 3, 4.
Williamsonis, Br. c. 1, 2, L. and H. 126.
propinqua, L. and H. cxix.
undans, L. and H. cxx.
V. Pachypteris lanceolata, Br. xlv. 1.
ovata, Br. xlv. 2.
VI. Tæniopteris latifolia, Br. lxxxii. 6.
major, L. and H. xcii.
vittata, L. and H. lxii.
VII. Clathropteris, 1 species.
VIII. Neuropteris arguta, L. and H. cv.
ingens, L. and H. xci. A.
ligata, L. and H. lxix.
recentior, L. and H. lxviii.
undulata, L. and H. lxxxiii.
IX. Solenites Murrayana, L. and H. cxxi.

4. *Lycopodiaceæ*.

Genus I. Lycopodites foliatus, L. and H. lxi.
Williamsonis, L. and H. xciii.

Genus II. Equisetum columnare, Br. xiii. 1—6.

5. *Fucaceæ.*

Genus I. Fucoides Brardii, Br. ii. 8—19.
digitatus, Br. ix. 1.
encœlioides, Br. vi. 1, 2.
frumentarius, Schlot. xxviii. 1.
furcatus, Br. v. 1.
Lycopodioides, Br. ix. 3.
orbignianus, Br. ii. 6, 7.
pectinatus, Schlot. xxvii. 2.
Selaginoides, Br. ix. 2.
septentrionalis, Br. ii. 24.
Stockii, Br. vi. 3, 4.

V. PLANTS IN GREEN SAND.

1. *Dicotyledones.*

Genus I. Zamia macrocephala, L. and H. cxxv.

2. *Monocotyledones.*

Genus I. Zosterites, 4 species?*
II. Clathraria Lyellii.

3. *Filices.*

Genus I. Sphenopteris Mantelli.
II. Pecopteris Reichiana.
III. Lonchopteris Mantelli.

4. *Fucoides.*

Genus I. Fucoides æqualis, Br. v. 4.
difformis, Br. v. 5.
intricatus, Br. v. 6, 7, 8.
recurvus, Br. v. 2.
strictus, Br. ii. 1—5.
Targionii, Br. iv. 2—6.
tuberculosus, Br. vii. 5.

VI. PLANTS IN CHALK.

1. *Dicotyledones.*

Genus I. Cycadites Nilsonii.

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* Do they not rather belong to the chalk?

2. *Monocotyledones.*

Genus I. Zosterites Bellovisana.
caulinifolia.
elongata.
lineata.

3. *Confervæ.*

Genus I. Confervites ægagropiloides.
fasciculata.

4. *Fucoides.*

Genus I. Fucoides Brongniarti.
canaliculatus.
cylindricus, Br. iii. 4.
difformis.
intricatus.
Lyngbianus, Br. ii. 20, 21.
Orbignianus.
strictus.
Targioni.
tuberculosus.

VII. PLANTS IN BEDS ABOVE THE CHALK, PROBABLY MIOCENE.

1. *Musci.*

Genus I. Muscites squamatus, Br. x. 5—7.
Tournalii, Br. x. 1, 2.

2. *Equisetaceæ.*

Genus I. Equisetum brachyodon, Br. xii. 11, 12.
Meriani? Br. xii. 13.

3. *Filices.*

Genus I. Tæniopteris Bertrandi, Br. lxxxii. 5.

4. *Algæ.*

Genus I. Fucoides Agardhianus, Br. vi. 5, 6.
Bertrandi, Br. vii. 1, 2.
discophorus, Br. viii. 6.
flabellaris, Br. viii. 5.
gazolanus, Br. viii. 3.
Lamourouxii, Br. viii. 2.

Fucoides multifidus, Br. v. 9, 10.
Nilsonianus, Br. ii. 22, 23.
obtusus, Br. viii. 4.
spathulatus, Br. vii. 4.
Sternbergii, Br. iii. 1.
turbinatus, Br. viii. 1.

BICOTYLEDONOUS PLANTS FOUND IN THE TERTIARY BEDS.

Genus I. *Ulmus, 1.
II. *Carpinus, 1.
III. *Castanea, 1.
IV. *Betula, 1.
V. *Salix, 1.
VI. *Populus, 2.
VII. *Comptonia, 1.
VIII. *Juglans, 3.
IX. *Acer, 1.
X. *Pinus, 9.
XI. *Abies, 1.
XII. Taxites, 5.
XIII. Juniperites, 3.
XIV. *Thuya, 4.

MONOCOTYLEDONOUS PLANTS IN TERTIARY BEDS.

Genus I. Antholithes, 1.
II. Flabellaria, 1.
III. Palmacites, 1.
IV. Phænicites, 1.
V. *Cocos, 3.
VI. Culmites, 3.
VII. Amomocarpum, 1.
VIII. Pandanacarpum, 1.
IX. *Chara, 5.
Besides many fruits.

VIII. PLANTS IN FRESH WATER FORMATIONS.

Genus I. *Nymphæa, 1.
II. *Cinnamomum, 1.
III. *Comptonia, 1.
IV. *Podocarpus, 1.

Genus V. Smilacites, 1.
VI. Flabellaria, 1.
VII. Zosterites, 2.
VIII. Phyllites, 1.

In the preceding catalogue I have noticed very few of the fossil fruits, because it has been impossible to determine the kind of plants to which they belong. A description, and figures, of a considerable number of these fossil fruits, found in the Isle of Sheppy, by Dr. Parsons, will be found in the *Philosophical Transactions* for 1757, page 396.

DESCRIPTION OF THE GENERA OF FOSSIL PLANTS HITHERTO CLASSIFIED.

1. *Dicotyledonous Plants.*

Genus I.—*Sigillaria.* This generic name has been given to the large stems so frequently found upright in the sandstone in coal districts. Sternberg has applied to them the name *Rhytidolepis*, and *Artis* that of *Euphorbites*. A very remarkable specimen, found immediately above the coal in Killingworth Colliery, is figured and described in the *Transactions of the Natural History Society of Newcastle*, vol. i. page 206, by Mr. Nicholas Wood. From this it has been copied into Lindley and Hutton's *Fossil Flora*, plate 54, vol. i. p. 149. Various opinions have been started respecting the analogy of these stems to existing plants. Mr. Artis thinks that they are related to the Euphorbiaceæ; Schlotheim refers them to Palms; Brongniart at first considered them as completely different from any thing at present known; but now, with Count Sternberg, he places them among the *ferns.*

I think Messrs. Lindley and Hutton have shown clearly that they have no analogy to ferns. As these stems exhibit a true and separable bark, always in the fossil specimens converted into coal, it is evident that they belonged to dicotyledonous plants. But what are the analogous living plants, or whether there be any living plant, to which they bear any analogy, are questions that the present state of our knowledge does not enable us to answer.

When they lie in the direction of the strata these stems are always pressed flat, and are usually distinguished by oval or variously shaped scars disposed in regular rows longitudinally on the stem. It was from this probably that Sternberg distinguished them by the name of Syringodendron.

Genus II.—*Favularia.* This, like the last genus, constitutes casts of stems in the sandstone of the coal formation. It resembles sigillaria, only the rows of scars run longitudinally, or parallel to the axis of the stem, each row being separated by a groove. They are much smaller and more numerous than the scars in sigillaria, though the plants are doubtless analogous.

Genus III.—*Stigmaria.* The fossil plants belonging to this curious genus were first accurately described by Steinhauer. It constitutes the most common of the fossil vegetables in the coal formation. From the round cavities somewhat resembling the pits left by the small-pox, it has been distinguished by Sternberg by the name of *Variolaria.* The most perfect form in which it occurs is that of a cylinder more or less compressed, and generally flatter on one side than the other. Pretty often the flattened side turns in so as to form a groove. Mr. Steinhauer has shown that the pustules on the stem constituted the origin of fibres or branches which radiate in all directions from the stem, and he traced them on the banks of a rivulet between the townships of Pudsey and Tong, issuing in rays in every direction, and extending to a distance of above 20 feet from the central stem. This demonstrates that the plant grew originally in a horizontal direction, and shot out its fibres in every direction through the yielding mud. Messrs. Lindley and Hutton have shown that the stigmaria was a succulent and dicotyledonous plant, and have rendered it probable that what Steinhauer described as fibres or branches were cylindrical leaves, and they consider it as probable that it is intermediate between the Euphorbiaceæ and Cacteæ.

Genus IV.—*Bothrodendron.* Large stems, of which only fragments remain. On the surface of the stem are many minute dots, arranged in quincunces, and something less than half an inch apart. They may be the scars of leaves. At intervals of ten or eleven inches the stem is marked with deep circular concavities, four or five inches across, at the bottom of each of which is a distinct fracture indicating that something has been broken out, while the sides of the cavities have concentric marks, as if from the pressure upon them of rounded scales. From the fragments taken out of these cavities, it is clear that they were the points of attachment of very large cones. Hence there can be no doubt that the plant belonged to the natural order of coniferæ.

Genus V.—*Pinites.* This name has been given to the large stems discovered at Wideopen, near Newcastle-upon-Tyne, and at Craigleith, near Edinburgh. Mr. Witham first proved that they were the stems of dicotyledonous plants, and analogous to pines in their structure. Hence the term *pinites.* Four different species have been described by Lindley and Hutton.

Genus VI.—*Knorria.* This name has been given by Sternberg to certain stems, or fragments of stems, found in the coal formation. Lindley and Hutton have shown that they exactly coincide with the appearance of branches of the Yew. There can be no doubt that they belong to succulent and dicotyledonous plants.

Genus VII.—*Sphenophyllum.* This genus, called *rotularia* by Sternberg, is distinguished by the following characters:—Branches deeply furrowed; leaves verticillate, wedge-shaped, with dichotomous veins. Lindley and Hutton have shown that it approaches nearer to the *coniferæ* than to the filices.

Genus VIII.—*Peuce.* The only known species of this genus was found in sandstone at Ushaw, about four miles north of the city of Durham. Its characters are as follows: Axis composed of pith; wood in concentric circles; bark and medullary rays; but no vessels; walls of the woody fibre marked with oblong deciduous areolæ having a circle in their middle. Mr. Witham has shown that it is the stem of a dicotyledonous plant, and probably a pine. It resembles the Pinites Withami so much that we do not see how they can be distinguished.

Genus IX.—*Asterophyllites.* This genus, the *Bornia* and *Bruckmannia* of Sternberg, is distinguished by the following characters: Stems scarcely tumid at the articulations, branched; leaves verticillate, linear, acute, with a single midrib, quite distinct at their base; fruit a one-seeded? ovate, compressed nucule, bordered by a membranous wing and emarginate at the apex.

Genus X.—*Pinnularia.* This name has been given by Lindley and Hutton to a fossil plant found by Dr. Buckland in the Leebotwood coal pit. It is a branch from which issues at regular distances on opposite sides capillary appendages divided in a pinnated manner. It is obviously the fragment of a dicotyledonous plant.

Genus XI.—*Hippurites*. This name has been given by Lindley and Hutton to a fragment of a stem found in Jarrow colliery, from its analogy to the genus *hippuris*.

Genus XII.—*Megaphyton*. This name has been given by Lindley and Hutton to a fossil plant found in the roof of the high main coal at Jarrow. It is a portion of a dotted stem with scars of leaves placed in parallel lines.

Genus XIII.—*Halonia*. This name has been given by Lindley and Hutton to those fossil stems which resemble the *lepidodendra* in their rhomboidal scars, but want the dichotomous mode of branching. This brings them nearer to the coniferæ than the lycopodiaceæ to which the lepidodendra have been referred.

Genus XIV.—*Phyllotheca*. The characters of this genus are as follows: Stem simple, straight, articulated, surrounded at equal distances by sheaths, having long linear leaves, which have no distinct midrib.

Genus XV.—*Annularia*. This genus, the *Bornia* of Sternberg, is characterized as follows: Stem slender, articulated, with opposite branches springing from above the leaves; leaves verticillate, flat, usually obtuse, with a single midrib, united at their base, of unequal length.

Genus XVI.—*Bechera*. Only one species of this genus has been met with. It occurs in the coal formation, and its characters are as follows:—Stem branched, jointed, tumid at the articulations, deeply and widely furrowed. Leaves verticillate, very narrow, acute, ribless?

Genus XVII.—*Æthophyllum*. Only one species of this genus has been observed; it is situated in the new red sandstone. Its characters are as follows:—stem simple, leaves alternate, linear, ribless, not sheathing, having at the base two smaller linear leaflets. Inflorescence spiked; spikes ovate. Flowers numerous, with a subcylindrical tube or inferior ovarium, and a bilabiate? perianthium with subulate segments. Brongniart refers this genus to monocotyledons; but the above characters belong to no known natural class.

Genus XVIII.—*Echinostachys*. One species only of this genus in the new red sandstone. Inflorescence an oblong spike, beset on all sides with sessile, contiguous, subconical, flowers or fruits. Brongniart refers this also to monocotyledons; but of this there is hitherto no evidence.

Genus XIX.—*Cupressites.* Branches arranged irregularly. Leaves inserted spirally, in six or seven rows, sessile, enlarged at their base. Fruit consists of peltate scales, marked with a conical protuberance in their centre.

Genus XX.—*Voltzia.* A genus of coniferous plants. Branches pinnated. Leaves inserted all round the branches, sessile, slightly decurrent or dilated at the base, and almost conical; often distichous. Fruit forming spikes or loose cones, composed of distant imbricated scales, which are more or less deeply three lobed.

Genus XXI.—*Taxites.* A genus of coniferous plants. Leaves solitary, supported on a short petiole, articulated, and inserted in a single spire, not very dense, distichous.

Genus XXII.—*Thuytes.* A genus of coniferous plants. Branches as in Thuya. Fruit unknown.

Genus XXIII.—**Zamia.* A genus belonging to the natural order of Cycadeæ. Leaves pinnated; leaflets entire, or toothed at their extremity, pointed, sometimes enlarged and auricled, as it were, at their base, attached only by the midrib, which is often thickened; veins fine, equal and parallel, or scarcely diverging.

Genus XXIV.—*Zamites.* Branches and leaves as in Zamia.

Genus XXV.—*Pterophyllum.* A genus belonging to the natural order of Cycadeæ. Leaves pinnated; leaflets almost equally broad each way, inserted by the whole of their base, truncated at the summit; veins fine, equal, simple, but little marked, all parallel.

Genus XXVI.—*Nilsonia.* Belongs to the Cycadeæ. Leaves pinnated; leaflets approximated, oblong, more or less elongated, rounded at the summit, adhering to the rachis by the whole of their base, with parallel veins, some of which are much more strongly marked than others.

Genus XXVII.—*Cycadeoidea.* This name has been given by Buckland, to the genus called *Mantellia*, by Ad. Brongniart. Stem roundish or oblong, covered with densely imbricated scales, which are scarred at their apex.

Genus XXVIII.—**Araucaria.* This name has been given by Lindley and Hutton, to a branch about a foot long, found in the lias of Lyme in Dorsetshire. From the branch proceed four or five laterals, spreading widely from the main stem, and slightly curved. The whole closely covered by thick, *ovate, blunt* leaves, which seem to have had a very broad edge and a rhomboidal figure, overlapping each other nearly half their length; exactly similar to the *Araucaria excelsa*, a coniferous plant of Norfolk island.

Genus XXIX.—*Dictyophyllum.* This name has been given by Lindley and Hutton to a fossil leaf, first described by Mr. Phillips, from the upper sandstone, shale and coal of the oolitic formation in Yorkshire. It is not unlike the leaf of a sow thistle. Doubtless it belonged to a dicotyledonous plant, though no evidence exists to show its nature. The term *dictyophyllum* is employed to designate all fossil leaves of a common reticulated structure; while the term phyllites is applied to those whose principal veins converge at both the base and apex.

Genus XXX.—*Cycadites.* Leaves pinnated; leaflets linear, entire, adhering by their whole base, having a single thick midrib; no secondary veins.

Genus XXXI.—*Juniperites.* Branches arranged irregularly. Leaves short, obtuse, inserted by a broad base, opposite, decussate, and arranged in four rows.

The remaining genera of dicotyledonous plants being recent, are not described, because the student can easily have recourse to those systems of botany in which descriptions of them occur.

2. *Monocotyledonous Plants.*

Genus I.—*Nœggerathia.* A palm. Leaves petiolated, pinnated; leaflets obovate, nearly cuneiform, applied against the edges of the petiole, toothed towards their apex, with fine diverging veins.

Genus II.—*Flabellaria.* A palm. Leaves petiolated, flabelliform, divided into linear lobes, plaited at their base.

Genus III.—*Cannophyllites.* Leaves simple, entire, traversed by a very strong midrib; veins oblique, simple, parallel, all of equal size.

Genus IV.—*Poacites.* This name has been given to all monocotyledonous leaves, the veins of which are parallel, simple, of equal thickness, and not connected by transverse bars.

Genus V.—*Sternbergia.* Called *Columnaria* by Sternberg. Stem taper, slender, naked, cylindrical, terminating in a cone; marked by transverse furrows, but with no articulations. Slight remains of a fleshy cortical integument.

Genus VI.—*Convallarites.* Leaves verticillate, linear, with *parallel, slightly* marked veins. Stem straight or curved.

Genus VII.—*Palæoxyris.* Inflorescence a terminal fusiform spike, with appressed, closely imbricated scales; its external portion, where it is not covered by scales, rhomboidal, concave in the middle. The tuft of filaments, noticed by Brongniart, as proceeding from its apex, is at variance with Xyris, to which it would otherwise be referred. Is it a dicotyledonous plant?

Genus VIII.—*Zosterites.* Leaves oblong or linear, marked with a small number of equal veins, which are at a marked distance from each other, and are not connected by transverse veins.

Genus IX.—*Bucklandia.* Stem covered by reticulated fibres, giving rise to imbricated leaves, which are not amplexicaul, and the petioles of which are distinct to their base.

Genus X.—*Ctenis.*

Genus XI.—*Clathraria.* Stem composed of an axis, the surface of which is covered by reticulated fibres, and of a bark formed by the complete union of the bases of petioles, whose insertion is rhomboidal.

Genus XII.—*Antholithes.* The flower only of a species of this genus has been met with in the beds above the chalk.

Genus XIII.—*Palmacites.*

Genus XIV.—*Phœnicites.* A palm. Leaves petiolated, pinnated; leaflets linear, united by pairs at the base; their veins fine and little marked.

Genus XV.—**Cocos.* A palm. The fruit only of this palm has been found fossil. Fruit ovate, slightly three cornered, marked with three orifices near their base.

Genus XVI.—*Culmites.* Stem articulated, with two or more scars at the joints.

Genus XVII.—*Amomocarpum.* Fruit only found: analogous to that of ginger.

Genus XVIII.—*Pandanocarpum.* Fruit only found; analogous to that of *Pandanus,* or *screw pine-tree* of the Isle of France.

Genus XIX.—*Smilacites.* Leaves heart-shaped, or hastate, with a well defined midrib, and two or three secondary ribs on each side, parallel to the edge of the leaf: veins reticulated.

Genus XX.—*Phyllites.* This is the *Potamo-phyllites* of Brongniart. It includes all monocotyledonous leaves, the veins of which are confluent at the base and apex, and connected by transverse bars or secondary veins.

Genus XXI.—**Chara*. Fruit, oval or spheroidal, consisting of five valves twisted spirally; a small opening at each extremity. Stems friable, jointed, composed of straight tubes arranged in a cylinder.

3. *Filices*.

Genus I.—*Cyclopteris*. Leaves simple, entire, somewhat orbicular; veins numerous, radiating from the base, dichotomous, equal; midrib wanting.

Genus II.—*Glossopteris*. Leaves simple, entire, somewhat lanceolate, narrowing gradually to the base, with a thick vanishing midrib; veins oblique, curved, equal, frequently dichotomous, or sometimes anastomosing and reticulated at the base.

Genus III.—*Schizopteris*. Leaves linear, plane, without midrib, finely striated, almost flabelliform, dividing into several lobes, which are linear and dichotomous, or rather irregularly pinnated, and erect; lobes dilated and rounded towards the extremity.

Genus IV.—*Caulopteris*. A tree fern. Stem cylindrical, closely marked by large, oblong, convex, uneven scars, wider than the tortuous depressed spaces that separate them.

Genus V.—*Sphenopteris*. Leaves bi-tripinnatifid; leaflets contracted at the base, not adherent to the rachis, lobed; the lower lobes largest, diverging, somewhat palmate; veins bipinnate, radiating, as it were, from the base.

Genus VI.—*Neuropteris*. Leaves bipinnate, or rarely pinnate; leaflets usually somewhat cordate at the base, neither adhering to each other nor to the rachis, by their whole base, only by the middle portion of it; midrib vanishing at the apex; veins oblique, curved, very fine, dichotomous—*Fructification*; sori lanceolate, even (covered with an indusium), arising from the veins of the apex of the leaflets, and often placed in the bifurcations.

Genus VII.—*Pecopteris*. Leaf once, twice, or thrice pinnate; leaflets adhering by their base to the rachis, or occasionally distinct; midrib running quite through the leaflet; veins almost perpendicular to the midrib, simple, or once or twice dichotomous.

Genus VIII.—*Odontopteris*. Leaves bipinnated; leaflet membranous, very thin, adhering by their base to the rachis, *with no*, or almost no, midrib; veins equal, simple, or forked, *very fine*, most of them springing from the rachis.

Genus IX.—*Anomopteris.* Leaves pinnated; leaflets linear, entire, somewhat plaited transversely at the veins, having a midrib; veins simple, perpendicular, curved. *Fructification* arising from the veins, uncertain as to form; perhaps dot-like and inserted in the middle of the veins; or perhaps linear, attached to the whole of a vein, naked (as in Meniscia) or covered by an indusium, opening inwardly.

Genus X.—*Tæniopteris.* Leaves simple, entire, with a stiff, thick midrib; veins perpendicular, simple, or forked at the base. *Fructification* dot-like.

Genus XI.—*Clathropteris.* Leaf deeply pinnatifid; leaflets having a very strong complete midrib; veins numerous and simple, parallel, almost perpendicular to the midrib, united by transverse veins, which form a network of square meshes upon the leaf.

Genus XII.—*Lonchopteris.* Leaf many times pinnatifid; leaflets more or less connate at the base, having a midrib; veins reticulated.

Genus XIII.—*Pachypteris.* Leaves pinnated or bipinnated; leaflets entire, coriaceous, ribless, or one-ribbed, contracted at the base, but not adherent to the midrib.

Genus XIV.—*Filicites.* To this are referred all the fossil ferns which do not belong to any of the preceding genera.

4. *Equisetaceæ.*

Genus I.—*Calamites.* Stem jointed, regularly and closely furrowed, hollow, divided internally at the articulations by a transverse diaphragm, covered with a thick cortical integument. Leaves? verticillate, very narrow, numerous, simple.

Genus II.—**Equisetum.* Stems articulated, surrounded by cylindrical sheaths, which are regularly tooth-letted and pressed close to the stem.

5. *Lycopodiaceæ.*

Genus I.—*Lycopodites.* Branches pinnated; leaves inserted all round the stem in two opposite rows, not leaving clean and well defined scars.

Genus II.—*Selaginites.* Stems dichotomous, not presenting regular elevations at the base of the leaves, even near the lower end of the stems. Leaves often persistent, enlarged at their base.

Genus III.—*Ulodendron.* Stem covered with rhomboidal *areolæ, which* are broader than long; scars large, few, placed one above another, circular, composed of broad cuneate scales, radiating from a common centre, and indicating the former presence of organs analogous to the cones of coniferæ.

Genus IV.—*Lepidodendron.* Stems dichotomous, covered near their extremities by simple, linear, or lanceolate leaves, inserted upon rhomboidal areolæ ; lower part of the stems leafless; areolæ (longer than broad) marked near their upper part by a minute scar, which is broader than long, and has three angles, of which the two lateral are acute, the lower obtuse ; the latter sometimes wanting.

Genus V.—*Lepidophyllum.* Stem unknown; leaves sessile, simple, entire, lanceolate, or linear, traversed by a single midrib, or by three parallel ribs; no veins.

6. *Musci.*

Genus I.—*Muscites.* Stem simple, or branched, filiform, with membranous leaves, having scarcely any midrib, and being sessile or amplexicaul, imbricated, or somewhat spreading.

7. *Algæ.*

Genus I.—*Confervites.* Filaments simple or branched, divided by internal partitions.

Genus II.—*Fucoides.* Frond continuous, never articulated, usually not symmetrical or subcylindrical, simple, or oftener branched, naked, or more commonly leafy; or membranous, entire, or more or less lobed, with no ribs, or imperfectly marked ones, which branch in an irregular manner, and never anastomose.

These descriptions of the fossil genera of plants are chiefly translated from the definitions of M. Adolphe Brongniart. A few of them are from the *Fossil Genera of Plants*, drawn up by Messrs. Lindley and Hutton, at the end of the preface to the first volume of their *Fossil Flora*, an exceedingly interesting and valuable work still going on. It is to be feared that M. Brongniart has not met with that encouragement which his *Histoire des Végétaux Fossiles* so eminently deserves. A long interval has elapsed since the publication of the 9th livraison of that work, which is the last number that we have seen.

Abbreviations employed in the following Table.

Al. Br.	Alex. Brongniart.
Blain.	Blainville.
Broc.	Brocchi.
Brug.	Bruguière.
Cuv.	Cuvier.
Dalm.	Dalman.
Defr.	Defrance.
De H.	De Haan.
De la B.	De la Beche.
Desh.	Deshayes.
Desm.	Desmarest.
Des M.	Des Moulins.
D'Orb.	D'Orbigny.
Flem.	Fleming.
Goldf.	Goldfuss.
Hoen.	Hoeninghaus.
His.	Hisinger.
Kön.	König.
Lam.	Lamarck.
Lamx.	Lamouroux.
Lin.	Linnæus.
List.	Lister.
Mant.	Mantell.
Mill.	Miller.
Mont.	Montfort.
Munst.	Munster.
Nils.	Nilson.
Park.	Parkinson.
Phil.	Phillips.
Raf.	Rafinesque.
Rein.	Reinecke.
Schlot.	Schlotheim.
Schröt.	Schröter.
Sm.	Smith.
Sow.	Sowerby.
St. F.	Faujas de St. Fond.
V. Buch.	Von Buch.
Wahl.	Wahlenberg.
Y. & B.	Young and Bird.
Ziet.	Zieten.

Table of the Zoophites, Radiata, Crustacea, Annelides,

CLASS I.

Greywacke.	Coal Formation.	New Red Sandstone.
	1.	1.
Manon cribrosum, *Goldf.* favosum, *Goldf.*	2.	2.
Scyphia conoidea, *Goldf.* costata, *Goldf.* turbinata, *Goldf.* clathrata, *Goldf.*	3.	3.

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* No attempt has been made to give an enumeration of the shells, &c., in the tertiary beds. We
nt engaged in a work on fossil conchology, which will, doubtless, be very complete when it appears.

*nchifera and Mollusca; found fossil in the mineral kingdom.**

-ZOOPHYTES.

Oolite.	Greensand.	Chalk.
Achilleum dubium, *Goldf.*	1.	1. Achilleum glomeratum, *Goldf.*
cheirotonum, *Goldf.*		fungiforme, *Goldf.*
muricatum, *Goldf.*		Morchella, *Goldf.*
tuberosum, *Munst.*		
cancellatum, *Munst.*		
costatum, *Munst.*		
Manon Peziza, *Goldf.**	2.	2. Manon Peziza, *Goldf.**
marginatum, *Munst.*		tubuliferum, *Goldf.*
impressum, *Munst.*		pulvinarium, *Goldf.*
		capitatum, *Goldf.*
		stellatum, *Goldf.*
Scyphia cylindrica, *Goldf.*	3.	3. Scyphia mammillaris, *Goldf.*
elegans, *Goldf.*		furcata, *Goldf.*
calopora, *Goldf.*		infundibuliformis, *Goldf.*
pertusa, *Goldf.*		foraminosa, *Goldf.*
texturata, *Goldf.*		Sackii, *Goldf.*
texata, *Goldf.*		tetragona, *Goldf.*
polyommata, *Goldf.*		
clathrata, *Goldf.*		
milleporata, *Goldf.*		
parallela, *Goldf.*		
psilopora, *Goldf.*		
obliqua, *Goldf.*		
rugosa, *Goldf.*		
articulata, *Goldf.*		
pyriformis, *Goldf.*		
radiciformis, *Goldf.*		
punctata, *Goldf.*		
reticulata, *Goldf.*		
dictyota, *Goldf.*		
procumbens, *Goldf.*		
paradoxa, *Munst.*		
empleura, *Munst.*		
striata, *Munst.*		
Buchii, *Munst.*		
Munsteri, *Goldf.*		
propinqua, *Munst.*		
cancellata, *Munst.*		
decorata, *Munst.*		
Humboldtii, *Munst.*		
Sternbergii, *Munst.*		
Schlotheimii, *Munst.*		
Schweiggeri, *Goldf.*		
secunda, *Munst.*		
verrucosa, *Goldf.*		
Bronnii, *Munst.*		
milleporacea, *Munst.*		
intermedia, *Munst.*		
Neesii, *Goldf.*		

fer the reader for a copious catalogue to the third volume of Lyell's Geology. M. Deshayes is at pre

Greywacke.	Coal Formation.	New Red Sandstone.
4.	4.	4.
5.	5.	5.
6. Tragos acetabulum, *Goldf.* capitatum, *Goldf.*	6.	6.
7.	7.	7.
8.	8.	8.
9.	9.	9.
10.	10.	10.
11.	11.	11.
12.	12.	12.
13.	13.	13.
14.	14.	14.
15. Gorgonia antiqua, *Goldf.*	15.	15.
16. Stromatopora concentrica, *Goldf.* polymorpha, *Goldf.*	16.	16.
17.	17.	17.
18.	18. Millepora madreporiformis, *Wahl.* cervicornis, *Linn.* repens, *Wahl.* ? foliacea, *Wahl.* ? Retepora, *Wahl.*	18.
19.	19.	19.

ed.

Oolite.	Greensand.	Chalk.
gia floriceps, *Phil.* clavaroides, *Lam.*	4.	4. Spongia ramosa, *Mant.* lobata, *Hoen.* plana, *Phil.* capitata, *Phil.* osculifera, *Phil.* convoluta, *Phil.* marginata, *Phil.* radiciformis, *Phil.* terebrata, *Phil.* lævis, *Phil.* porosa, *Phil.* cribrosa, *Phil.*
	5.	5. Spongus Townsendi, *Mant.* labyrinthicus, *Mant.*
os acetabulum, *Goldf.** Patella, *Goldf.* sphærioides, *Goldf.* tuberosum, *Goldf.* pezizoides, *Goldf.* radiatum, *Munst.* rugosum, *Munst.* reticulatum, *Munst.* verrucosum, *Munst.*	6.	6. Tragos Hippocastanum, *Goldf.* deforme, *Goldf.* rugosum, *Goldf.* pisiforme, *Goldf.* stellatum, *Goldf.*
	7.	7. Alcyonium globulosum, *Defr.* ? pyriformis, *Mant.*
	8.	8. Choanites subrotundus, *Mant.* Königi, *Mant.* flexuosus, *Mant.*
orea mammillaris, *Lamx.*	9.	9.
	10.	10. Ventriculites radiatus, *Mant.* alcyonoides, *Mant.* Benettiæ, *Mant.*
nia pyriformis, *Goldf.*	11.	11. Siphonia Websteri, *Mant.* cervicornis, *Goldf.*
	12. Hallirhoa costata, *Lamx.*	12.
	13. Serea pyriformis, *Lam.*	13.
necium hemisphæricum, *Goldf.*	14.	14.
onia dubia, *Goldf.*	15.	15. Gorgonia bacillaris, *Goldf.*
	16.	16.
	17.	17. Nullipora racemosa, *Goldf.*
pora dumetosa, *Lamx.* corymbosa, *Lamx.* conifera, *Lamx.* pyriformis, *Lamx.* macrocaulis, *Lamx.* straminea, *Phil.*	18.	18. Millepora Fittoni, *Mant.* Gilberti, *Mant.* madreporacea, *Goldf.* compressa, *Goldf.*
	19.	19. Eschara cyclostoma, *Goldf.* pyriformis, *Goldf.* stigmatophora, *Goldf.* sexangularis, *Goldf.* cancellata, *Goldf.* arachnoidea, *Goldf.* dichotoma, *Goldf.* striata, *Goldf.*

ZOOPHYTES

Greywacke.	Coal Formation.	New Red Sandstone.
20. Cellepora antiqua, *Goldf.* favosa, *Goldf.*	20. Cellepora Urii, *Flem.*	20.
21. Retepora antiqua, *Goldf.* prisca, *Goldf.*	21. Retepora elongata, *Flem.*	21. Retepora flustracea, *Phil.* virgulacea, *Phil.*
22.	22.	22.
23. Ceriopora verrucosa, *Goldf.* affinis, *Goldf.* punctata, *Goldf.* granulosa, *Goldf.* oculata, *Goldf.*	23.	23.
24.	24.	24.
25.	25.	25.
26. Agaricia lobata, *Goldf.*	26.	26.
27. Lithodendron cæspitosum, *Goldf.*	27.	27.
28.	28. Caryophyllia stellaris, *Linn.* articulata, *Wahl.* truncata, *Linn.* duplicata. affinis. juncea, *Flem.*	28.
29. Anthophyllum bicostatum, *Goldf.*	29.	29.
30.	30.	30.
31.	31. Turbinolia turbinata, *Linn.* echinata, His.	31.

—*Continued.*

Oolite.	Greensand.	Chalk.
		Eschara filograna, *Goldf.* disticha, *Goldf.*
Cellepora orbiculata, *Goldf.* echinata, *Goldf.*	20.	20. Cellepora ornata, *Goldf.* Hippocrepis, *Goldf.* Velamen, *Goldf.* dentata, *Goldf.* crustulenta, *Goldf.* bipunctata, *Goldf.* escharoides, *Goldf.*
	21.	21. Retepora clathrata, *Goldf.* lichenoides, *Goldf.* truncata, *Goldf.* disticha, *Goldf.* cancellata, *Goldf.*
	22.	22. Flustra utricularis, *Lam.* ? reticulata, *Desm.* flabelliformis, *Lam.*
Ceriopora radiciformis, *Goldf.* striata, *Goldf.* angulosa, *Goldf.* alata, *Goldf.* crispa, *Goldf.* favosa, *Goldf.* radiata, *Goldf.* compressa, *Munst.* orbiculata.	23.	23. Ceriopora micropora, *Goldf.* cryptopora, *Goldf.* anomalopora, *Goldf.* dichotoma, *Goldf.* milleporacea, *Goldf.* madreporacea, *Goldf.* tubiporacea, *Goldf.* verticillata, *Goldf.* spiralis, *Goldf.* pustulosa, *Goldf.* compressa, *Goldf.* stellata, *Goldf.* Diadema, *Goldf.* polymorpha, *Goldf.* gracilis, *Goldf.* spongites, *Goldf.* clavata, *Goldf.* trigona, *Goldf.* Mitra, *Goldf.* venosa, *Goldf.* cribrosa, *Goldf.*
	24.	24. Lunulites cretacea, *Defr.*
	25. Orbitolites lenticulata, *Lamx.*	25. Orbitolites lenticulata, *Lamx.*
Agaricia rotata, *Goldf.* crassa, *Goldf.* granulata, *Munst.*	26.	26.
Lithodendron elegans, *Munst.* compressum, *Munst.*	27. Lithodendron gibbosum, *Munst* gracile, *Munst.*	27.
Caryophyllia cylindrica, *Phil.* truncata, *Lamx.* Brebissonii, *Lamx.* convexa, *Phil.*	28. Caryophyllia Conulus, *Phil.*	28. Caryophyllia centralis, *Mant.*
Anthophyllum turbinatum, *Munst.* obconicum, *Munst.* decipiens, *Goldf.*	29.	29.
Turbinolopsis ochracea, *Lamx.*	30.	30.
Turbinolia dispar, *Phil.*	31.	31. Turbinolia mitrata, Goldf. Königii, Mant.

Greywacke.	Coal Formation.	New Red Sandstone.
	Turbinolia pyramidalis, *His.*	
	mitrata, *Schlot.*	
	furcata, *His.*	
2.	32.	32.
3.	33. Fungites patellaris, *Lam.*	33.
	deformis, *Schlot.*	
4.	34.	34.
5. Cyathophyllum Dianthus, *Goldf.*	35. Cyathophyllum excentricum, *Goldf.*	35.
radicans, *Goldf.*		
marginatum, *Goldf.*		
explanatum, *Goldf.*		
turbinatum, *Goldf.*		
hypocrateriforme, *Goldf.*		
Ceratites, *Goldf.*		
flexuosum, *Goldf.*		
vermiculare, *Goldf.*		
vesiculosum, *Goldf.*		
secundum, *Goldf.*		
lamellosum, *Goldf.*		
placentiforme, *Goldf.*		
quadrigeminum, *Goldf.*		
cæspitosum, *Goldf.*		
hexagonum, *Goldf.*		
helianthoides, *Goldf.*		
6.	36.	36.
7.	37.	37.
8.	38.	38.
9. Strombodes pentagonus, *Goldf.*	39.	39.
0. Astrea porosa, *Goldf.*	40. Astrea interstincta, *Wahl.*	40. Astrea pediculata, *Desh.*
	undulata.	
41.	41.	41.
42. Calamopora alveolaris, *Goldf.*	42.	42.
favosa, *Goldf.*		
Gothlandica, *Goldf.*		

Continued.

Oolite.	Greensand.	Chalk.
Cyclolites elliptica, *Lam.*	32.	32.
Fungia orbiculites, *Lamx.*	33.	33. Fungia radiata, *Goldf.*
		cancellata, *Goldf.*
		coronula, *Goldf.*
	34. Chenendopora fungiformis, *Lam.*	34.
Cyathophyllum Tintinnabulum, *Goldf.*	35.	35.
Mactra, *Goldf.*		
	36. Hippalimus fungoides, *Lam.*	36.
	37.	37. Diploctenium cordatum, *Gold*
		Pluma, *Goldf.*
Meandrina Soemmeringii, *Munst.*	38.	38. Meandrina reticulata, *Goldf.*
astroides, *Goldf.*		
tenella, *Goldf.*		
	39.	39.
Astrea Microconos, *Goldf.*	40.	40. Astrea flexuosa, *Goldf.*
limbata, *Goldf.*		geometrica, *Goldf.*
concinna, *Goldf.*		clathrata, *Goldf.*
pentagonalis, *Munst.*		escharoides, *Goldf.*
gracilis, *Munst.*		textilis, *Goldf.*
explanata, *Munst.*		velamentosa, *Goldf.*
tubulosa, *Goldf.*		gyrosa, *Goldf.*
oculata, *Goldf.*		elegans, *Goldf.*
alveolata, *Goldf.*		angulosa, *Goldf.*
helianthoides, *Goldf.*		geminata, *Goldf.*
confluens, *Goldf.*		arachnoides, *Schröt.*
caryophylloides, *Goldf.*		Rotula, *Goldf.*
cristata, *Goldf.*		macrophthalma, *Gold*
sexradiata, *Goldf.*		muricata, *Goldf.*
favosioides, *Sm.*		stylophora, *Goldf.*
inæqualis, *Phil.*		
micastron, *Phil.*		
arachnoides, *Flem.*		
tubulifera, *Phil.*		
	41.	41. Pagrus Proteus, *Defr.*
	42.	42.

Greywacke.	Coal Formation.	New Red Sandstone.
Calamopora basaltica, *Goldf.*		
infundibulifera, *Goldf.*		
polymorpha, *Goldf.*		
spongites, *Goldf.*		
fibrosa, *Goldf.*		
3. Aulopora serpens, *Goldf.*	43.	43.
tubiformis, *Goldf.*		
spicata, *Goldf.*		
conglomerata, *Goldf.*		
4.	44.	44.
5. Columnaria alveolata, *Goldf.*	45.	45.
6. Coscinopora Placenta, *Goldf.*	46.	46.
7. Catenipora escharoides, *Lam.*	47. Catenipora fascicularis, *Wahl.*	47.
labyrinthica, *Goldf.*		
tubulosa, *Lam.*		
8.	48. Tubipora tubularia, *Lam.*	48.
9. Syringopora verticillata, *Goldf.*	49. Syringopora cæspitosa, *Goldf.*	49.
0. Favosites Gothlandica, *Lam.**	50. Favosites Gothlandica, *Lam.**	50.
Bromelli, *Ménard.*	Alcyonium, *Defr.*	
truncata, *Raf.*	septosus, *Flem.*	
Kentuckensis, *Raf.*	depressus, *Flem.*	
Boletus, *Ménard.*		
1.	51. Lithostrotion striatum.	51.
	floriforme.	
	marginatum, *Flem.*	
2. Amplexus coralloides, *Sow.**	52. Amplexus coralloides, *Sow.**	52.
3. Mastrema pentagona, *Raf.*	53.	53.
4.	54.	54.
5.	55.	55.
6.	56.	56.
7.	57.	57.
8.	58.	58.
9.	59.	59.
0.	60.	60.
1.	61.	61.
2.	62.	62.
3.	63.	63.

—*Continued.*

Oolite.	Greensand.	Chalk.
43. Aulopora compressa, *Goldf.* dichotoma, *Goldf.*	43.	43.
44. Entalophora cellarioides, *Lamx.*	44.	44.
45.	45.	45.
46.	46.	46.
47.	47.	47.
48.	48.	48.
49.	49.	49.
50.	50.	50.
51.	51.	51.
52.	52.	52.
53.	53.	53.
54. Spiropora tetragona, *Lamx.* cæspitosa, *Lamx.* elegans, *Lamx.* intricata, *Lamx.*	54.	54.
55. Eunomia radiata, *Lamx.*	55.	55.
56. Chrysaora damæcornis, *Lamx.* spinosa, *Lamx.*	56.	56.
57. Theonoa clathrata, *Lamx.*	57.	57.
58. Idmonea triquetra, *Lamx.*	58.	58.
59. Alecto dichotoma, *Lamx.*	59.	59.
60. Berenicea diluviana, *Lamx.*	60.	60.
61. Terebellaria ramosissima, *Lamx.* Antilope, *Lamx.*	61.	61.
62. Cellaria Smithii, *Phil.*	62.	62.
63. Thamnasteria Lamourouxii, *Sauv.*	63.	63.

CLASS II

Greywacke.	Coal Formation.	New Red Sandstone.
1. Cupressocrinites crassus, _Goldf._ gracilis, _Goldf._	1.	1.
2. Eugeniacrinites mespiliformis, _Goldf._	2.	2.
3. Eucalyptocrinites rosaceus, _Goldf._	3.	3.
4. Sphæronites Pomum, _Wahl._ Aurantium, _Wahl._ granatum, _Wahl._ Wahlenbergii, _Esmark._	4.	4.
5.	5. Pentremites Derbiensis, _Sow._ ellipticus, _Sow._ ovalis, _Goldf._	5.
6.	6. Poteriocrinites crassus, _Mill._ tenuis, _Mill._	6.
7. Platycrinites lævis, _Mill._* rugosus, _Mill._* pentangularis, _Mill._* ventricosus, _Goldf._	7. Platycrinites lævis, _Mill._* rugosus, _Mill._* pentangularis, _Mill._* granulatus, _Mill._ striatus, _Mill._ tuberculatus, _Mill._ depressus, _Goldf._	7.
8. Actinocrinites triacontadactylus, _Mill._* lævis, _Mill._* tesseratus, _Goldf._ moniliformis, _Mill._ cingulatus, _Goldf._ muricatus, _Goldf._ nodulosus, _Goldf._ monilifer, _Goldf._	8. Actinocrinites triacontadactylus, _Mill._* lævis, _Mill._* tesseratus, _Goldf._ polydactylus, _Mill._	8.
9. Melocrinites lævis, _Goldf._ gibbosus, _Goldf._	9. Melocrinites hieroglyphicus, _Goldf._	9.
0. Rhodocrinites verus, _Mill._* gyratus, _Goldf._ quinquepartitus, _Goldf._ canaliculatus, _Goldf._ crenatus, _Goldf._	10. Rhodocrinites verus, _Mill._*	10.
1. Cyathocrinites tuberculatus, _Mill._ rugosus, _Mill._ geometricus, _Goldf._ pinnatus, _Goldf._	11. Cyathocrinites planus, _Mill._* quinquangularis, _Mill._	11. Cyathocrinites planus, _Mill._*
2.	12.	12. Encrinites moniliformis, _Mill._ epithonius. ramosus, _Schlot._
3.	13.	13.
. _Pentacrinites priscus, Goldf._	14.	14.

—RADIATA.

Oolite.	Greensand.	Chalk.
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.
5.	5.	5.
6.	6.	6.
7.	7.	7.
8.	8.	8.
9.	9.	9.
10.	10.	10.
11.	11.	11.
12. Encrinites echinatus, *Schlot.* mespiliformis, *Schlot.*	12.	12.
13. Apiocrinites rotundus, *Mill.* Prattii, *Gray.* elongatus, *Mill.* rosaceus, *Schlot.* mespiliformis, *Schlot.* Milleri, *Schlot.* flexuosus, *Goldf.* subconicus, *Goldf.*	13.	13. Apiocrinites ellipticus,
14. Pentacrinites vulgaris, *Schlot.*	14.	14.

Greywacke.	Coal Formation.	New Red Sandstone.
15.	15.	15.
16.	16.	16.
17.	17.	17. Ophiura prisca, *Munst.* loricata, *Goldf.*
18.	18.	18. Asterias obtusa, *Goldf.*
19.	19.	19.
20.	20.	20.
21.	21.	21.
22.	22.	22.
[illegible]	23.	23.

Continued.

Oolite.	Greensand.	Chalk.
entacrinites subangularis, *Mill.*		
Briareus, *Mill.*		
basaltiformis, *Mill.*		
tuberculatus, *Mill.*		
subteres, *Goldf.*		
Jurensis, *Munst.*		
scalaris, *Goldf.*		
cingulatus, *Munst.*		
pentagonalis, *Goldf.*		
monilifer, *Munst.*		
subsulcatus, *Munst.*		
subteres, *Munst.*		
? paradoxus, *Goldf.*		
	15.	15. Marsupites ornatus, *Mill.*
	16.	16. Glenotremites paradoxus, *Goldf.*
	17.	17.
	18.	18.
Cidaris florigemma, *Phil.*	19. Cidaris variolaris, *Al. Br.**	19. Cidaris variolaris, *Al. Br.**
intermedia, *Park.*		cretosa, *Mant.*
monilipora, *Y. & B.*		claviger, *Kön.*
vagans, *Phil.*		vulgaris, *Lam.*
crenularis, *Lam.*		regalis, *Goldf.*
ornata.		vesiculosa, *Goldf.*
globata, *Schlot.*		scutiger, *Munst.*
maxima, *Munst.*		crenularis, *Lam.*
Blumenbachii, *Munst.*		granulosa, *Goldf.*
nobilis, *Munst.*		saxatilis, *Park.*
elegans, *Munst.*		
marginata, *Goldf.*		
coronata, *Goldf.*		
propinqua, *Munst.*		
glandifera, *Goldf.*		
Schmidelii, *Munst.*		
subangularis, *Goldf.*		
variolaris, *Al. Br.*		
Echinus germinans, *Phil.*	20. Echinus areolatus, *Wahl.*	20. Echinus regalis, *Hoen.*
lineatus, *Goldf.*	Benettiæ, *Kön.*	alutaceus, *Goldf.*
excavatus, *Leske.*		granulosus, *Munst.*
nodulosus, *Munst.*		
hieroglyphicus, *Goldf.*		
sulcatus, *Goldf.*		
Galerites depressus, *Lam.*	21. Galerites ? depressus, *Lam.*	21. Galerites albo-galerus, *Lam.*
speciosus, *Munst.*		vulgaris, *Lam.*
Patella.		subrotundus, *Mant.*
		Hawkinsii, *Mant.*
		abbreviatus, *Lam.*
		canaliculatus, *Goldf.*
		Subuculus, *Linn.*
		sulcato-radiatus, *Goldf.*
Clypeus sinuatus, *Park.*	22.	22.
emarginatus, *Phil.*		
cluncicularis, *Sm.*		
dimidiatus, *Phil.*		
semisulcatus, *Phil.*		
* orbicularis, *Phil.*		
Clypeaster pentagonalis, *Phil.*	23. Clypeaster oviformis, *Lam.*	23. Clypeaster Leskii, *Goldf.*

RAD

Greywacke.	Coal Formation.	New Red Sandstone.
24.	24.	24.
25	25.	25.
26.	26.	26.
27.	27.	27.

CLASS

Greywacke.	Coal Formation.	New Red Sandstone.
1.	1. Cypris Scoto-Bordigalensis, *Hibb.*	1.
2.	2. Daphnoidea, *Hibb.*	2.
3.	3.	3.
4.	4.	4.
5.	5.	5.
6.	6.	6.

tinued.

Oolite.	Greensand.	Chalk.
		Clypeaster fornicatus, *Goldf.*
	24. Echinoneus Lampas, *De la B.* peltiformis, *Wahl.*	24. Echinoneus subglobosus, *Goldf.* Placenta, *Goldf.*
cleolites scutatus. columbarius. granulosus, *Munst.* semiglobus, *Munst.* excentricus, *Munst.* canaliculatus, *Munst.*	25. Nucleolites Rotula, *Al. Br.** Lapis Cancri, *Goldf.** castanea, *Al. Br.*	25. Nucleolites Rotula, *Al. Br.** Lapis Cancri, *Goldf.** Ovulum, *Lam.* scrobicularis, *Goldf.* patellaris, *Goldf.* pyriformis, *Goldf.* lacunosus, *Goldf.* cordatus, *Goldf.* carinatus, *Goldf.*
anchytes bicordata.	26.	26. Ananchytes ovata, *Lam.* hemisphærica, *Al. Br.* intumescens. pustulosa, *Lam.* conoidea, *Goldf.* striata, *Lam.* sulcata, *Goldf.* Corculum, *Goldf.*
tangus ovalis, *Park.* intermedius, *Munst.* carinatus, *Goldf.* capistratus, *Goldf.*	27. Spatangus Cor-anguinum, *Lam.** suborbicularis, *Defr.** retusus, *Park.* Murchisonianus, *Kön.* argillaceus, *Phil.* lævis, *Defr.* Ambulacrum, *Desh.*	27. Spatangus Cor-anguinum, *Lam.** suborbicularis, *Defr.** cordiformis, *Mant.* punctatus, *Lam.* granulosus, *Goldf.* subglobosus, *Leske.* nodulosus, *Goldf.* radiatus, *Lam.* truncatus, *Goldf.* ornatus, *Cuv.* Bucklandii, *Goldf.* Bufo, *Al. Br.* arcuarius, *Lam.* Prunella, *Lam.* Amygdala, *Goldf.* gibbus, *Lam.* Cor-testudinarium, *Goldf.* Bucardium, *Goldf.* lacunosus, *Linn.* hemisphæricus, *Phil.*

RUSTACEA.

Oolite.	Greensand.	Chalk.
	1. Cypris Faba, *Desm.*	1.
	2.	2.
tacus modestiformis, *Holl.* minutus, *Holl.* rostratus, *Phil.*	3. Astacus ornatus, *Phil.* longimanus, *Sow.*	3. Astacus Leachii, *Mant.* Sussexiensis, *Mant.*
gurus mysticus, *Holl.*	4.	4. Pagurus Faujasii, *Desm.*
yllarus dubius, *Holl.*	5.	5. Scyllarus Mantelli, *Desm.*
yon Cuvieri, *Desm.* Schlotheimii, *Holl.*	6.	6.

CRUST

Greywacke.	Coal Formation.	New Red Sandstone.
7.	7.	7.
8.	8.	8. Palinurus Sueurii, *Des*
9. Calymene Blumenbachii, *Al. Br.*	9. Calymene Blumenbachii, *Al. Br.**	9.
variolaris, *Al. Br.**	variolaris, *Al. Br.**	
macrophthalma, *Al. Br.*	punctata, *Wahl.*	
Tristani, *Al. Br.*	concinna, *Dalm.*	
bellatula, *Dalm.*		
ornata, *Dalm.*		
verrucosa, *Dalm.*		
polytoma, *Dalm.*		
actinura, *Dalm.*		
Schrops, *Dalm.*		
Schlotheimi, *Bronn.*		
latifer, *Bronn.*		
? æqualis, *Meyer.*		
10. Asaphus corniger, *Al. Br.*	10. Asaphus cordatus, *Al. Br.*	10.
cordiger, *Al. Br.*		
Hausmanni, *Al. Br.*		
de Buchii, *Al. Br.*		
Brongniartii, *Deslongchamps.*		
extenuatus, *Wahl.*		
granulatus, *Wahl.*		
angustifrons, *Dalm.*		
Heros, *Dalm.*		
expansus, *Wahl.*		
platynotus, *Dalm.*		
frontalis, *Dalm.*		
læviceps, *Dalm.*		
palpebrosus, *Dalm.*		
crassacanda, *Wahl.*		
Sultzeri.		
11. Ogygia Guettardii, *Al. Br.*	11.	11.
Desmaresti, *Al. Br.*		
Wahlenbergii, *Al. Br.*		
Sillimani, *Al. Br.*		
12. Paradoxides spinulosus, *Al. Br.*	12. Paradoxicus spinulosus, *A. Br.*	12.
Tessini, *Al. Br.*		
gibbosus, *Al. Br.*		
scaraboides, *Al. Br.*		
Hoffii, *Goldf.*		
13. Nileus Armadillo, *Dalm.*	13.	13.
Glomerinus, *Dalm.*		
14. Illaenus Centaurus, *Dalm.*	14.	14.
centrotus, *Dalm.*		
latecauda, *Wahl.*		
15. Ampyx nasutus, *Dalm.*	15.	15.
16. Olenus Bucephalus, *Wahl.*	16.	16.
17. Agnostus pisiformis, *Al. Br.*	17.	17.
18. Isoletus Gigas, Dekay.	18.	18.
planus, Dekay.		

med.

Oolite.	Greensand.	Chalk.
emon spinipes, *Desm.*	7.	7.
longimanatus.		
Walchii, *Holl.*		
modestiformis, *Holl.*		
minutus, *Holl.*		
rostratus, *Phil.*		
	8.	8.
	9.	9.
	10.	10.
	11	11.
	12.	12.
	13.	13.
	14.	14.
	15.	15.
	16.	16.
	17.	17.
	18.	18.

CLASS IV.

Greywacke.	Coal Formation.	New Red Sandstone.
1.	1.	1.
2. Serpula epithonia, *Goldf.* ammonia, *Goldf.* omphalodes, *Goldf.* socialis, *Goldf.*	2. Serpula Lithuus, *Schlot.* compressa, *Sow.*	2. Serpula valvata, *Goldf.* colubrina, *Goldf.*

NNELIDES.

Oolite.	Greensand.	Chalk.
mbricaria Intestinum, *Munst.*	1.	1.
Colon, *Munst.*		
recta, *Munst.*		
gordialis, *Munst.*		
conjugata, *Munst.*		
Filaria, *Munst.*		
rpula squamosa, *Bean.*	2. Serpula Carinella, *Sow.*	2. Serpula ampullacea, *Sow.*
lacerata, *Phil.*	antiquata, *Sow.*	Plexus, *Sow.*
intestinalis, *Phil.*	rustica, *Sow.*	obtusa, *Sow.*
deplexa, *Bean.*	articulata, *Sow.*	fluctuata, *Sow.*
capitata, *Phil.*		? macropus, *Sow.*
quadrangularis.		
sulcata, *Sow.*		
tricarinata, *Sow.*		
triangulata, *Sow.*		
runcinata, *Sow.*		
tricristata, *Goldf.*		
quinquecristata, *Munst.*		
quinquesulcata, *Munst.*		
circinnalis, *Munst.*		
complanata, *Goldf.*		
grandis, *Goldf.*		
Limax, *Goldf.*		
conformis, *Goldf.*		
convoluta, *Goldf.*		
lituiformis, *Munst.*		
Delphinula, *Goldf.*		
capitata, *Goldf.*		
limata, *Munst.*		
plicatilis, *Munst.*		
gibbosa, *Goldf.*		
nodulosa, *Goldf.*		
Spirolinites, *Munst.*		
tricarinata, *Goldf.*		
pentagona, *Goldf.*		
quinquangularis, *Goldf.*		
quadrilatera, *Goldf.*		
vertebralis, *Sow.*		
prolifera, *Goldf.*		
planorbiformis, *Munst.*		
trochleata, *Munst.*		
macrocephala, *Goldf.*		
heliciformis, *Goldf.*		
quadristriata, *Goldf.*		
convoluta, *Munst.*		
canaliculata, *Munst.*		
Deshayesii, *Munst.*		
volubilis, *Munst.*		
spiralis, *Munst.*		
cingulata, *Munst.*		
Flagellum, *Munst.*		
substriata, *Munst.*		
flaccida, *Munst.*		
gordialis, *Schlot.*		
intercepta, *Goldf.*		
Ilium, *Goldf.*		
Filaria, *Goldf.*		
socialis, *Goldf.*		
problematica, *Munst.*		

CLASS V.

Greywacke.	Coal Formation.	New Red Sandstone.
1.	1.	1.

CLASS VI.

Greywacke.	Coal Formation.	New Red Sandstone.
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.
5.	5. Mya ? tellinaria. ? ventricosa. ? minuta.	5.
6.	6.	6. Myacites musculoides, *Schlot.* intermedius. elongatus, *Schlot.* ventricosus, *Schlot.*
7.	7.	7. Panopæa gibbosa, *Sow.*
8.	8.	8. Axinus obscurus, *Sow.*
9.	9. Saxicava Blainvillii, *Hoen.**	9. Saxicava Blainvillii, *Hoen.**
10.	10. Hyatella carbonaria.	10.
11.	11.	11.
12.	12.	12.
13.	13.	13.
14.	14.	14.
15.	15.	15.
16.	16. Sanguinolaria gibbosa, *Sow.*	16.
17.	17.	17.
18.	18. Tellina lineata, *Hoen.*	18.
19.	19.	19.
20.	20.	20.
21.	21.	21

—CIRRHIPEDA.

Oolite.	Greensand.	Chalk.
1.	1.	1. Pollicipes sulcatus, *Sow.* maximus, *Sow.*

—CONCHIFERA.

Oolite.	Greensand.	Chalk.
1.	1. Fistularia pyriformis, *Mant.*	1.
2.	2. Teredina personata, *Lam.*	2.
3. Pholas recondita, *Phil.* ? compressa, *Sow.*	3. Pholas constricta, *Phil.*	3.
4. Gastrochæna tortuosa, *Sow.*	4.	4.
5. Mya literata, *Sow.* depressa, *Sow.* calceiformis, *Phil.* dilata, *Phil.* æquata, *Phil.* V scripta, *Sow.* Mandibula, *Sow.* angulifera, *Sow.*	5. Mya mandibula, *Sow.* depressa, *Sow.* phaseolina, *Phil.* plana, *Sow.*	5.
6.	6.	6.
7.	7. Panopæa plicata, *Sow.*	7.
8.	8.	8.
9.	9.	9.
10.	10.	10.
11. Lutraria Jurassi, *Al. Br.*	11. Lutraria Gurgitis, *Al. Br.*	11. Lutraria ? carinifera, *Sow.*
12. Mactra gibbosa.	12.	12.
13.	13.	13. Crassatella latissima. tumida.
14. Amphidesma decurtatum, *Phil.* recurvum, *Phil.* securiforme, *Phil.* donaciforme, *Phil.* rotundatum, *Phil.*	14.	14.
15. Corbula curtansata, *Phil.* depressa, *Phil.* ? cardioides, *Phil.* obscura, *Sow.*	15. Corbula striatula, *Sow.* Punctum, *Phil.* gigantea, *Sow.* lævigata, *Sow.* anatina, *Desh.*	15. Corbula ovalis, *Nils.* caudata, *Nils.*
16. Sanguinolaria undulata, *Sow.* elegans, *Phil.*	16.	16.
17. Psammobia lævigata, *Phil.*	17.	17.
18. Tellina ampliata, *Phil.*	18. Tellina æqualis, *Mant.* inæqualis, *Sow.* striatula, *Sow.*	18.
19. Donax Alduini, *Al. Br.*	19.	19.
20. Pullastra recondita, *Phil.* oblita, *Phil.*	20.	20.
21. Corbis lævis, *Sow.* ovalis, *Phil.* uniformis, *Phil.*	21.	21.

Greywacke.	Coal Formation.	New Red Sandstone.
22.	22.	22.
23.	23.	23.
24.	24.	24.
25.	25.	25.
26.	26.	26.
27.	27.	27.
28.	28.	28.
29.	29.	29.
30.	30. Cypricardia ? annulata, *Hoen.*	30.
31. Cardium costellatum, *Munst.* hybridum, *Munst.* alæforme, *Sow.** lineare, *Munst.* priscum, *Munst.* striatum, *Munst.*	31. Cardium elongatum, *Sow.* hibernicum, *Sow.* alæforme, *Sow.*	31. Cardium ? striatum.
32. Cardita costellata, *Munst.* gracilis, *Munst.* plicata, *Munst.* tripartita, *Munst.*	32.	32.
33. Isocardia Humboldtii, *Hoen.* oblonga, *Sow.*	33.	33.

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Oolite.	Greensand.	Chalk.
Lu.ina crassa, *Sow.* lyrata, *Phil.* despecta, *Phil.*	22. Lucina sculpta, *Phil.*	22.
Astarte cuneata, *Sow.* excavata, *Sow.* planata, *Sow.* trigonalis, *Sow.* orbicularis, *Sow.* pumila, *Sow.* Voltzii.	23. Astarte striata, *Sow.*	23.
Crassina ovata, *Sm.* elegans, *Sow.* aliena, *Phil.* extensa, *Phil.* carinata, *Phil.* lurida, *Sow.* minima, *Phil.*	24.	24.
Myoconcha crassa, *Sow.*	25.	25.
	26. Cyclas membranacea, *Sow.* media, *Sow.* cornea, (*not Lam.*).	26.
	27. Thetis minor, *Sow.* major, *Sow.*	27.
Cytherea dolabra, *Phil.* trigonellaris, *Voltz.* lucinea, *Voltz.* cornea, *Voltz.*	28.	28.
Venus varicosa, *Sow.*	29. Venus parva, *Sow.* angulata, *Sow.* Faba, *Sow.* ovalis, *Sow.* lineolata, *Sow.* plana, *Sow.* caperata, *Sow.*	29. Venus Ringmeriensis, *Mant.* ? exerta, *Nils.*
	30.	30.
Cardium lobatum, *Phil.* dissimile, *Sow.* citrinoideum, *Phil.* cognatum, *Phil.* acutangulum, *Phil.* semiglabrum, *Phil.* incertum, *Phil.* striatulum, *Sow.* gibberulum, *Phil.* truncatum, *Sow.* multicostatum, *Bean.*	31. Cardium Hillanum, *Sow.* proboscideum, *Sow.* bullatum, *Lam.*	31. Cardium decussatum, *Sow.*
Cardita similis, *Sow.* lunulata, *Sow.* striata, *Sow.*	32. Cardita tuberculata, *Sow.*	32. Cardita Esmarkii, *Nils.* Modiolus, *Nils.* crassa.
Isocardia rhomboidalis, *Phil.* tumida, *Phil.* minima, *Sow.* concentrica, *Sow.* angulata, *Phil.* rostrata, *Sow.* striata, *D'Orb.*	33.	33.

Greywacke.	Coal Formation.	New Red Sandstone.
34.	34. Hippopodium abbreviatum, *Goldf.*	34.
35.	35.	35.
36.	36. Arca cancellata, *Sow.*	36. Arca tumida, *Sow.*
37.	37.	37.
38.	38.	38. Cucullæa sulcata, *Sow.*
39.	39. Nucula attenuata, *Flem.* gibbosa, *Flem.* Palmæ, *Sow.*	39.
40.	40.	40. Trigonia vulgaris, *Schlot.* Pes-anseris, *Schlo*

—*Continued.*

Oolite.	Greensand.	Chalk.
4. Hippopodium ponderosum, *Sow.*	34.	34.
5. Pholadomya Murchisoni, *Sow.*	35.	35.
simplex, *Phil.*		
deltoidea, *Sow.*		
obsoleta, *Phil.*		
ovalis, *Sow.*		
acuticostata, *Sow.*		
nana, *Phil.*		
producta, *Sow.*		
obliquata, *Phil.*		
fidicula, *Sow.*		
obtusa, *Sow.*		
ambigua, *Sow.*		
æqualis, *Sow.*		
gibbosa.		
Proteii, *Al. Br.*		
clathrata, *Munst.*		
6. Arca quadrisulcata, *Sow.*	36. Arca carinata, *Sow.*	36. Arca exaltata, *Nils.*
æmula, *Phil.*		clathrata.
pulchra, *Sow.*		ovalis, *Nils.*
trigonella.		subacuta.
elongata.		
rostrata.		
7. Pectunculus minimus, *Sow.*	37. Pectunculus sublævis, *Sow.*	37. Pectunculus lens, *Nils.*
oblongus, *Sow.*	umbonatus, *Sow.*	
8. Cucullæa oblonga, *Sow.*	38. Cucullæa decussata, *Sow.**	38. Cucullæa decussata, *Sow.**
contracta, *Phil.*	glabra, *Sow.*	auriculifera.
triangularis, *Phil.*	carinata, *Sow.*	crassatina.
pectinata, *Phil.*	fibrosa, *Sow.*	
elongata, *Sow.*	costellata, *Sow.*	
concinna, *Phil.*		
imperialis, *Bean.*		
cylindrica, *Phil.*		
cancellata, *Phil.*		
reticulata, *Bean.*		
minuta, *Sow.*		
rudis, *Sow.*		
9. Nucula elliptica, *Phil.*	39. Nucula pectinata, *Mant.*	39. Nucula ovata, *Nils.*
nuda, *Y. & B.*	ovata, *Mant.*	truncata, *Nils.*
variabilis, *Sow.*	impressa, *Sow.*	panda, *Nils.*
Lachryma, *Sow.*	subrecurva, *Phil.*	producta, *Nils.*
axiniformis, *Phil.*	antiquata, *Sow.*	
Ovum, *Sow.*	angulata, *Sow.*	
pectinata, *Sow.*	undulata, *Sow.*	
clariformis.		
mucronata, *Sow.*		
0. Trigonia costata, *Sow.*	40. Trigonia Dædalea, *Park.*	40. Trigonia pumila, *Nils.*
clavellata, *Sow.*	aliformis, *Sow.*	
conjungens, *Phil.*	spinosa, *Sow.*	
striata, *Sow.*	rugosa, *Lam.*	
angulata, *Sow.*	scabra, *Lam.*	
literata, *Y. & B.*	eccentrica, *Sow.*	
gibbosa, *Sow.*	nodosa, *Sow.*	
duplicata, *Sow.*	spectabilis, *Sow.*	
elongata, *Sow.*	arcuata, *Lam.*	
imbricata, *Sow.*	alata.	
cuspidata, *Sow.*		

Greywacke.	Coal Formation.	New Red Sandstone.
1.	41. Chama ? antiqua, *Hoen.*	41.
2.	42.	42.
3.	43. Mytilus minimus, *Hoen.* crassus, *Flem.*	43. Mytilus eduliformis, *Schlot.* squamosus, *Sow.*
4.	44.	44.
5. Megalodon cucullatus, *Sow.**	45. Megalodon cucullatus, *Sow.**	45.
6.	46. Modiola Goldfussii, *Hoen.*	46. Modiola acuminata, *Sow.*
7.	47. Unio Urii, *Flem.*	47.
8.	48.	48.

ontinued.

Oolite.	Greensand.	Chalk.
Trigonia Pullus, *Sow.*		
navis, *Lam.*		
incurva, *Benett.*		
Chama ? mima, *Phil.*	41.	41. Chama Cornu Arietis, *Nils.*
? crassa, *Sm.*		laciniata, *Nils.*
		recurvata.
Inoceramus dubius, *Sow.*	42. Inoceramus concentricus, *Park.**	42. Inoceramus concentricus, *Park.**
	sulcatus, *Park.**	sulcatus, *Park.**
	Cuvieri, *Sow.**	Cuvieri, *Sow.*
	Brongniarti, *Mant.**	Brongniarti, *Mant.**
	mytiloides, *Mant.*	mytiloides, *Mant.**
	rugosus.	cordiformis, *Sow.*
	gryphæoides, *Sow.*	latus, *Mant.*
		Websteri, *Mant.*
		striatus, *Mant.*
		undulatus, *Mant.*
		involutus, *Sow.*
		tenuis, *Mant.*
		Cripsii, *Mant.*
Mytilus cuneatus, *Phil.*	43. Mytilus lanceolatus, *Sow.*	43. Mytilus lævis, *Defr.*
amplus.	edentulus, *Sow.*	
pectinatus, *Sow.*	problematicus.	
sublævis, *Sow.*		
solenoides.		
	44.	44. Pachymya Gigas, *Sow.*
	45.	45.
Modiola imbricata, *Sow.*	46. Modiola æqualis, *Sow.*	46.
ungulata, *Y. & B.*	bipartita, *Sow.*	
bipartita, *Sow.*		
cuneata, *Sow.*		
pulchra, *Sow.*		
plicata, *Sow.*		
aspera, *Sow.*		
Scalprum, *Sow.*		
Hillana, *Sow.*		
lævis, *Sow.*		
depressa, *Sow.*		
minima, *Sow.*		
subcarinata, *Lam.*		
tulipea, *Lam.*		
pallida, *Sow.*		
gibbosa, *Sow.*		
livida, *Goldf.*		
ventricosa, *Goldf.*		
Unio peregrinus, *Phil.*	47. Unio porrectus, *Sow.*	47.
abductus, *Phil.*	compressus, *Sow.*	
concinnus, *Sow.*	antiquus, *Sow.*	
crassiusculus, *Sow.*	aduncus, *Sow.*	
Listeri, *Sow.*	cordiformis, *Sow.*	
crassissimus, *Sow.*		
Gervillia aviculoides, *Sow.**	48. Gervillia aviculoides, *Sow.**	48. Gervillia solenoides, *Defr.**
? acuta, *Sow.**	? acuta, *Sow.**	
lata, *Phil.*	solenoides, *Defr.**	
pernoides, *Desl.*		
siliqua, *Desl.*		

CONCHI

Greywacke.	Coal Formation.	New Red Sandstone.
49.	49.	49.
50.	50.	50.
51.	51.	51.
52.	52.	52.
53.	53.	53. Avicula socialis, *Des* gryphæoides,
54.	54. Vulsella lingulata, *Hoen.* elongata, *Blain.* brevis, *Blain.*	54.
55.	55. Lingula striata.	55.
56.	56.	56.
57.	57.	57.
58.	58.	58.
59.	59.	59.
60.	60.	60.

ntinued.

Oolite.	Greensand.	Chalk.
ervillia monotis, _Desl._		
costellata, _Desl._		
erna quadrata, _Sow._	49.	49.
mytiloides, _Lam._		
isogonoides.		
renatula ventricosa, _Sow._	50.	50.
rigonellites antiquatus, _Phil._	51.	51.
politus, _Phil._		
inna lanceolata, _Sow._	52. Pinna gracilis, _Phil._	52. Pinna affinis.
mitis, _Phil._	tetragona, _Sow._	flabellum.
cuneata, _Bean._		nobilis.
Folium, _Y. & B._		restituta.
pinnigena.		subquadrivalvis.
granulata, _Sow._		
vicula expansa, _Phil._	53.	53. Avicula cærulescens, _Nils._
ovalis, _Phil._		
elegantissima, _Bean._		
tonsipluma, _Y. & B._		
Braamburiensis, _Sow._		
inæquivalvis, _Sow._		
echinata, _Sow._		
cygnipes, _Y. & B._		
costata, _Sow._		
lanceolata, _Sow._		
ovata, _Sow._		
	54.	54.
ingula Beanii, _Phil._	55.	55.
licatula spinosa, _Sow._	56. Plicatula pectinoides, _Sow._*	56. Plicatula pectinoides, _Sow._*
		inflata, _Sow._
	57. Sphæra corrugata, _Sow._	57.
	58.	58. Podopsis lata, _Mant._
		obliqua, _Mant._
		striata, _Sow._
		truncata, _Lam._
		lamellosa, _Nils._
		spinosa.
ryphæa chamæformis, _Phil._	59. Gryphæa auricularis, _Al. Br._*	59. Gryphæa auricularis, _Al. Br._*
bullata, _Sow._	Columba, _Lam._*	Columba, _Lam._*
inhærens, _Phil._	plicata, _Lam._*	plicata, _Lam._*
dilatata, _Sow._	vesiculosa, _Sow._	truncata, _Goldf._
incurva, _Sow._	sinuata, _Sow._	
nana, _Sow._	Aquila, _Al. Br._	
Maccullochii, _Sow._	secunda.	
depressa, _Phil._	canaliculata, _Sow._	
obliquata, _Sow._		
Cymbium, _Lam._		
lituola, _Lam._		
gigantea, _Sow._		
minuta, _Sow._		
virgula, _Defr._		
	60. Exogyra haliotidea, _Sow._*	60. Exogyra haliotidea, _Sow._*
	conica, _Sow._*	conica, _Sow._*
	digitata, _Sow._	
	undata, _Sow._	
	lævigata, _Sow._	

Greywacke.	Coal Formation.	New Red Sandstone.
61.	61. Ostrea prisca, *Hoen.*	61. Ostrea spondyloides.
62.	62. Hinnites Blainvillii, *Hoen.*	62.
63.	63.	63.
64.	64.	64. Plagiostoma lineatum. rigidum. lævigatum. punctatum. striatum.
65. Posidonia Becheri, *Bronn.*	65.	65. Posidonia Keuperina, *Voltz.*
66.	66.	66.
67. Pecten primigenius, *Meyer.* Munsteri, *Meyer.*	67. Pecten papyraceus, *Sow.* dissimilis, *Flem.* priscus, *Schlot.* granosus, *Sow.* plicatus, *Sow.*	67. Pecten reticulatus, *Schlot.*

—_Continued._

Oolite.	Greensand.	Chalk.
.. Ostrea gregarea, _Sow._	61. Ostrea carinata, _Lam._*	61. Ostrea carinata, _Lam._*
solitaria, _Sow._	serrata, _Defr._*	serrata, _Defr._*
duriuscula, _Bean._	parasitica.	vesicularis, _Lam._
inæqualis, _Phil._	truncata.	semiplana, _Mant._
undosa, _Bean._	biauricularis.	canaliculata, _Sow._
archetypa, _Phil._		lateralis, _Nils._
Marshii, _Sow._		clavata, _Nils._
sulcifera, _Phil._		Hippopodium, _Nils._
deltoidea, _Sm._		curvirostris, _Nils._
expansa, _Sow._		acutirostris, _Nils._
palmetta, _Sow._		flabelliformis, _Nils._
acuminata, _Sow._		pusilla, _Nils._
rugosa, _Sow._		lunata, _Nils._
minima, _Desl._		incurva, _Nils._
plicatilis.		? plicata, _Nils._
costata, _Sow._		
pectinata.		
pennaria.		
flabelloides, _Lam._		
læviuscula, _Sow._		
obscura, _Sow._		
Meadii, _Sow._		
2.	62.	62. Hinnites ? Dubuissoni.
3.	63. Spondylus ? strigilis, _Al. Br._	63.
4. Plagiostoma læviusculum, _Sow._	64. Plagiostoma spinosum, _Sow._*	64. Plagiostoma spinosum, _Sow_
rigidum, _Sow._	turgidum, _Lam._*	turgidum, _Lam._*
pectinoïdes, _Sow._*	pectinoïdes, _Sow._*	Hoperi, _Mant._
rusticum, _Sow._		Brightoniensis, _Ma_
duplicatum, _Sow._		elongatum, _Sow._
rigidulum, _Phil._		asperum, _Mant._
interstinctum, _Phil._		ovatum, _Nils._
cardiiforme, _Sow._		semisulcatum, _Nils_
giganteum, _Sow._		Mantelli, _Al. Br._
obscurum, _Sow._		granulatum, _Nils._
punctatum, _Sow._		elegans, _Nils._
sulcatum.		pusillum, _Nils._
ovale, _Sow._		denticulatum, _Nils_
Hermanni, _Voltz._		
obliquatum, _Sow._		
acuticostatum, _Sow._		
concentricum, _Sow._		
5. Posidonia Bronni, _Goldf._	65.	65.
6. Lima rudis, _Sow._	66.	66. Lima pectinoides.
proboscidea, _Sow._		
gibbosa, _Sow._		
antiquata, _Sow._		
7. Pecten abjectus, _Phil._	67. Pecten quinquecostatus, _Sow._*	67. Pecten quinquecostatus, _Sow_
inæquicostatus, _Phil._	orbicularis, _Sow._*	orbicularis, _Sow._*
cancellatus, _Bean._	quadricostatus, _Sow._*	quadricostatus, _Sow._
arcuatus, _Sow._*	arcuatus, _Sow._*	arcuatus, _Sow._*
demissus, _Phil._	asper, _Lam._*	asper, _Lam._*
Lens, _Sow._	nitidus, _Sow._*	nitidus, _Sow._*
vagans, _Sow._	obliquus, _Sow._	Beaveri, _Sow._
fibrosus, _Sow._	asperrimus.	triplicatus, _Mant._
virgulifer, _Phil._	gryphæatus.	cretosus, _Defr._
sublævis, _Y. & B._	sulcatus, _Sow._	arachnoides, _Defr._
æquivalvis, _Sow._	versicostatus.	extextus, _Al. Br._
lamellosus, _Sow._		serratus, _Nils._

Greywacke.	Coal Formation.	New Red Sandstone.
8.	68. Crania prisca, *Hoen.*	68.
9.	69.	69.
0.	70.	70.
1.	71.	71.
2. Strygocephalus Burtini, *Defr.*	72.	72.
elongatus, *Goldf.*		
3. Calceola sandalina, *Lam.*	73.	73.
heteroclita, *Defr.*		
4. Strophomena Goldfussii, *Hoen.*	74.	74.
rugosa, *Raf.*		
euglypha, *Hoen.*		
pileopsis, *Raf.*		
umbraculum, *Schlot.*		
marsupita, *Defr.*		
5. Terebratula lacunosa, *Schlot.**	75. Terebratula lacunosa, *Schlot.**	75. Terebratula lacunosa, *Schlot*
lævigata, *Schlot.**	lævigata, *Schlot.**	inflata, *Schlot.*
elongata, *Schlot.**	resupinata, *Sow.*	elongata, *Schlot.**
intermedia, *Lam.**	vestita, *Schlot.*	intermedia, *Lam.**
acuminata, *Sow.**	acuminata, *Sow.**	perovalis.
crumena, *Sow.**	crumena, *Sow.**	sufflata.
monticulata, *Schlot.**	monticulata, *Schlot.**	vulgaris, *Schlot.*
Sacculus, *Sow.**	Sacculus, *Sow.**	orbiculata, *Schlot.*

inued.

Oolite.	Greensand.	Chalk.
ten similis, *Sow.*		Pecten septemplicatus, *Nils*
laminatus, *Sow.*		multicostatus, *Nils.*
barbatus, *Sow.*		undulatus, *Nils.*
vimineus, *Sow.*		subaratus, *Nils.*
obscurus, *Sow.*		pulchellus, *Nils.*
annulatus, *Sow.*		lineatus, *Nils.*
concinnus.		virgatus, *Nils.*
marginatus.		membranaceus, *Nils*
		lævis, *Nils.*
		inversus, *Nils.*
		regularis, *Schlot.*
		corneus, *Sow.*
		dentatus, *Nils.*
	68.	68. Crania Parisiensis, *Defr.*
		antiqua, *Defr.*
		striata, *Defr.*
		stellata, *Defr.*
		spinulosa, *Nils.*
		tuberculata, *Nils.*
		Nummulus, *Lam.*
icula reflexa, *Sow.*	69.	69.
? radiata, *Phil.*		
granulata, *Sow.*		
	70.	70. Hippurites radiosa, *Des M.*
		Cornu Pastoris, *Des*
		striata, *Defr.*
		sulcata, *Defr.*
		dilatata, *Defr.*
		bioculata, *Lam.*
		Fistulæ, *Defr.*
	71.	71. Sphærulites dilatata, *Des*
		Bournonii, *Des M.*
		ingens, *Des M.*
		Hoeninghausii, *Des*
		foliacea, *Lam.*
		Jodamia, *Des M.*
		Jouanettii, *Des M.*
		crateriformis, *Des M*
		Moulinii, *Goldf.*
	72.	72.
	73.	73.
	74.	74.
ebratula subrotunda, *Sow.**	75. Terebratula subrotunda, *Sow.**	75. Terebratula subrotunda, *So*
globata, *Sow.*	carnea, *Sow.**	carnea, *Sow.**
ornithocephala, *Sow.*	ovata, *Sow.**	ovata, *Sow.**
ovata, *Sow.*	plicatilis, *Sow.**	plicatilis, *Sow.**
obsoleta, *Sow.*	subundata, *Sow.**	subundata, *Sow.**
crumena, *Sow.**	Defrancii, *Al. Br.*	Defrancii, *Al. Br.*
ovoides, *Sow.*	octoplicata, *Sow.**	octoplicata, *Sow.**
digona, *Sow.*	Gallina, *Al. Br.**	Gallina, *Al. Br.**

CONCHIFE

Greywacke.	Coal Formation.	New Red Sandstone.
Terebratula Wilsoni, *Sow.** Mantiæ, *Sow.** cordiformis, *Sow.** platyloba, *Sow.** Pugnus, *Sow.** reniformis, *Sow.** lateralis, *Sow.** rostrata, *Schlot.* prisca, *Schlot.* affinis, *Sow.* plicatella, *Linn.* osteolata, *Schlot.* aperturata, *Schlot.* lenticularis, *Wahl.* alata, *Lam.* aspera, *Schlot.* comprimata, *Schlot.* curvata, *Schlot.* excisa, *Schlot.* explanata, *Schlot.* imbricata, *Sow.* speciosa, *Schlot.* hysterolita, *Hoen.* paradoxa, *Hoen.*	Terebratula Wilsoni, *Sow.** Mantiæ, *Sow.** cordiformis, *Sow.** platyloba, *Sow.** Pugnus, *Sow.** reniformis, *Sow.** lateralis, *Sow.** hastata, *Sow.* cuneata, *Dalm.* diodonta, *Dalm.* bidentata, *His.* marginalis, *Dalm.* didyma, *Dalm.* affinis, *Sow.* ? lineata, *Sow.* ? imbricata, *Sow.* Fimbria, *Sow.*	Terebratula cristata. paradoxa, *Schlo* pelargonata, *Sc* pygmæa, *Schlot*
76.	76.	76.
77.	77. Pentamerus Aylesfordii, *Sow.* Knightii, *Sow.* lævis, *Sow.*	77.
78.	78. Læptæna rugosa, *His.* depressa, *Sow.*	78.

inued.

Oolite.	Greensand.	Chalk.
ebratula spinosa,	Terebratula pectita, *Sow.**	Terebratula pectita, *Sow.**
Townsend & Sm.	semiglobosa, *Sow.**	semiglobosa, *Sow.**
trilineata, *Y. & B.*	dissimilis, *Schlot.**	dissimilis, *Schlot.**
bidens, *Phil.*	lata, *Sow.**	lata, *Sow.**
lata, *Sow.**	tetraedra, *Sow.**	elongata, *Sow.*
tetraedra, *Sow.**	dimidiata, *Sow.**	subplicata, *Mant.*
dimidiata, *Sow.**	inconstans, *Sow.**	curvirostris, *Nils.*
inconstans, *Sow.**	Lyra, *Sow.*	Mantelliana, *Sow.*
intermedia, *Sow.*	obtusa, *Sow.*	Martini, *Mant.*
obovata, *Sow.*	curvata, *Schlot.*	rostrata, *Sow.*
reticulata, *Sow.*	lacunosa, *Schlot.*	squamosa, *Mant.*
media, *Sow.*	nucleus, *Defr.*	undata, *Sow.*
socialis, *Phil.*	ovoidea, *Sow.*	alata, *Lam.*
concinna, *Sow.*	semistriata, *Lam.*	recurva, *Defr.*
biplicata, *Sow.*	striatula, *Sow.*	lævigata, *Nils.*
tetrandra.	biplicata, *Sow.*	triangularis, *Wahl.*
coarctata, *Park.*	lineolata, *Phil.*	longirostris, *Wahl.*
plicatella, *Sow.*	ornithocephala, *Sow.*	rhomboidalis, *Nils.*
serrata, *Sow.*		obesa, *Sow.*
truncata, *Sow.*		aperturata, *Schlot.*
punctata, *Sow.*		chrysalis, *Schlot.*
dimidiata, *Sow.*		microscopica, *St. F*
bullata, *Sow.*		peltata.
sphæroidalis, *Sow.*		varians.
emarginata, *Sow.*		vermicularis, *Schlo*
quadrifida.		minor, *Nils.*
numismalis, *Lam.*		pulchella, *Nils.*
perovalis, *Sow.*		costata, *Nils.*
maxillata, *Sow.*		Lens, *Nils.*
flabellula, *Sow.*		depressa, *Lam.*
furcata, *Sow.*		
orbicularis, *Sow.*		
hemisphærica, *Sow.*		
bisuffarcinata, *Schlot.*		
loricata, *Schlot.*		
Pectunculus, *Schlot.*		
rostrata, *Schlot.*		
spinosa, *Lam.*		
substriata, *Schlot.*		
resupinata, *Sow.*		
acuta, *Sow.*		
vulgaris, *Schlot.*		
Defrancii, *Al. Br.*		
Hoeninghausii, *Blain.*		
sexangula, *Dufr.*		
rimosa, *V. Buch.*		
bicanaliculata, *Sow.*		
cornuta, *Sow.*		
trilobata, *Munst.*		
	76.	76. Magas pumilus, *Sow.*
	77.	77.
	78.	78.

Greywacke.	Coal Formation.	New Red Sandstone.
	Læptæna ruglypha, *Dalm.*	
	transversalis, *Wahl.*	
9.	79. Orthis Pecten, *Dalm.*	79.
	striatella, *Dalm.*	
	basalis, *Dalm.*	
	elegantula, *Dalm.*	
0.	80. Atrypa reticularis, *Wahl.*	80.
	alata, *His.*	
	aspera, *Schlot.*	
	galeata, *Dalm.*	
	Prunum, *Dalm.*	
	tumida, *Dalm.*	
1.	81. Gypidium Conchydium.	81.
2.	82. Cyrtia exporrecta, *Wahl.*	82.
	trapezoidalis, *His.*	
3. Thecidea ? antiqua, *Hoen.*	83.	83.
4. Producta longispina, *Sow.**	84. Producta longispina, *Sow.**	84. Producta longispina, *Sow.**
rostrata, *Sow.*	rugosa, *Schlot.**	rugosa, *Schlot.**
depressa, *Sow.*	antiquata, *Sow.**	antiquata, *Sow.**
hemisphærica, *Sow.*	spinosa, *Sow.**	spinosa, *Sow.**
Scotica, *Sow.**	Scotica, *Sow.**	aculeata, *Al. Br.*
Martini, *Sow.**	Martini, *Sow.*	spiluncaria, *Al. Br.*
concinna, *Sow.**	concinna, *Sow.**	calva, *Sow.*
lobata, *Sow.**	lobata, *Sow.**	
punctata, *Sow.**	punctata, *Sow.**	
sulcata, *Sow.**	sulcata, *Sow.**	
sarcinulata, *Goldf.**	sarcinulata, *Goldf.**	
fimbriata, *Sow.**	fimbriata, *Sow.*	
	comoides, *Sow.*	
	fornicata.	
	humerosa, *Sow.*	
	latissima, *Sow.*	
	personata, *Sow.*	
	plicatilis, *Sow.*	
	spinulosa, *Sow.*	
	transversa.	
	Flemingii, *Sow.*	
	crassa, *Flem.*	
	aculeata, *Sow.*	
	scabricula, *Sow.*	
	gigantea, *Sow.*	
	costata, *Sow.*	
	depressa.	
5.	85. Delthyris elevata, *Dalm.*	85.
	cyrtæna, *Dalm.*	
	crispa, *Dalm.*	
	sulcata, *His.*	
	ptycodes, *Dalm.*	
	cardiospermiformis, *His.*	
6. Spirifer speciosus, *Sow.*	86. Spirifer trigonalis, *Sow.**	86. Spirifer trigonalis, *Sow.**
ambiguus, *Sow.**	ambiguus, *Sow.**	undulatus, *Sow.*
glaber, *Sow.**	glaber, *Sow.**	multiplicatus.
obtusus, *Sow.**	obtusus, *Sow.**	minutus.
pinguis, *Sow.**	rotundatus, *Sow.**	
attenuatus, *Sow.**	attenuatus, *Sow.**	
	distans, *Sow.**	

tinued.

Oolite.	Greensand.	Chalk.
	79.	79.
	80.	80.
	81.	81.
	82.	82.
	83.	83. Thecidea radians, *Defr.* recurvirostra, *Defr.* hieroglyphica, *Def*
	84.	84.
lthyris verrucosa, *V. Buch.* rostrata, *Schlot.*	85.	85.
irifer Walcotii, *Sow.*	86.	86.

CONCHIFERA

Greywacke.	Coal Formation.	New Red Sandstone.
Spirifer minimus, *Sow.**	Spirifer octoplicatus, *Sow.**	
cuspidatus, *Sow.**	cuspidatus, *Sow.*	
decurrens, *Sow.*	obtusus, *Sow.*	
Sowerbii.	plicatus, *Hoen.*	
lineatus, *Sow.*	trigonalis, *Sow.*	
rotundatus, *Sow.*	triangularis, *Sow.*	
uncinulatus, *Schlot.*	striatus, *Sow.*	
alatus, *Sow.*	resupinatus, *Sow.*	
intermedius, *Schlot.*	Martini, *Sow.*	
speciosus, *Bronn.*	Urii, *Flem.*	
	exaratus, *Flem.*	
	bisulcatus, *Sow.*	

CLASS VII.

Greywacke.	Coal Formation.	New Red Sandstone.
1.	1.	1. Dentalium torquatum, *Schlot.* læve, *Schlot.*
2.	2.	2.
3. Patella ? conica, *Wahl.* pennicostis, *Wahl.* concentrica, *Wahl.*	3. Patella Primigenus, *Schlot.*	3.
4. Pileopsis vetusta, *Sow.*	4.	4.
5.	5.	5.
6.	6.	6.
7.	7. Helix ? cirriformis, *Sow.*	7.
8.	8.	8.
9.	9.	9.
10.	10. Planorbis æqualis, *Sow.*	10.
11. Melania bilineata, *Goldf.* constricta, *Sow.*	11. Melania bilineata, *Goldf.* constricta, *Sow.*	11.
12. Melanopsis coronata, *Hoen.*	12. Melanopsis coronata, *Hoen.*	12.
13.	13. Ampullaria helicoides, *Sow.* nobilis, *Sow.*	13.
14.	14.	14.
15. Nerita spirata ? *Sow.*	15. Nerita striata, *Flem.* spirata, *Sow.*	15.
16.	16. Natica elongata, *Hoen.* Gaillardotii.	16. Natica Gaillardotii.

'ontinued.

Oolite.	Greensand.	Chalk.

-MOLLUSCA.

Oolite.	Greensand.	Chalk.
Dentalium giganteum, *Phil.* cylindricum, *Sow.*	1. Dentalium striatum, *Sow.* ellipticum, *Sow.* decussatum, *Sow.* fissura, *Lam.*	1. Dentalium nitens.
Bulla elongata, *Phil.*	2.	2.
Patella latissima, *Sow.* rugosa, *Sow.* lævis, *Sow.* lata, *Sow.* ancyloides, *Sow.* nana, *Sow.* discoides, *Schlot.*	3.	3. Patella ovalis, *Nils.*
	4.	4.
Pileolus plicatus, *Sow.*	5.	5.
Emarginula scalaris, *Sow.*	6.	6.
	7. Helix Gentii, *Sow.*	7.
Helicina polita, *Sow.* compressa, *Sow.* expansa, *Sow* solarioides, *Sow.*	8.	8.
Auricula Sedgewickii, *Phil.*	9. Auricula incrassata, *Sow.* turgida, *Sow.*	9. Auricula incrassata, *Sow.* obsoleta, *Phil.*
	10.	10.
Ielania Heddingtoniensis, *Sow.* striata, *Sow.* vittata, *Phil.* lineata, *Sow.*	11. Melania attenuata. triannata.	11.
	12.	12.
	13. Ampullaria canaliculata, *Montf.*	13. Ampullaria spirata.
	14. Paludina vivipara, *Lam.* ? elongata, *Sow.* carinfera, *Sow.* extensa, *Sow.*	14.
Nerita costata, *Sow.* sinuosa, *Sow.* lævigata, *Sow.* minuta, *Sow.*	15.	15. Nerita rugosa.
Natica arguta, *Sm.* nodulata, *Y. & B.*	16. Natica canrena, *Park.* spirata.	16.

Greywacke.	Coal Formation.	New Red Sandstone.
	Natica globosa.	
17.	17.	17.
18.	18.	18.
19. Delphinula æquilatera, *Wahl.*	19. Delphinula æquilatera, *Wahl.*	19.
	canalifera.	
	alata, *Wahl.*	
	catenulata, *Wahl.*	
	Cornu Arietis, *Wahl.*	
	funata, *æow.*	
	subsulcata, *His.*	
	tuberculata, *Flem.*	
20.	20. Pyramidella antiqua, *Hoen.*	20.
21.	21.	21.
22. Cirrus acutus, *Sow.*	22. Cirrus acutus, *Sow.*	22.
	rotundatus, *Sow.*	
23. Euomphalus catillus, *Sow.*	23. Euomphalus catillus, *Sow.*	23.
dubius, *Goldf.*	nodosus, *Sow.*	
funatus.	angulosus, *Sow.*	
	delphinularis, *Hoen.*	
	pentangulatus, *Sow.*	
	coronatus.	
	rotundatus.	
	rugosus, *Sow.*	
	discus, *Sow.*	
	centrifugus, *Wahl.*	
	angulatus, *Wahl.*	
	substriatus, *His.*	
	costatus, *His.*	
24. Solarium fasciatum.	24.	24.
25. Trochus catenulatus.	25. Trochus catenulatus.	25.

tinued.

Oolite.	Greensand.	Chalk.
tica cincta, *Phil.*		
adducta, *Phil.*		
	17.	17. Sigaretus concavus.
rmetus compressus, *Y. & B.*	18. Vermetus polygonalis, *Sow.*	18. Vermetus umbonatus, *Mant.*
Nodus, *Phil.*	concavus, *Sow.*	Sowerbii, *Mant.*
	19.	19.
	20.	20.
teon retusus, *Phil.*	21.	21.
glaber, *Bean.*		
humeralis, *Phil.*		
cuspidatus, *Sow.*		
acutus, *Sow.*		
rrus cingulatus, *Phil.*	22. Cirrus plicatus, *Sow.*	22. Cirrus depressus, *Mant.*
depressus, *Sow.*		perspectivus, *Mant.*
nodosus, *Sow.*		granulatus, *Mant.*
Leachii, *Sow.*		
carinatus, *Sow.*		
	23.	23.
larium Calyx, *Bean.*	24.	24.
conoideum, *Sow.*	25. Trochus agglutinans, *Lam.*	25. Trochus Basteroti, *Al. Br.*
ochus arenosus, *Sow.*	Gurgitis, *Al. Br.*	linearis, *Mant.*
tornatilis, *Phil.*	Rhodani, *Al. Br.*	Rhodani, *Al. Br.*
Tiara, *Sow.*	Cirroides, *Al. Br.*	lævis, *Nils.*
guttatus, *Phil.*		onustus, *Nils.*
monilitectus, *Phil.*		
pyramidatus, *Bean.*		
Anglicus, *Sow.*		
angulatus, *Sow.*		
dimidiatus, *Sow.*		
duplicatus, *Sow.*		
elongatus, *Sow.*		
punctatus, *Sow.*		
abbreviatus, *Sow.*		
fasciatus, *Sow.*		
prominens, *Sow.*		
imbricatus, *Sow.*		
reticulatus, *Sow.*		

MOLL

Greywacke.	Coal Formation.	New Red Sandstone.
26. Turbo Tiara, *Sow.* antiquus, *Goldf.* cirriformis, *Sow.* bicarinatus, *Wahl.*	26. Turbo Tiara, *Sow.* carinatus, *Hoen.* helicinæformis. striatus, *Hoen.*	26.
27.	27.	27.
28. Turritella abbreviata, *Sow.* prisca, *Munst.*	28. Turitella Urii, *Flem.* elongata, *Flem.* cingulata, *His.* constricta, *Flem.*	28. Turritella terebralis, Schloteri.
29.	29.	29.
30.	30.	30.
31. Pleurotoma cirriforme.	31. Pleuromoma delphinulatum.	31.
32.	32.	32.
33. Murex Harpula, *Sow.*	33.	33.
34.	34.	34.
35.	35.	35.
36.	36.	36.
37.	37.	37.
38.	38.	38.
39.	39.	39.
40.	40.	40.
41. Buccinum spinosum, *Sow.* acutum, *Sow.* breve, *Sow.* imbricatum, *Sow.*	41. Buccinum arculatum, *Schlot.* subcostatum, *Schlot.* cribrarium, *Hoen.* lævissimum. acutum, *Sow.*	41. Buccinum obsoletum,
42. Terebra Hennahiana, *Sow.*	42.	42.
43.	43.	43.
44. Bellerophon hiulcus, *Sow.* apertus, *Sow.* tenuifascia, *Sow.* costatus, *Sow.* Cornu Arietis, *Sow.* *ovatus, Sow.* *Hüpschii, Defr.*	44. Bellerophon hiulcus, *Sow.* apertus, *Sow.* tenuifascia, *Sow.* costatus, *Sow.* Cornu Arietis, *Sow.* decussatus, Flem. striatus, Flem.	44.

d.

Oolite.	Greensand.	Chalk.
us rugatus, *Benett.*		
speciosus, *Munst.*		
muricatus, *Sow.*	26. Turbo monilifer, *Sow.*	26. Turbo pulcherrimus, *Bean.*
funiculatus, *Phil.*	carinatus, *Sow.*	sulcatus, *Nils.*
sulcostomus, *Phil.*		
unicarinatus, *Bean.*		
lævigatus, *Phil.*		
undulatus, *Phil.*		
ornatus, *Sow.*		
obtusus, *Sow.*		
nella cincta, *Phil.*	27.	27.
tella muricata, *Sow.*	28. Turritella terebra, *Broc.*	28. Turritella duplicata.
cingenda, *Sow.*		
4 vittata, *Phil.*		
concava, *Sow.*		
echinata, *V. Buch.*		
lævis, *Sow.*	29.	29.
acuta, *Sow.*		
obliquata, *Sow.*		
duplicata, *Sow.*		
ium intermedium.	30. Cerithium excavatum, *Al. Br.*	30.
muricatum.		
toma conoideum, *Desh.*	31.	31.
ornatum, *Defr.*		
ea tuberculata, *Blain.*	32.	32.
Mossæ, *Desh.*		
x Vaccanensis, *Phil.*	33. Murex Calcar, *Sow.*	33.
stellariformis, *V. Buch.*		
llaria bispinosa, *Phil.*	34. Rostellaria carinata, *Mant.*	34. Rostellaria anserina, *Nils.*
trifida, *Bean.*	Parkinsoni, *Mant.*	Parkinsoni, *Mant.*
composita, *Sow.*	fissura, *Lam.*	composita, *Sow.*
	calcarata, *Sow.*	
ceras Oceani, *Al. Br.*	35.	35. Pteroceras maxima, *Hoen.*
Ponti, *Al. Br.*		
Pelagi, *Al. Br.*		
	36.	36. Strombus papilionatus.
	37. Fusus quadratus, *Sow.*	37.
	38. Pyrula minima, *Hoen.*	38. Pyrula planulata, *Nils.*
	39.	39. Dolium nodosum, *Sow.*
	40.	40. Cassis avellana, *Al. Br.*
um unilineatum, *Sow.*	41.	41.
ra melanioides, *Phil.*	42.	42.
granulata, *Phil.*		
vetusta, *Phil.*		
sulcata.		
	43.	43. Voluta ambigua, *Sow.*
		Lamberti, *Sow.*
	44.	44.

Greywacke.	Coal Formation.	New Red Sandstone.
Bellerophon nodulosus, *Goldf.*	Bellerophon depressus, *Montf.* Urii, *Flem.* vasulites, *Montf.*	
45. Nautilus globatus, *Sow.* multicarinatus, *Sow.* complanatus, *Sow.* carinifer, *Sow.* divisus, *Munst.* funatus, *Flem.* compressus, *Flem.* ovatus, *Flem.*	45. Nautilus globatus, *Sow.* discus, *Sow.* ingens. marginatus, *Flem.* quadratus, *Flem.* biangulatus, *Flem.* sulcatus, *Sow.* Woodwardii, *Sow.* excavatus, *Flem.* bilobatus. pentagonus.	45. Nautilus bidorsatus, nodosus,
46.	46.	46.
47. Cyrtoceratites ammonius, *Goldf.* compressus, *Goldf.* depressus, *Goldf.* ornatus, *Goldf.*	47.	47.
48.	48.	48.
49. Ammonites Henslowi, *Sow.* subnautilinus, *Schlot.*	49. Ammonites Listeri, *Sow.* primordialis, *Sow.* sacer. subcrenatus, *Schlot.* Diadema, *De Haan.* sphæricus, *Sow.* Dalmanni, *His.* striatus, *Sow.*	49. Ammonites nodosus, bipartitus, latus, subnodosus

tinued.

Oolite.	Greensand.	Chalk.
utilus hexagonus, *Sow.* lineatus, *Sow.* astacoides, *Y. & B.* annularis, *Phil.* obesus, *Sow.* sinuatus, *Sow.* intermedius, *Sow.* striatus, *Sow.* truncatus, *Sow.* angulosus, *D'Orb.*	45. Nautilus inæqualis, *Sow.* simplex, *Sow.* undulatus, *Sow.*	45. Nautilus elegans, *Sow.* expansus, *Sow.* obscurus, *Nils.* aperturatus.
	46. Nummulites lenticulina.	46. Nummulites lenticulina. Faujasii.
	47.	47.
aphites bifurcatus, *Hart.*	48.	48. Scaphites striatus, *Mant.* costatus, *Mant.*
mmonites perarmatus, *Sow.* gagateus, *Y. & B.* planicostatus, *Sow.* balteatus, *Phil.* arcigerens, *Phil.* brevispina, *Sow.* Jamesoni, *Sow.* erugatus, *Bean.* fimbriatus, *Sow.* Rotula, *Sow.** nitidus, *Y. & B.* angulifer, *Phil.* crenularis, *Phil.* Cleavelandicus, *Y. & B.* Turneri, *Sow.* plicomphalus, *Sow.* triplicatus, *Sow.* plicatilis, *Sow.* Williamsonii, *Phil.* Sutherlandii, *Sow.* sublævis, *Sow.* lenticularis, *Phil.* vertebratus, *Sow.* cordatus, *Sow.* instabilis, *Phil.* solaris, *Phil.* oculatus, *Phil.* Vernoni, *Bean.* Athleta, *Phil.* Koenigi, *Sow.* bifrons, *Phil.* Gowerianus, *Sow.* Calloviensis, *Sow.* Duncani, *Sow.* gemmatus, *Phil.*	49. Ammonites varians, *Sow.** planulatus, *Sow.* Catillus, *Sow.* splendens, *Sow.* auritus, *Sow.* planus, *Mant.* rusticus, *Sow.* lautus, *Park.* Mantelli, *Sow.* Rotula, *Sow.** venustus, *Phil.* concinnus, *Phil.* trisulcosus, *Phil.* marginatus, *Phil.* hystrix, *Phil.* fissicostatus, *Phil.* curvinodus, *Phil.* inflatus, *Sow.* Deluci, *Al. Br.* subcristatus, *De L.* Beudanti, *Al. Br.* clavatus, *De L.* Selliguinus, *Al. Br.* Gentoni, *Defr.* varicosus, *Sow.* Benettianus, *Sow.* denarius, *Sow.* Buchii, *Hoen.* ornatus.	49. Ammonites varians, *Sow.* Woolgari, *Mant.* navicularis, *Mant.* catinus, *Mant.* Lewesiensis, *Mant.* peramplus, *Mant.* rusticus, *Sow.** undatus, *Sow.* Mantelli, *Sow.** Rhotomagensis, *Al. Br.* cinctus, *Mant.* falcatus, *Mant.* curvatus, *Mant.* complanatus, *Mant.* rostratus, *Sow.* tetrammatus, *Sow.* constrictus, *Sow.* Stobæi, *Nils.* Hippocastanum, *Sow.* Nutfieldiensis, *Sow.*

MOLLUSCA

Greywacke.	Coal Formation.	New Red Sandstone.

Continued.

Oolite.	Greensand.	Chalk.
Ammonites Herveyi, *Sow.*		
flexicostatus, *Phil.*		
funifer, *Phil.*		
terebratus, *Phil.*		
Blagdeni, *Sow.*		
striatulus, *Sow.*		
heterophyllus, *Sow.*		
subcarinatus, *Y. & B.*		
Henleii, *Sow.*		
heterogeneus, *Y. & B.*		
crassus, *Y. & B.*		
communis, *Sow.*		
angulatus, *Sow.*		
annulatus, *Sow.*		
fibulatus, *Sow.*		
subarmatus, *Sow.*		
maculatus, *Y. & B.*		
geometricus, *Phil.*		
vittatus, *Y. & B.*		
signifer, *Phil.*		
Hawkeserensis, *Y. & B.*		
Conybeari, *Sow.*		
Bucklandi, *Sow.*		
obtusus, *Sow.*		
Walcotii, *Sow.*		
ovatus, *Y. & B.*		
Mulgravius, *Y. & B.*		
exaratus, *Y. & B.*		
Lythensis, *Y. & B.*		
concavus, *Sow.*		
elegans, *Sow.*		
discus, *Sow.*		
Banksii, *Sow.*		
Braikenridgii, *Sow.*		
Brocchii, *Sow.*		
Sowerbii, *Mill.*		
falcifer, *Sow.*		
Brownii, *Sow.*		
læviusculus, *Sow.*		
acutus, *Sow.*		
contractus, *Sow.*		
giganteus, *Sow.*		
Lamberti, *Sow.*		
excavatus, *Sow.*		
armatus, *Sow.*		
modiolaris, *Sm.*		
jugosus, *Sow.*		
Strangwaysii, *Sow.*		
Brookii, *Sow.*		
Bechii, *Sow.*		
stellaris, *Sow.*		
Greenovii, *Sow.*		
Loscombi, *Sow.*		
Birchii, *Sow.*		
omphaloides, *Sow.*		
quadratus, *Sow.*		
Gervillii, *Sow.*		
Brongniartii, *Sow.*		

MOLLUSCA

Greywacke.	Coal Formation.	New Red Sandstone.

ntinued.

Oolite.	Greensand.	Chalk.
nmonites biplex, *Sow.*		
rotundus, *Sow.*		
decipiens.		
Deslongchampi.		
vulgaris.		
coronatus.		
Humphresianus, *Sow.*		
Parkinsoni, *Sow.*		
Gulielmii, *Sow.*		
Davæi, *Sow.*		
planorbis, *Sow.*		
Johnstonii, *Sow.*		
corrugatus, *Sow.*		
rotiformis, *Sow.*		
multicostatus, *Sow.*		
lævigatus, *Sow.*		
latecostatus, *Sow.*		
Murchisonæ, *Sow.*		
serpentinus, *Schlot.*		
cristatus, *Defr.*		
interruptus, *Schlot.*		
opalinus, *Rein.*		
latina, *Sow.*		
ammonius, *Schlot.*		
comptus, *Rein.*		
planulatus, *De H.*		
Knorrianus, *De H.*		
Reineckii, *Holl.*		
pustulatus, *De H.*		
granulatus, *Brug.*		
bifurcatus, *Brug.*		
trifurcatus, *De H.*		
macrocephalus, *Schlot.*		
gracilis, *Munst.*		
Planula, *Heyl.*		
Fonticola, *Mencke.*		
scutatus, *V. Buch.*		
canaliculatus, *Munst.*		
flexuosus, *Munst.*		
crenatus, *Rein.*		
subfurcatus, *Schlot.*		
costulatus, *Schlot.*		
striolaris, *Rein.*		
mæander, *Rein.*		
abruptus, *Stahl.*		
sublævis, *Munst.*		
punctatus, *Stahl.*		
undulatus, *Stahl.*		
complanatus, *Rein.*		
hecticus, *Rein.*		
refractus, *Rein.*		
annularis, *Rein.*		
discus, *Rein.*		
Pollux, *Rein.*		
Bollensis, *Ziet.*		
æquistriatus, *Munst.*		
inæqualis, *Merian.*		
tenuistriatus, *Munst.*		

Continued.

Oolite.	Greensand.	Chalk.
Ammonites dubius, *Schlot.*		
Kridion, *Heyl.*		
Jason, *Rein.*		
alternans, *V. Buch.*		
Gigas, *Ziet.*		
dentatus, *Rein.*		
denticulatus, *Ziet.*		
raricostatus, *Ziet.*		
decoratus, *Ziet*		
bipartitus, *Ziet.*		
Calcar, *Benz.*		
torulosus, *Schüb.*		
varians, *Sow.*		
oblique costatus, *Ziet.*		
insignis, *Schüb.*		
oblique-interruptus, *Schüb.*		
polygonius, *Ziet.*		
discoides, *Ziet.*		
Leachii, *Sow.*		
bispinosus, *Ziet.*		
biarmatus, *Sow.*		
Turrilites Babeli, *Al. Br.**	50. Turrilites Babeli, *Al. Br.**	50. Turrilites costatus, *Sow.*
	Bergeri, *Al. Br.*	undulatus, *Sow.*
		tuberculatus, *Sow.*
	51.	51. Baculites Faujasii, *Lam.*
		obliquatus, *Sow.*
		vertebralis, *Defr.*
		anceps, *Lam.*
		triangularis, *Desm.*
	52.	52.
	53.	53. Lituites nautiloideus, *Lam.*
		difformis, *Lam.*
	54. Lenticulites Comptoni, *Sow.*	54. Lenticulites cristella, *Nils.*
	55. Nodosaria sulcata, *Nils.**	55. Nodosaria sulcata, *Nils.**
	lævigata, *Nils.*	
	56.	56. Planularia elliptica, *Nils.*
		augusta, *Nils.*
Orthocera elongata, *De la B.*	57.	57.

Greywacke.	Coal Formation.	New Red Sandstone.
Orthocera regularis, *Schlot.* exceptica, *Goldf.* striolaris, *Meyer.* acuaria, *Munst.* striopunctata, *Munst.* cingulata, *Munst.* torquata, *Munst.* carnata, *Munst.* linearis, *Munst.* irregularis, *Munst.*	Orthocera lineata, *His.* Gesneri. cylindracea, *Flem.* attenuata, *Flem.* sulcata, *Flem.* undata, *Flem.* cordiformis. gigantea.	
58.	58.	58.
59.	59.	59. Belemnites Aalensis,

ntinued.

Oolite.	Greensand.	Chalk.
amites annulatus, *Desh.*	58. Hamites maximus, *Sow.*	58. Hamites armatus, *Sow.*
	intermedius, *Sow.*	plicatilis, *Mant.*
	alternatus, *Mant.**	alternatus, *Mant.**
	attenuatus, *Sow.**	attenuatus, *Sow.**
	tenuis, *Sow*	ellipticus, *Mant.*
	rotundus, *Sow.*	cylindricus, *Defr.*
	compressus, *Sow.*	
	raricostatus, *Phil.*	
	Beanii, *Y. & B.*	
	Philipsii, *Bean.*	
	funatus, *Al. Br.*	
	canteriatus, *Al. Br.*	
	virgulatus, *Al. Br.*	
	spinulosus, *Sow.*	
	grandis, *Sow.*	
	Gigas, *Sow.*	
	spiniger, *Sow.*	
lemnites Aalensis, *Voltz.**	59. Belemnites mucronatus, *Schlot.**	59. Belemnites mucronatus, *Schlot*
sulcatus, *Mill.*	minimus, *List.*	granulatus, *Defr.*
fusiformis, *Mill.*	attenuatus, *Sow.*	lanceolatus, *Schlot.*
gracilis, *Phil.*		mamillatus, *Nils.*
gracilis, *Hehl.*		
abbreviatus, *Mill.*		
elongatus, *Mill.*		
trisulcatus, *Blain.*		
compressus, *Blain.*		
dilatatus.		
apicicurvatus, *Blain.*		
pistilliformis, *Blain.*		
brevis, *Blain.*		
longissimus, *Mill.*		
canaliculatus, *Schlot.*		
ellipticus, *Mill.*		
longus, *Voltz.*		
aduncatus, *Mill.*		
subclavatus, *Voltz.*		
tenuis, *Stahl.*		
subdepressus, *Voltz.*		
subaduncatus, *Voltz.*		
digitalis, *Biguet.*		
breviformis, *Voltz.*		
ventroplanus, *Voltz.*		
paxillosus, *Schlot.*		
longisulcatus, *Voltz.*		
trifidus, *Voltz.*		
comprimatus, *Voltz.*		
grandis, *Schüb.*		
quinquesulcatus, *Blain.*		

MOLLU

Greywacke.	Coal Formation.	New Red Sandstone.
60.	60.	60.
61.	61.	61.
62.	62.	62.
63.	63.	63.
64.	64.	64.

Continued.

Oolite.	Greensand.	Chalk.
Belemnites tumidus, *Ziet.*		
acutus, *Blain.*		
teres, *Stahl.*		
lævigatus, *Ziet.*		
crassus, *Voltz.*		
semihastatus, *Blain.*		
incurvatus, *Ziet.*		
pyramidatus, *Schüb.*		
rostratus, *Ziet.*		
irregularis, *Schlot.*		
papillatus, *Plien.*		
acuminatus, *Schüb.*		
subhastatus, *Ziet.*		
canaliculatus, *Schlot.*		
oxyconus, *Heyl.*		
carinatus, *Heyl.*		
pygmæus, *Ziet.*		
consulcatus, *Hart.*		
quadrisulcatus, *Hart.*		
pyramidalis, *Munst.*		
bipartitus, *Hart.*		
unicanaliculatus, *Hart.*		
2-canaliculatus, *Hart.*		
3-canaliculatus, *Hart.*		
4-canaliculatus, *Hart.*		
5-canaliculatus, *Hart.*		
.	60.	60. Actinocamax verus, *Mill.*
. Aptychus lævis, *Meyer.*	61.	61.
imbricatus, *Meyer.*		
bullatus, *Meyer.*		
Elasma, *Meyer.*		
. Onychoteuthis angusta, *Munst.*	62.	62.
. Loligo prisca, *Rüppell.*	63.	63.
antiqua, *Munst.*		
. Sepia hastæformis, *Rüppell.*	64.	64.

PART III.

OF THE METHOD OF ANALYZING MINERALS.

INTRODUCTION.

The art of analyzing minerals, or of determining the different ingredients of which they are composed, can scarcely be considered to have originated before the middle of the last century; for the chemical analysis of vegetables, undertaken by Lemery, &c., and of mineral waters, by Dominic du Clos, were so imperfect and erroneous that they are hardly entitled to attention. Margraaff was the first chemist who attempted to determine the true constituents of minerals by analysis; in 1748 he published his chemical experiments on the Osteocolla of the March of Brandenburg in the *Memoirs of the Berlin Academy*, and proved by satisfactory trials that the constituents were carbonate of lime and silica, slightly tinged with iron. Bergman attempted not merely to analyze minerals and mineral waters, but to reduce the method of proceeding to a regular system. To him we are indebted for the first rudiments of our present processes; in 1778 he was the author of an elaborate treatise on the analysis of water; he had previously published his analysis of the waters of Upsala and of the Denmark spring, of sea water, and on the artificial preparation of mineral waters, both cold and hot. In the year 1777 he published his experiments on the analysis of *gems*. He showed that an earthenware crucible could not be employed in such experiments, and substituted for a Hessian crucible a vessel of polished iron. His method of proceeding was, to reduce the mineral to be analyzed to a very fine powder; this powder was mixed with twice its weight of anhydrous carbonate of soda, and the mixture strongly heated for three or four hours in the iron vessel. The fused mass was taken out of the iron vessel and digested in muriatic acid till every thing soluble was taken up. The insoluble portion after ignition was examined by the blowpipe; if it fused with effervescence with carbonate of soda into a colourless glass it was considered as silica, if it did not effervesce nor fuse with the soda it was considered as a portion of the mineral undecomposed, which required to be again subjected to fusion with carbonate of soda in the iron crucible.

The muriatic solution was mixed with prussiate of potash, which threw down the iron, if any was present. The liquor, thus freed from iron, was mixed with a sufficient quantity of fixed alkali, probably in the state of carbonate. The precipitate was washed, dried and ignited; it was then digested for an hour in six times its weight of cold acetic acid. The acid dissolved any lime, barytes or magnesia that might be present, while it left the alumina undissolved.

The acetic solution was thrown down by an alkaline carbonate. The precipitate was washed, dried, weighed and examined; if its neutral solution in muriatic acid was converted into sulphate of barytes, or into gypsum, or into epsom salt, when mixed with a solution of sulphate of potash, the presence of barytes, or lime, or magnesia was indicated. The undissolved portion was presumed to be alumina. This was determined by dissolving it in sulphuric acid and converting it into alum.

Such was the process of Bergman for the analysis of minerals—rude and imperfect undoubtedly, but exhibiting the rudiments of the methods at present adopted with so much success by modern chemists. Klaproth, who began his chemical career almost at the termination of Bergman's useful life, took up the method of analyzing minerals where Bergman left it, and gradually corrected the imperfections of Bergman's apparatus, and of his method of separating the different constituents from each other. He substituted crucibles of pure silver for the iron vessels of Bergman. This was an important step towards accuracy, because when iron vessels were used, it was scarcely possible to prevent some iron from the vessel from being mixed and confounded with the mineral under examination. He substituted caustic potash in certain cases for the carbonate of soda used by Bergman, and showed that it was much more efficacious in such cases in rendering the mineral soluble in muriatic acid. He pointed out the necessity of obtaining a complete solution of the mineral under analysis in muriatic acid, and showed that when any insoluble portion remained it consisted almost always of the mineral undecomposed. He pointed out the necessity of evaporating the muriatic solution to dryness, and of digesting the dry residue in water acidulated with muriatic acid. What remained undissolved was silica, the purity of which was tested by fusing it before the blowpipe with carbonate of soda. To the muriatic solution thus freed from silica, he added an excess of caustic ammonia; the alumina, glucina, yttria, zirconia, oxide of iron and oxide of manganese were precipitated, but the barytes, strontian, lime, or magnesia remained in solution. The oxides of iron and manganese were separated from the earths by digestion in caustic potash; and Gehlen afterwards introduced the method of precipitating peroxide of iron and separating it from oxide of manganese by means of succinate of ammonia.

Klaproth's improvements in the art of analyzing metallic ores were no less important. Indeed, he in a great measure created this branch of the analytical art; almost all attempts at the analysis of such ores made before his time being unsuccessful.

About the year 1790 Vauquelin began his great analytical career, in Paris. His turn of mind led him to analytical investigations, which he prosecuted with much accuracy and with great delight. His skill as an analyser of minerals was little inferior to that of Klaproth, and his patience nearly as inexhaustible; but his analyses of minerals are much less valuable, not from any want of precision or of skill, but because sufficient care was not taken in selecting specimens for analysis. For it is too obvious to require illustration, that the chemical analysis of a mineral can lead to no useful results unless specimens of the greatest possible purity be selected. When Vauquelin was connected with the School of Mines, Haüy was engaged in his crystallographical researches, and had projected his *Treatise on Mineralogy*. At that time few analyses of minerals existed, and none to be depended on except those which had been made by Klaproth; this led him to request the assistance of Vauquelin, whom he supplied with specimens for analysis, and Vauquelin entered upon the task with great alacrity. The selection of the specimens then belonged to Haüy, and it must have been owing to the little care with which that illustrious crystallographer made his selection that so many of Vauquelin's analyses have been found inaccurate by more recent experimenters. To Vauquelin we are indebted for the first treatise on the analysis of stony bodies, in which the various improvements introduced into the processes by Klaproth and himself are fully detailed. This treatise was published in the year 1799,* and doubtless contributed very materially to the analytical skill which soon after became very general among practical chemists.

An improvement in the crucibles used for fusing the minerals subjected to analysis with carbonate of soda was still wanting to enable chemists to make their analyses with rigid accuracy. Silver crucibles, unless great care be employed in managing the heat, are apt to melt, and when this happens the analysis is of course destroyed. Silver is easily acted upon by the mineral acids. In nitric acid it dissolves as readily as sugar does in water, and both muriatic acid and sulphuric acid act upon it slowly, especially when the action is assisted by heat. This limits the use to which these crucibles can be put, and prevents the possibility of employing acids to remove from the silver vessel the last remains of the mineral mass which had been fused in it. The introduction of platinum crucibles by Dr. Wollaston, about the commencement of the present century, may be said to have carried the apparatus used in analyzing minerals to a state of perfection. It is only the analyses made since the introduction of these crucibles that can be depended on. Dr. Wollaston also made an important improvement in the art of analysis, by reducing the quantity operated on. Klaproth usually analyzed 100 grains of a mineral, and sometimes even 200 grains, and Vauquelin's quantity was not in general less; but Dr. Wollaston introduced the custom of taking a much smaller portion: 25 or even 20 grains was the quantity which he usually employed. This is attended with many advantages. It greatly shortens the time necessary for such analyses, and proudces a proportional diminution in the expense; even the accuracy of the result is rather promoted than injured, provided the requisite care be taken in all the steps, and the balance employed be nice enough to weigh to the hundredth of a grain with accuracy. If the mineral analyzed contain only substances with which the chemist is acquainted, he will find no difficulty

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* Ann. de Chim. xxx. 66.

in determining their nature and weight, even when the quantity does not exceed a grain or half a grain. If new substances, or substances with the properties of which the chemist is not acquainted, occur during the analysis, it may not be in his power to determine them with accuracy. In such cases he will naturally repeat his analysis upon a larger quantity of the mineral, that he may be enabled to produce the unknown substance in sufficient abundance to determine its nature.

The art of analyzing minerals has now become so universally known to chemists that it would be difficult to point out all the individuals to whom it lies under obligations. Stromeyer, Professor of Chemistry at Göttingen, has devoted a great portion of his time to the analyses of minerals, and has published a volume* containing no fewer than fifty analyses of minerals, made with the utmost attention to accuracy, and all of them models of analytical sagacity. He has pointed out various improvements in the art of analysis, and his descriptions are so minute and exact, that the study of his work must be of very great importance to all who wish to acquire the difficult but important art of chemical analysis. Thirteen years have elapsed since the appearance of this work, and Stromeyer has doubtless ample materials for another. That another volume has not hitherto appeared must be considered as injurious to the progress of analytical chemistry; probably the sale of such a work must be very limited, because it can interest nobody except practical chemists, the number of whom, unfortunately for the science, is but small. It is a pity that works of such importance to the progress of chemistry were not published at the expense of the State. Were the Göttingen, Berlin, Munich, &c. Academies in Germany enabled by their respective governments to publish works of sterling value, but of limited sale, from the nature of the subjects, the sciences would advance with much greater rapidity than at present.

Professor Berzelius of Stockholm must not be forgotten when we are giving a sketch of the progress of analytical chemistry. He has been perhaps the most active chemist of his day, and has analyzed a greater number of minerals than any other individual. His laborious investigations respecting

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* Untersuchungen über die Mischung der Mineralkörper. Erster Band. Göttingen, 1821.

the atomic weights of bodies have contributed most materially to the precision of mineral analysis. Not satisfied with this he has contrived many new analytical methods, and as he has extended his researches to almost every kind of mineral, his analytical investigations are highly worthy of the study of all who wish to become adepts in this most important branch of practical chemistry. At one time of his life, Berzelius was in the habit of taking practical pupils, whom he instructed in the methods of analyzing minerals; and not a few of these pupils have since distinguished themselves as analysts. Of these, M. H. Rose of Berlin has perhaps been the most active. He turned his attention to several complicated ores of copper and silver, remarkable for the number of their constituents, and has wonderfully disentangled one of the most complicated departments of mineralogy. His treatise on *Analytical Chemistry*, in two volumes, the second edition of which appeared in 1831, is by far the most complete work on the subject, and is an indispensable book in the laboratory of every practical chemist. An excellent English translation of this book, by Mr. Griffin, was published some years ago, and its perusal cannot be too strongly recommended to all those British chemists who wish to become adepts in mineral analysis.

Another of Berzelius's pupils, who has distinguished himself by numerous analyses both of minerals and salts, is Professor Mitscherlich of Berlin, though the high reputation which he has acquired is connected with other branches of the science of chemistry, which cannot be alluded to here. Professor C. G. Gmelin of Tübingen is another pupil of Berzelius, who has in a great measure devoted himself to the analysis of minerals. His analyses are numerous and exact, and he has turned his attention to some tribes of minerals, the analysis of which is attended with peculiar difficulty: the tourmalin may be mentioned as an example. For some years past we have seen very little of his analyses in the German Journals. This may probably be occasioned by the *System of Chemistry*, which he is at present engaged in drawing up. Such a task, from the vast extent of the subject, is attended with considerable difficulty, and requires very extensive reading and research.

Professor Bonsdorff, formerly of Abo, is not the least distinguished of the pupils of Berzelius. His analyses of the numerous varieties of Amphibole, published in the *Memoirs of the Stockholm Academy* for 1821, are perfect models of chemical research. Nor is less praise due to many other important analyses which he has published, but which it would be impossible to particularize here.

In France by far the most active analyst of the present day is Berthier, who occupies the department formerly held by Vauquelin in the *School of Mines* in Paris. His memoirs, mineralogical, metallurgical, and geological, have been published chiefly in the *Annales de Chimie et de Physique*, and in the *Annales des Mines.* His analyses of minerals amount to more than a hundred, and he has lately published a most important work intimately connected with mineral analysis, entitled *Traité des Essais par la voie sèche*, in two very thick octavo volumes. It contains the result of many analytical investigations in this most important department of metallurgy, and must be a valuable addition to a branch of the science, which has been too much neglected by modern chemists.

If we except Mr. Hatchett and Mr. Chenevix, Great Britain has produced very few analytical chemists. Almost the only modern chemists of this country, who have published analyses of minerals, are Mr. R. Phillips, Dr. Turner, and Mr. Connell. The analyses published by these gentlemen are not numerous, but they are accurate, and characterized by a neatness and ingenuity which does them great credit. Mr. Connell's discovery of barytes and strontian in Brewsterite proves incontestibly the minute accuracy of his investigations, and augurs well for his future eminence in this branch of chemistry. The department of analytical chemistry, and even mineralogical investigations in general have been sneered at by several chemists in this country, as a branch of chemistry below the notice of men of true science. But such allegations are ill founded and improper. Mineralogy has been to chemistry what astronomy has been to mathematics—the cause of many improvements of the most important kind. If we turn our attention to the great improvers of chemistry, we shall find that they have been analytical chemists. Indeed the only means of advancing the science is analytical investigation, and the best school for acquiring the power of making such investigations is the study of the methods of analyzing minerals. A good analytical chemist must be familiar with the properties of the different substances which come under his investigation, and with the best methods of separating them from each other, and of determining their quantity. Among the chemists of the last century none acquired a higher or more deserved reputation than Scheele. Now all Scheele's discoveries were the results of analytical investigations. Cavendish's great discoveries of the constituents of water and nitric acid were the results of synthetical experiments, similar in their consequences to analytical investigations. Berthollet's discovery of the composition of ammonia was equally an analytical investigation, and the same remark applies to the great discoveries of Sir H. Davy, namely the constituents of the fixed alkalies and alkaline earths. For our knowledge of all the earths and most of the metals we are entirely indebted to those chemists who have devoted themselves to the analysis of minerals. In fact, had it not been for the new views that opened themselves in consequence of the chemical study of the mineral kingdom, the science of chemistry could have made but little progress.

Minerals, as far as analytical processes are concerned, may be divided into two classes. The first class consists of oxydized bodies, earths, oxides, and fixed alkalies, either combined with each other or with an acid. The second class consists of combustible bodies, namely, sulphur, selenium, metals, &c., united together. The methods employed in analyzing these two sets of bodies differing somewhat, it will be proper to consider each class separately.

BOOK I.

OF THE ANALYSIS OF OXYDIZED BODIES.

The greater number of stony bodies, and even some metallic ores, belong to this class. Now the analysis of these bodies consists of three series of operations which must be conducted in succession. The object of the first is to know the quantity of water or other volatile matter which the mineral may contain. The object of the second is to ascertain the nature and number of the fixed constituents. While the object of the third is to determine the weight of each of these constituents.

CHAP. I.

METHOD OF DETERMINING THE QUANTITY OF WATER OR OF OTHER VOLATILE MATTER IN A MINERAL.

This is always the first step in the analysis of a mineral. Because, till the quantity of volatile matter be known, we have no data for estimating the accuracy of our analysis. Nor can we determine accurately the quantity of matter which we must employ in order to ensure a correct result. The volatile matter is always lost during the process, and a deficiency in the weight would ensue, unless we knew its amount, which could not be accounted for without supposing a mistake in the analysis.

Water may exist in minerals in two states. It may be chemically combined with the other constituents, or it may be only mechanically (so to speak) mixed with them. When a mineral is porous, the pores almost always imbibe water by capillary attraction. But when a mineral is reduced to powder, the particles lying light upon each other, leave numerous interstices into which the air loaded with moisture makes its way. This *moisture* is deposited and retained by capillary attraction. Hence all powders contain water lodged between their particles even when no combined water exists in them.

Many foliated minerals, as common salt, calcareous spar, &c., when suddenly heated split with a crackling noise, which is called *decrepitating*. This is a proof that such minerals contain water lodged mechanically between their plates. The sudden heat by converting this water into steam, causes it to expand and split the mineral in pieces, which occasions the decrepitation.

When water is chemically combined it always exists in a mineral in a determinate quantity. Indeed when the quantity of combined water in a mineral changes, though the other constituents remain unaltered, the properties of the mineral alter, and it becomes a new species. Many examples of this occur in the first part of this work, especially among magnesian, aluminous, and ferruginous minerals.

Some minerals contain carbonic acid, fluoric acid, muriatic acid, or arsenious acid, all of which may be driven off by the application of heat, provided the bases with which they are combined do not retain them too powerfully. Thus carbonic acid is easily driven off by a red heat when combined with magnesia, oxide of zinc, oxide of lead, oxide of copper, oxide of silver, or oxide of bismuth. But it requires a white heat to drive it off when combined with lime; and when it is united to barytes or strontian, we cannot drive it off by heat without some peculiar contrivance. Thus we separate it if we mix the pounded carbonate with charcoal powder, and expose the mixture to heat; because the charcoal has the property of decomposing the carbonic acid, and converting it into carbonic oxide, which has no sensible affinity for barytes and strontian.

Fluoric acid may be driven off from most minerals by heat; but a very high temperature is necessary for the purpose. Hence, when a mineral contains water and fluoric acid, we may sometimes determine the quantity of each. Incipient ignition will drive off the water, and its quantity may be ascertained by weighing the mineral before and after ignition. Afterwards a white heat will drive off the fluoric acid, and the additional loss of weight will determine its quantity. This was the method employed by Bonsdorff, to determine the quantity of fluoric acid in the different varieties of amphibole which he analyzed.

When water only is present, as is the case with most minerals, the process for detecting it is easy. Counterpoise a platinum crucible* in the scales of a delicate balance, and put into it 20 grains of the mineral, either in crystals or in a coarse powder. Cover the crucible with its lid, and keep it for a quarter of an hour in a good red heat, either raised by a spirit lamp, or a charcoal or coal fire. When the crucible is cold enough to be handled, but not quite so cold as the air of the room, put it again into the scale of the balance, and observe whether it is still counterpoised by the weights in the opposite scale. If not, add weights till the counterpoise is exactly restored.† The weights thus added give you the quantity of water driven off by the heat. Suppose 2 grains is required to be added to the scale containing the crucible in order to restore the equilibrium. This shows that the 20 grains of mineral had lost 2 grains by ignition, and consequently, that the water in the mineral amounts to ten per cent.

As powders have the property of imbibing moisture again very speedily when exposed to the air, it is best to allow the lid to remain on the crucible during the process of weighing. The lid therefore should be weighed along with the crucible at first. It is best also to put the crucible into the scales when about ten degrees hotter than the air of the room. You cannot weigh with perfect accuracy, if the crucible be hotter than the air; but so small a difference as ten degrees, which is diminishing during the process of weighing, will occasion a smaller error than is likely to arise from the imbibition of water, if the powder, when weighed, be cold and fully exposed to the air.

It is better not to reduce the mineral, whose water we mean to determine, to a fine powder, but only to fragments; because such fragments do not imbibe water so rapidly as a fine powder does.

When we suspect the presence of any volatile gaseous substance in the mineral, together with water, the process to be followed is different.

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* It is convenient to have a brass counterpoise for the crucible; but the experimenter ought to be aware that a platinum crucible loses weight by use. The crucible which I at present use in my analyses, is 11 grains lighter than when I first began to employ it.

† The weights used by chemists are grains. I use the following weights:

1000, 500, 400, 300, 200, 100 grains.
50, 40, 30, 20, 10 grains.
9, 8, 7, 6, 5, 4, 3, 2, 1 grains.
0·9, 0·8, 0·7, 0·6, 0·5, 0·4, 0·3, 0·2, 0·1 grain.
0·09, 0·08, 0·07, 0·06, 0·05, 0·04, 0·03, 0·02, 0·01 grain.

Weigh a small bottle glass retort, and mark on it the weight with a diamond. Introduce into it 100 grains of the mineral under examination, previously reduced to a fine powder. To the beak of this retort, a glass tube about a foot long, and filled with fragments of chloride of calcium that have been fused, is to be luted. The fragments of chloride of calcium, are to be of such a size as to leave a free passage to air, while at the same time, they fill up the whole of the tube, which ought to have a diameter of about $\frac{3}{4}$ths or $\frac{1}{2}$ of an inch. At the two extremities of the tube, a little amianthus or cotton, must be introduced, to keep the chloride of calcium from passing into the retort or falling out of the tube. The glass tube is fitted to the retort (so as to be air tight) by a perforated cork introduced into the end of the tube, through which the beak of the retort passes. To insure accuracy, the retort and tube ought to be luted together by a ribbon of caoutchouc tied firmly to the tube and retort by a string.* The tube with its chloride of calcium, must be accurately weighed before it is luted to the receiver.

The belly of the retort is placed upon a chauffer containing a charcoal fire. It must be cautiously heated at first to prevent it from cracking. By degrees the heat is raised till the powder become distinctly red hot, and it must be kept red hot for at least an hour, and then the whole is to be left to cool. The retort and glass tube are then to be separated, cleaned, and weighed. The loss of weight sustained by the retort, gives the water and elastic fluid evolved by the heat from the mineral. The increase of weight of the glass tube gives the quantity of water, and this weight subtracted from the loss sustained by the retort, gives the quantity of elastic fluid evolved. Suppose the retort to have lost 20 grains, and the glass tube to have gained 15 grains, the inference would be, that the mineral had given off 15 grains of water and 5 grains of elastic fluid.

If the process has not been continued long enough, or if the quantity of elastic fluid evolved be very small, we observe a little water in the beak of the retort. This may be removed by means of a slip of bibulous paper applied to the place where

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* The best caoutchouc for the purpose, is what is sold in London in thin sheets. I besmear one side of such a ribbon with a varnish composed of caoutchouc dissolved in naphtha, wrap it tight round the place where the tube and retort beak come in contact, and then tie it firmly with a piece of twine.

the water is lodged, taking care to determine its amount by weighing the retort before and after it is dried. Should drops of water appear attached to the beak of the retort, too high up to be removed by bibulous paper, we must proceed in the following manner:—The retort is first weighed. It is then placed again on the charcoal fire, and heated till every part, beak and all, is hotter than boiling water. We now push as far into the retort as possible, a small glass tube open at both ends, and quite dry. By drawing air from this tube with the mouth, we cause a current of air to pass through the hot retort, which in a few minutes renders the inside of it quite dry. The retort being now weighed again, the loss of weight sustained indicates the quantity of water which has been driven off by this drying process.

The water driven off from minerals by heat, may be collected also in a small receiver attached to the beak of the retort by lute. But the simplest way of examining this water, is to put a quantity of the mineral into a thin glass tube shut at one end. The portion of mineral at the bottom of the tube is gradually heated, almost to redness, over a spirit lamp, while the tube is held in nearly a horizontal position. The water is driven off by the heat, and is condensed in the cold part of the tube. In this situation it may be easily examined by re-agents, and its purity determined.

Some minerals, as mica, pyroxene, &c., when treated in this way, give a few drops of acidulous water. The sour taste is owing to the presence of a little fluoric acid; the presence of which may be known by the following properties:—

(1.) When a drop of the liquid is evaporated to dryness on a slip of glass, a particle of silica remains on the glass, easily known by its white colour and insolubility in acids.

(2.) It gives a yellow colour to paper stained with brazil wood.

In some cases the acid is the fluoboric. This acid does not corrode glass. It renders brazil wood paper yellow; but when the paper is dried, it becomes white in the place where the acid liquid had been applied.

It is scarcely necessary to observe, that if any other substance, besides water, be distilled over, it must be examined by the rules about to be given.

Porcelain retorts may be used instead of green glass ones. Indeed, when the mineral requires to be exposed to a white heat, *as is the case when* our object is to drive off the fluoric acid, no other retorts but those of porcelain can be employed. The best porcelain retorts are those of Berlin.[*] They bear sudden changes of temperature without cracking, much better than those made in this country. The small Wedgwood retorts occasionally employed in this country are very bad. They seldom stand two processes, and often crack the first time we attempt to heat them.

When we have ascertained that a mineral when exposed to a red heat, besides water, gives out some other gaseous substance, the next point is to determine the nature of the gaseous body evolved. For this purpose a bent tube is to be luted to the extremity of the tube containing the chloride of calcium, and by means of it the gas is to be conducted to a glass jar standing over a water, or mercurial trough. If it render lime water or barytes water milky, it is carbonic acid. If it occasion a curdy precipitate when passed through a solution of nitrate of silver, it is chlorine. If it produces no sensible effect with these re-agents, but causes a stick of phosphorus when immersed in it to smoke, while the gas gradually disappears, it is oxygen gas. Scarcely any other gas except these three, is evolved when minerals are exposed to a red heat. Should any others make their appearance, the mode of determining their nature will be given afterwards.

CHAP. II.

METHOD OF DETERMINING THE NATURE OF THE FIXED CONSTITUENTS OF MINERALS WHICH ARE BASES.

It is needless to attempt a rigid analysis of a mineral till we know the substances of which it is composed. Because the plan of analysis cannot be devised or arranged till we are aware what the bodies are which must be separated from each other. This second step of the analysis then is an essential one, and ought never to be neglected.

1. Before we can detect the constituents of a mineral, we must have it in a state of solution. Some of the minerals (most of the *zeolites*, for instance) may be dissolved at once

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[*] *Dresden* porcelain is said to be equally good, but I have never tried *it*. *Sèvre* porcelain, from Paris, is apt to crack in the glazing.

in an acid; but the greater number are not acted on by acids till they have been heated with a fixed alkali.

When a mineral is directly soluble in acids, we may employ either nitric or muriatic acid as the solvent. But muriatic acid is preferable, except in certain cases, which will easily suggest themselves to an analyst acquainted with the properties of the constituents of mineral bodies. It is needless to observe, that the acid employed should be pure. Were it contaminated with sulphuric acid, for example, it would not dissolve the mineral completely if it contained lime, strontian, or barytes.

The first step of the process is to reduce the mineral, under examination, to powder. This is a most important part of the process; the success of an analysis sometimes depending upon the reduction of a mineral to a very fine powder. This was well exemplified, in my laboratory, a good many years ago:—I gave to two of my practical pupils, a quantity of chrysoberyl from Brazil, to analyze. One of the gentlemen was at great pains in pounding it, and reduced it to the finest possible powder. He fused it with thrice its weight of anhydrous carbonate of soda, and kept it in that state for a couple of hours. It was thus rendered soluble in muriatic acid, and the analysis was happily conducted and finished in a few days. The other gentleman was not at the same pains in pounding his portion of the mineral. After fusing it successively with carbonate of soda, and then with caustic potash, and spending a great many days in these disagreeable repetitions, he was unable to render the mineral soluble in muriatic acid, and gave up the analysis in despair. On examining the powder on which he had been operating, I showed him that it had not been made fine enough, and satisfied him by a repetition of the process, that want of care in pounding was the only reason of his failure.

The mineral to be pounded (if it happens to be in a mass, as is usually the case) must, in the first place, be broken into small fragments. This is easily accomplished by means of a hammer and anvil, which ought therefore to be kept in every laboratory where minerals are analyzed.

The fragments thus obtained, are to be introduced one by one into the steel mortar employed for pounding diamonds, and therefore called a *diamond mortar*, and by repeated blows of the hammer, reduced to a moderately fine powder. The diamond *mortar* consists of a cylindrical vessel of polished steel, about 2 inches in diameter, and 1½ inch in depth. Into this cylinder, another cylinder or ring of steel is fitted. It goes to the bottom of the first cylinder, and is fixed in its place by two pieces of iron which pass through two holes in the outer cylinder, and penetrate so far into this internal cylinder or ring. This cylinder is about an inch and a half in depth, and has a circular hole in the centre about ¾ inch in diameter, and open both above and below. A pestle of steel is ground to fit this cylinder. The fragments of the mineral to be pounded are introduced into the cylinder one by one, the pestle is put into its place, the mortar is laid on the anvil, and by repeated strokes of the hammer, the fragment is reduced to powder.

A little of this powder (not more than two or three grains at a time) is put into a small chalcedony mortar, and pounded by means of a chalcedony pestle till it feels quite smooth under the pestle, and till it begins to cohere together. A little perseverance and address will enable us by this process alone to bring the mineral to a powder sufficiently fine. But if we are afraid that some particles may have escaped the action of the pestle, when the stone is very hard and difficult to pound, the best way is to pound the whole a second time, adding a little distilled water, and rubbing it upon the chalcedony mortar till the whole is reduced to the consistence of cream. This cream is to be washed into a glass jar, and stirred up with water. After allowing it to stand a few seconds, that the larger particles may fall to the bottom, the milky liquid is poured off, and the coarser particles are ground anew, mixed again with water, the milky liquid again poured off, and these processes of grinding and floating are continued till the whole is reduced to so impalpable a powder that it has been all floated off without leaving any residue whatever.

This fine impalpable powder is allowed to subside, the water is drawn off, and the powder dried, first on the sand bath, and afterwards by exposure to a red heat in a platinum crucible.

It is scarcely possible to grind a mineral in this manner without loss, and in some cases it is essential to know precisely the amount of this loss, because when the mineral is very hard (as sapphire, corundum, chrysoberyl,) a portion of the chalcedony mortar is ground down along with it. Before beginning to pound such a mineral, the chalcedony mortar must be weighed, and its weight noted down. Weigh it again after the process is finished: the difference between the two weights gives you the quantity of matter which has been abraded from the mortar.

In like manner the mineral is to be weighed before we begin to pound it, and the pounded mineral is to be weighed after having been exposed to a red heat. The knowledge of these particulars will enable us to determine the quantity of silica abraded from the mortar which is contained in the powder to be subjected to analysis.

Let the loss of the mortar, . = 4 grains.
weight of unpounded mineral, = 20
weight of powder collected, = 22

To discover the quantity of silica from the mortar contained in these 22 grains, we say, 24 : 4 : : 22 : 3$\frac{2}{3}$ = quantity of silica from the mortar contained in the 22 grains of powder. Hence that powder is composed of

Pure mineral, .	18$\frac{1}{3}$
Silica from mortar, .	3$\frac{2}{3}$

The general formula is as follows :—

Let weight of mineral, . . = a
loss of mortar, . . . = b
weight of powder, . . = c

Silica abraded from the mortar, contained in the powder, = x.
Then

$$x = \frac{bc}{a + b}.$$

It is needless to observe that when the mineral is analyzed, this portion of silica must be carefully subtracted.

The powder should be weighed before the crucible is quite cold. It is best to weigh it in the crucible in which it is to be afterwards fused, because it is scarcely possible to transfer a very fine powder from one vessel to another without loss.

When the mineral under analysis is soluble in acids, we counterpoise a clean glass flask, and then introduce into it, while still in the scales, the quantity of powder which we mean to examine ; or we may weigh the powder in a watch glass, and after introducing as much of it as we can into the flask, wash in the remainder by letting fall into the watch glass, while held inclined over the mouth of the flask, a small stream of distilled water from the extremity of a sucker. If this method be carefully executed, it occasions no loss whatever. Muriatic acid is now poured into the flask in sufficient quantity to dissolve the powder. In general it is better to dilute the acid with twice its bulk of water ; though there are some cases, to be noticed afterwards, when the acid is required to be as concentrated as possible. The flask being placed on the sand bath, is allowed to remain till the whole powder is dissolved. We ought to watch the moment when the solution is complete, because soon after this the silica (if it be a constituent of our mineral) assumes the form of a jelly, and if this be allowed to remain a little while in the vessel it adheres so firmly to the bottom of the flask that it cannot be washed out.

When from an oversight of this nature the silica, or a portion of it, adheres to the inside of the flask, we must not attempt to remove it by drawing a glass rod over the adhering portion. This would not remove the whole of the silica, but it would almost always be sure to destroy the flask, by driving out its bottom. The best way is to pour some dilute potash or soda ley into the flask, and place it again on the sand bath. In a few minutes the whole adhering silica will be dissolved, while the flask, if the ley be dilute, will not be attacked. This ley being poured out is to be saturated with muriatic acid, and evaporated to dryness in a porcelain vessel. Water will dissolve off the chloride of potassium or sodium and leave the silica, which may be washed, dried, and ignited.

Some minerals dissolve easily in acids before ignition, but lose their solubility after being deprived of their water by exposure to a red heat. Many of the zeolites are in this predicament; they are hydrous silicates of alumina, lime, soda, &c. In such cases one portion of the mineral must be employed to determine the quantity of water which it contains, and another for solution in acids.

Minerals soluble in acids are in general soft and easily pounded. They never abrade the chalcedony mortar.

When a mineral is insoluble in acids, we in general give it solubility by mixing it with twice or thrice its weight of anhydrous carbonate of soda, and keep the mixture in a state of ignition for about an hour in a platinum crucible. The mineral and the carbonate are first intimately mixed together by rubbing them together in a mortar. Should any thing adhere to the mortar it may be removed by triturating in it a new quantity of carbonate of soda, which is to be added to the mixture. In some cases the mineral requires more than twice its weight of carbonate of soda to render it soluble; in some rare cases as much as six times its weight of that alkaline carbonate is requisite.

The crucible, covered with its lid, is exposed at first to a *gentle heat*, which is gradually increased to ignition, and it is kept in a red heat for about an hour. Towards the end of the process it is good to raise the heat sufficiently to produce fusion. If we raise the temperature at once high enough to produce fusion, the carbonic acid, if the mineral contain much silica, is driven off so rapidly that portions of the melted matter are dashed about, and may be lost by running out between the crucible and the lid. It is not necessary to raise the temperature so high as to produce fusion, though I generally do so. The whole process may be conducted over a spirit lamp, but in general it is more convenient to make use of the fire which is kindled for heating the sand bath.

Some minerals cannot be decomposed or rendered soluble by heating them with carbonate of soda, but require to be ignited with caustic potash, or soda. This is the case with minerals containing zirconia, oxide of tin, and perhaps also columbic acid. Though I find that I can make minerals containing this acid soluble by fusing them with a sufficient quantity of carbonate of soda.* When a caustic alkali is employed, we must employ a crucible of pure silver, because the caustic alkalies act upon platinum. The mineral (previously reduced to a very fine powder) is weighed in the crucible, and then mixed with from four to six times its weight of the alkaline hydrate. The application of the heat requires very great care, because the hydrate of potash melts easily, and the escape of its water during the process occasions a boiling and agitation by which portions of the mixture are apt to be driven out and lost. The crucible should be deep and covered with a lid. The heating is best performed over a spirit lamp, which may have a circular wick, and a short copper chimney. This gives a sufficient heat, and it can be conveniently applied. Too high a temperature would fuse the crucible. When the water has been driven off, the mixture in general loses its fluidity. The crucible should then be raised to a red heat and kept in that state for an hour.

When the process is concluded, and the crucible allowed to cool, the next step is to dissolve the whole matter contained in it in dilute muriatic acid. When carbonate of soda has been employed, and the heat never so high as to fuse the mixture, if we invert the crucible over a porcelain dish, and give it a few gentle blows with a hammer, the mixture is

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* I have succeeded also with the zircon when sufficient care is taken to reduce it to the *finest possible* powder.

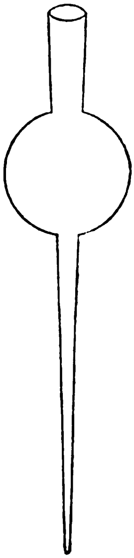
loosened and readily drops out. But when fusion has taken place, the matter adheres so firmly to the crucible that we can seldom disengage it in that way. We must in such a case pour the dilute muriatic acid into the crucible till it fill about two-thirds of it, and place the crucible on the sand bath covered with a slip of glass till it ceases to effervesce. The liquid is then poured into a porcelain basin, taking care to scrape the surface of the undissolved portion with a platinum spatula. More dilute muriatic acid is poured into the crucible, and the same steps repeated till a complete solution is effected.

If we employ muriatic acid sufficiently dilute, and if the mineral has been sufficiently acted on by the carbonate of soda, a complete solution is obtained, or only a few white flocks remain undissolved, easily distinguishable from undecomposed mineral. If any portion of the mineral has escaped the action of the alkaline carbonate, it will be seen at the bottom of the basin in the form of a dense heavy powder. If the muriatic acid be too strong, the silica instead of dissolving is separated in white flocks.

The porcelain basin is now placed on the sand bath, and the liquid in it slowly evaporated to dryness. To prevent any dust from falling into it while the evaporation is going on, lay two glass rods, or two platinum wires across the mouth of the basin, and cover its surface with a piece of wrapping paper. When the liquid has become concentrated, if the mineral contains a considerable portion of silica, the silica assumes the form of a jelly, transparent and tremulous, and often tinged yellow with iron, which is a very general constituent of minerals. When this jelly has become a little stiff it should be scraped off the bottom with a platinum spatula, and very frequently stirred till it is converted into a dry powder. It is best to continue the heat till the powder ceases to give out muriatic acid fumes. For unless this be done a portion of the silica is apt to retain water, which causes it to dissolve partially again when water is poured on the powder.

When the powder is dried in this way, the oxide of iron, alumina, and even the magnesia, should such bodies be present, have generally lost a portion of their acid, and have in consequence become partially insoluble in water. To restore their solubility the dry mass is to be moistened with concentrated muriatic acid, and the mouth of the vessel being covered with a glass plate, it is left for one or two hours on the sand bath exposed to a gentle heat. Water is then to be poured into it, and after a little digestion the whole is to be thrown on a filter. The dissolved portion passes through, but the silica, which is in the state of a fine white powder, remains on the filter. It must be washed with boiling hot distilled water till the filtered liquid ceases to be affected by nitrate of silver; a salt which causes a white flocky precipitate to appear as long as any muriatic acid is contained in the water which passes through.

The washing of a filter requires some precautions, otherwise the upper part of the paper is apt to retain a portion of the solution after the under part is washed. This is prevented by employing the glass tube represented in the margin, which, from the mode of using it, may be called a *sucker*. It is about fifteen inches long, and the upper extremity has an internal diameter of about half an inch, but at the lower end it narrows so as to be almost but not quite capillary. About two inches from the upper end the tube is blown by the lamp into a spherical cavity capable of holding about a cubic inch of water. The narrow end of the sucker is dipt into the hot water, and by the mouth which is applied to the other end, the water is drawn into the tube till the spherical cavity is filled. We then place the sucker in such a direction that the jet of water forced out of it with some violence by the action of the cheeks strikes against the upper edge of the filter, and we gradually turn the filter round so that the water may strike against every part of the upper edge. This process is continued without intermission till the upper edge of the filter is quite tasteless, and till the water which passes through the filter is not precipitated by nitrate of silver. A good deal of washing, and for a considerable time is requisite before these objects are accomplished. But they are indispensable if we wish to obtain accurate results.



When the mineral had been fused with caustic potash in a silver crucible, and the fused mass dissolved out with muriatic acid, the silica is always mixed with some chloride of silver.

This chloride may be removed by digesting the silica in caustic ammonia; but it is better to avoid the formation of chloride of silver altogether. This may be done by dissolving the matter out of the crucible by distilled water, and not adding the muriatic acid till we have got the whole into a porcelain basin.

While the muriatic solution is evaporating care should be taken not to allow it to boil, because whatever is driven upon the paper cover is lost. When the liquid has become so concentrated that strong muriatic acid fumes are exhaled, we should remove the paper cover altogether, because if allowed to remain it would be corroded and would at last fall into the acid liquid. This would not only be troublesome from the quantity of paper flocks mixed with the constituents of the mineral, but it would render the results inaccurate, because the earthy constituents of the paper thus corroded would be confounded with those of the mineral.

The silica thus separated, to be pure, must possess the following characters:

(1.) It is a fine white powder and continues white after ignition. It feels gritty between the teeth.

(2.) When digested in muriatic acid after having been exposed to a red heat it is altogether insoluble.

(3.) After ignition it is tasteless and quite insoluble in water.

(4.) When heated before the blowpipe with its own weight of anhydrous carbonate of soda it fuses, with a strong effervescence, into a transparent colourless glass. This is the usual test by which pure silica is recognised by chemists.

(5.) When silica has been dried, but not exposed to a red heat, it dissolves completely when digested in a ley of caustic potash or soda. The solution is colourless and does not gelatinize however concentrated.*

(6.) If we mix it after ignition with 3·375 times its weight of anhydrous carbonate of soda, and expose the mixture in a platinum crucible to a strong red heat, it fuses into a colourless glass, which, when pounded and digested, dissolves in water without leaving any residue.†

(7.) Dried (but not ignited) silica dissolves readily by the

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* Even after ignition silica dissolves in alkaline leys, but the process is slow.

† If the silica contain any lime, barytes, strontian, or magnesia, the glass formed is not completely soluble in water.

assistance of heat in solutions of carbonate of potash or soda; but on cooling the solution assumes the form of an opal-coloured jelly, which is the stiffer, and forms the more rapidly, the more concentrated the solution is. This solution succeeds also when ignited silica is used, but it is much slower and more imperfect.

(8.) Fluoric is the only acid which dissolves silica after it has been dried in a red heat. The solution takes place rapidly, and the more so the more concentrated the fluoric acid is; when it is so strong as to smoke when exposed to the air, the solution of the silica sets so much heat at liberty that the whole acid is raised to the boiling temperature. These experiments must be made in vessels of silver or platinum, because fluoric acid instantly corrodes glass.

(9.) When a soluble combination of silica and an alkali is dissolved in a great deal of water, if we pour muriatic acid, or, indeed, any other acid, into the liquid, the silica is not precipitated, but remains in solution. If we now evaporate this liquid till it has reached a certain point of concentration, and then allow it to cool, the silica assumes the form of a white jelly, exceedingly similar to a jelly of isinglass. If we pour water upon this jelly, the greater part of the silica separates in white flocks, but a portion dissolves again. This is the reason why it is necessary to bring the muriatic acid solution of a mineral containing silica to the state of a dry powder before we attempt to separate the silica.

All deviations from these properties indicate the presence of a foreign body in the silica. It is necessary in such cases* to treat the silica again with an alkaline carbonate, as we did with the mineral at first; we must then get a solution of the whole in muriatic acid, and proceed as before, till we separate the foreign body from the silica.

II. The filtered liquid thus freed from silica contains the remaining constituents of the mineral in solution, combined with muriatic acid and mixed with abundance of common salt. There is also an excess of muriatic acid present. This liquid, together with the water employed in washing the silica, is to be put into a porcelain basin and evaporated on the sand bath till its volume is reduced to about ten cubic inches.†

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* For example, when it fuses into a coloured glass with carbonate of soda.

† To economise time, which is an object in chemical analyses, I usually reserve the last washings of the silica, containing very little impurity. The

The excess of muriatic acid is then to be nearly saturated by pouring into it carbonate of ammonia, taking care to agitate the liquor strongly and for some time, in order to get rid of the carbonic acid; and to make sure of this a little excess of muriatic acid ought to be allowed to remain in the liquid. To make sure of the escape of all the carbonic acid, it is best to heat the liquid almost to the boiling temperature and then allow it to cool.

This done we pour into it caustic ammonia, till the liquid, after agitation, smells sensibly of that alkali. Unless we add ammonia in excess, the precipitate which falls is apt to contain muriatic acid, and is in part redissolved again while we are washing it on the filter. But we should avoid a great excess of ammonia, because it might dissolve a portion of some of the substances at first precipitated.

The ammonia throws down every base which the solution can contain, except the fixed alkalies, barytes, strontian, lime and magnesia. If the solution contained protoxide of manganese, a portion of it will remain in solution, and the more the greater the proportion of sal ammoniac which our liquid contains. Magnesia will be partially precipitated by the ammonia, unless the solution contains enough of sal ammoniac to convert the whole magnesia into a double salt. If iron be present in the solution, and if we have not converted it into peroxide, a portion of protoxide of iron will also remain in solution.

Should oxides of zinc, nickel, cobalt or copper, be present, the greater part of these oxides would remain in solution. But these bodies are rare ingredients, except in ores: we shall therefore defer giving an account of the mode of detecting them till we come to the second book of this treatise.

III. The ammonia precipitates certain earths and metallic oxides. We leave the whole in a cylindrical glass jar, the mouth of which is covered with a plate so as to exclude the external air till the precipitate subsides, which it does slowly. The clear liquor above the precipitate is now carefully drawn off, by means of a sucker, and preserved. The precipitate, thus freed from a considerable portion of the liquid, is mixed with distilled water and thrown upon a filter: it must then be washed with boiling hot distilled water till every thing

muriatic liquor is evaporated almost, but not quite, to dryness, and then mixed with these washings. This serves two purposes; it saves time and it gets rid of a good deal of the excess of muriatic acid present.

soluble is removed. This process is tedious, especially when the precipitate contains much alumina, because alumina forms a plastic jelly-looking mass, through which water filters but slowly.

IV. The liquid which passes through the filter may contain any or all of the alkaline earths. It may also contain portions of any of the metallic oxides that are soluble in ammonia; namely, oxides of zinc, manganese, nickel, cobalt and copper. Oxides of zinc and manganese do not communicate any colour to the liquid; oxide of copper gives it a blue colour, with a shade of red, oxide of nickel communicates a pure sky-blue, and oxide of cobalt a reddish-brown colour.

The first thing to be done with this liquid is to mix with it a few drops of sulpho-hydrate of ammonia; if a precipitate fall, it indicates the presence of one or more of these metallic oxides. Let this precipitate be collected, washed and dried, upon a slip of glass or a piece of platinum foil. It consists of one or more metallic sulphurets.

(1.) Sulphuret of cobalt and nickel have a greyish-yellow or yellowish-grey colour, and when heated acquire something of the metallic lustre. Sulphuret of manganese, while still moist, is yellowish, but when heated it becomes green; sulphuret of zinc,* while moist, is white, but when heated it acquires a yellowish colour.

(2.) The easiest way of determining the nature of the metal in these precipitates is to test them before the blowpipe. The following instructions will enable the young analyst to accomplish this object.

The first step is to roast the sulphuret on charcoal, by the cautious application of the blast, taking care not to fuse it, which would prevent the object in view. This roasting must be continued till the whole of the sulphur is driven off, and the metal reduced to an oxide.

Sulphuret of zinc does not fuse, but it forms an annular deposit of the oxide of zinc, when strongly heated in the exterior flame on charcoal. When heated with carbonate of soda the zinc is reduced, and in a good flame burns, and flowers of zinc are deposited on the charcoal.

Sulphuret of manganese, when properly roasted on charcoal, is converted into brownish scoriæ, constituting an oxide of manganese. When this oxide is fused with carbonate of soda

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* *It is, in fact,* a sulpho-hydrate of zinc.

before the blowpipe, a green transparent bead is obtained, which on cooling becomes bluish-green and opaque. This experiment is best made on platinum foil. A very minute quantity of manganese may be detected by this colour. With borax it fuses into an amethyst-coloured glass, which loses its colour in the reducing flame; but if we add a little nitre and fuse again, the amethyst colour is restored with considerable intensity. If the quantity of manganese be considerable, compared with the borax, the glass in the exterior flame becomes so deep coloured as to appear black. With biphosphate of soda it fuses into a transparent colourless glass in the reducing flame, and an amethyst-red in the oxidizing flame; but never so deep as to render the glass opaque.

Sulphuret of copper, after the sulphur has been driven off, melts with carbonate of soda into a fine green glass, which loses its colour and transparency on cooling. With borax in the oxidizing flame it fuses into a fine green glass, which becomes colourless in the reducing flame; with biphosphate of soda it fuses and exhibits the same phenomena as with borax. If the quantity of copper be so small that the blue colour cannot be developed in the reducing flame, add a little tin to the assay and continue the blast. The bead now becomes red and opaque on cooling. If the blast be kept up too long, the copper precipitates in the metallic state, and the colour is destroyed.

Sulphuret of cobalt, after being roasted, fuses readily with borax or biphosphate of soda into a transparent blue bead.

Sulphuret of nickel, after being roasted on charcoal, readily fuses with borax or biphosphate of soda into an orange-yellow or reddish glass, which becomes yellow or almost colourless by cooling. If the proportion of oxide of nickel be great the glass is opaque and dull brown while in fusion, but on cooling becomes dull red and transparent. It behaves in the same way in the oxidizing and reducing flames; this distinguishes nickel from iron, which, in the colours that it communicates, it much resembles.

After determining the kind of metallic oxides, if any be present, in the solution, we next test it for lime, barytes, strontian, and magnesia.

1. The presence of lime is indicated by the white precipitate produced when the liquid is mixed with oxalate of ammonia. To apply this test put a little of the ammoniacal liquid into a watch glass, and let fall into it a drop of the *aqueous* solution of oxalate of ammonia. The presence of

lime in the liquid will be immediately indicated by a white precipitate appearing in it.

Should the presence of oxide of manganese have been indicated by the application of sulphohydrate of ammonia, and the consequent examination of the precipitate; it is possible that the white precipitate produced by the mixture of oxalate of ammonia may consist of oxalate of manganese instead of oxalate of lime. To decide the matter, we must collect, wash, and dry a little of the precipitate, and then heat it to redness on a piece of platinum foil. If it consisted of oxalate of lime, it will become grey, and will dissolve with effervescence in muriatic acid, except a few flocks of charcoal. If it consisted of oxalate of manganese, it will become black after ignition, and will dissolve in muriatic acid, giving out a strong smell of chlorine. The solution will be colourless, and will be precipitated yellow by sulphohydrate of ammonia, whereas the solution of the lime in the same acid will not be precipitated at all by sulphohydrate of ammonia.

In applying the test of oxalate of ammonia to detect the presence of lime, the liquid should be dilute. If too much concentrated, barytes and strontian might be thrown down as well as lime.

2. Sulphate of soda in solution, when added to the liquid, detects the presence of barytes and strontian by throwing down a white precipitate. The liquid is to be tested for these two bodies in the same way as for lime. To determine whether the precipitate be sulphate of barytes or sulphate of strontian, we saturate a few drops of the ammoniacal liquid with muriatic acid, and then let fall into it a drop of fluosilicic acid. A precipitate will appear if it contain barytes, but not if it contain only strontian.

3. Should none of these three alkaline earths be present, we must next test the ammoniacal liquid for magnesia. This is done by saturating a few drops of it with phosphoric acid, or dropping into it a little biphosphate of ammonia. If magnesia be present a white precipitate falls, or at least lines drawn on the watch glass containing the liquor will become visible in a few minutes by the precipitation of a little ammonia-phosphate of magnesia. Should our liquid contain lime, we must precipitate the whole of that earth from it and filter the solution before we test it for magnesia. Because phosphoric acid and biphosphate of ammonia have the property of throwing down *lime from its solution* in acids.

V. Having thus ascertained the nature of the substances which remain in solution, we must next turn our attention to the precipitate which was thrown down by ammonia, and which had been carefully washed on a filter. We dry it upon this filter without exposing it to heat.

The precipitate thus obtained is put into a flask with a sufficient quantity of moderately strong potash or soda ley, and boiled on the sand-bath for an hour, or for several hours, if the quantity be considerable. The potash will dissolve the alumina and glucina should these earthy bodies be present, while it leaves the other constituents undissolved.

When the boiling has been continued till every thing soluble has been taken up, we allow it to cool, and throw the whole on a filter to separate the dissolved from the undissolved portion. The filter is to be washed with the same precautions as before indicated, till every thing soluble is carried off.

The alkaline liquid, together with the washings, being reduced to a quantity sufficiently small for convenient examination, is saturated with muriatic acid, added in such excess, as to dissolve the whole of the precipitate which at first appeared. Then add a sufficient quantity of carbonate of ammonia to throw down the whole earthy matter held in solution, and put the mixture into a glass phial with a ground stopper. Let it remain at rest till the precipitate has subsided, and draw off the clear liquid by means of a sucker. Pour over the white precipitate a considerable quantity of a moderately strong solution of carbonate of ammonia, replace the ground stopper, and agitate the whole pretty strongly at intervals for several hours. Then allow the undissolved portion to subside. Draw off the clear liquid, and pouring in an additional portion of carbonate of ammonia, repeat the agitation as before. The carbonate of ammonia will dissolve the glucina, should any be present; but it will leave the alumina in the state of white, light, and very fine flocks.

The undissolved alumina is separated from the ammoniacal solution by means of a filter, which is to be washed with the precautions already described.

Boil the ammoniacal liquid in a flask, till the greatest part of the ammonia is expelled. It becomes milky, and deposits the glucina under the form of a bulky white powder.

If the carbonate of ammonia be employed in very great excess, it dissolves not only the glucina, but a portion also of the alumina. This portion renders the liquid muddy as soon as it begins to boil. It might be separated by stopping the process, and allowing the alumina to subside before we separate the glucina.* The precipitate thus obtained, is a mixture of alumina and glucina. Add a little carbonate of ammonia, and set it aside for a few hours to digest. The glucina will be dissolved, and will leave the alumina unaltered.

Glucina, when separated, washed, and dried, is a soft white powder, without taste or smell. It is insoluble in water, but dissolves readily in acids, provided it has not been exposed to a red heat. Its acid solutions are colourless, and are distinguished by a sweet taste.

Glucina is precipitated from its solution in acids, by a solution of potash, in a voluminous precipitate, which dissolves completely in an excess of potash. If this experiment be made with a solution of sulphate of glucina, the solution, though set aside, deposits no crystals of alum. This circumstance readily distinguishes glucina from alumina.

Ammonia produces equally a voluminous white precipitate when poured into solutions of glucina, and the precipitate is not re-dissolved by an excess of ammonia; nor is it prevented from falling, though a quantity of sal ammoniac be mixed with the solution.

A solution of carbonate of ammonia likewise produces a bulky precipitate in solutions of glucina, which is re-dissolved in an excess of the carbonate. This also distinguishes glucina from alumina.

Carbonate or bicarbonate of potash acts in the same manner; only it requires a greater excess of these bodies than of the carbonate of ammonia to re-dissolve the precipitated glucina.

Alumina, when pure, is a soft, white, tasteless, powder, bearing externally considerable resemblance to glucina. It is insoluble in water, but dissolves readily in acids, provided it has not been ignited. After ignition, it dissolves slowly in muriatic or sulphuric acid by digestion on the sand-bath. The acid solutions of alumina have a sweet and astringent taste.

Like glucina, alumina is precipitated from its solutions by caustic potash, and the precipitate is again re-dissolved by adding the potash in excess. It is also precipitated by ammonia, but no excess of this alkali re-dissolves it. It is pre-

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* *The quantity* is so small that this process is unnecessary.

cipitated equally by carbonate of potash, bicarbonate of potash, and carbonate of ammonia; but no excess of these carbonates is capable of re-dissolving the precipitate.

When to a solution of alumina in sulphuric acid we add sulphate of potash, or sulphate of ammonia, and set the solution aside, crystals of alum are gradually deposited in it, easily recognizable by their octahedral shape and by their taste.

VI. The portion of matter undissolved by the caustic potash ley must now claim our attention. In general it consists of peroxide of iron, or of a mixture of peroxide of iron and sesquioxide of manganese; but it is possible also that it may contain yttria, zirconia, oxide of cerium, and even oxide of uranium. The yttria, zirconia, and protoxide of cerium are white, the peroxides of cerium and uranium are yellow, and the peroxide of iron red. The first thing to be done is to digest the whole in muriatic acid. A few white flocks commonly remain undissolved. They consist usually of silica, though in some rare cases it is possible that they may consist of columbic acid, or even of titanic acid.

We determine whether it be silica by fusing it before the blowpipe with carbonate of soda. It melts with effervescence into a colourless bead.

Columbic acid is white and tasteless as well as silica, and is equally infusible before the blowpipe per se. When heated with carbonate of soda an effervescence takes place, but the oxide neither dissolves nor is reduced. With borax it forms a colourless transparent glass, which becomes opaque by flaming, and if the proportion of oxide be large, it assumes on cooling the appearance of a white enamel. With biphosphate of soda it fuses easily, and in large quantity, into a transparent glass, which retains its transparency after cooling.

Titanic acid, when pure, is white, but it is usually combined with some peroxide of iron, which gives it a reddish-yellow colour, more or less deep according to the quantity of iron present. This substance, like silica and columbic acid, is infusible per se before the blowpipe. With carbonate of soda it fuses with effervescence and sputtering into a dull yellow transparent glass, which is not absorbed by the charcoal, and becomes white, or greyish-white on cooling. This globule has the property of crystallizing at the moment it ceases to be ignited, disengaging at the same time so much heat, that the globule ignites afresh, and even becomes white hot. The *intensity* of this phenomenon depends chiefly on the soda and titanic acid being exactly in the proper proportions, an excess of either ingredient greatly diminishing or entirely destroying the appearance.

With borax (on platinum wire) titanic acid fuses readily into a colourless glass, which becomes milk white by flaming. If the proportion of acid be increased, the glass turns white spontaneously on cooling. If the quantity be small, the glass becomes first yellow in the reducing flame, and when the reduction is complete it assumes a dull amethyst colour, which becomes more distinct when the bead cools. This glass is transparent, and a good deal resembles that of the oxide of manganese, acted on by the oxidizing flame, but inclines rather more to blue. With a larger portion of titanic acid the glass becomes dull yellow on charcoal in the reducing flame, and on cooling acquires so deep a blue colour that it appears black and opaque. If it be then flamed, it becomes light blue, but opaque and like enamel.

Biphosphate of soda dissolves titanic acid in the exterior flame, and converts it into a clear colourless glass. In the reducing flame the glass appears yellowish-white while hot, but on cooling it becomes at first red, and then assumes a very beautiful bluish violet colour. With too large a quantity of acid the colour is so deep that the glass seems opaque, without having the appearance of enamel. The colour may be discharged by the exterior flame.

If the titanic acid contain iron, the violet colour derived from the protoxide of titanium does not appear, and in the reducing flame the glass assumes a red colour, similar to that developed by ferruginous tungstic acid. If these substances be in small quantity the colour becomes yellowish-red, but it does not appear till the glass begins to cool, and generally does not acquire its full intensity till the globule is perfectly cold. Such is the delicacy of this test, that when the glass contains so little titanic acid that we cannot decidedly ascertain its presence by examining the colour, we may immediately perceive it by adding iron, particularly metallic iron, when the effect is instantly and unequivocally produced. If we add a little tin to this glass, and continue the blast, the colour derived from the iron disappears, and the violet tint of the oxide of titanium re-appears. But in order to produce this effect it is necessary that the colour of the glass be not too intense; if it be, a fresh portion of the flux must be added.*

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* *Berzelius on the Blowpipe*, p. 74.

VII. What is dissolved in the muriatic acid is seldom any thing else than a mixture of peroxide of iron and protoxide of manganese. If it contains a great excess of muriatic acid, it must be evaporated nearly to dryness to drive off this excess. Dilute it with water, and drop into the solution weak ammonia cautiously till the excess of acid is very nearly saturated. This is known by the colour of the liquid changing from yellow to red. After this add ammonia, drop by drop, stirring the liquid after each addition, till the peroxide of iron begins to precipitate. If we now raise the temperature of the liquid (which ought to be in a flask) to the boiling point, the whole peroxide of iron falls, while the manganese remains in solution. By throwing the whole upon a filter while boiling hot, we separate the peroxide of iron, and leave the manganese in solution. The peroxide of iron must be well washed in the way above described with boiling water.

I sometimes follow this process, which was first suggested by Sir John Herschell, but it is a method which is apt to fail, unless we are very careful of the quantity of ammonia added; a very little too much throws down manganese along with the iron. The method which I usually follow was suggested by Hisinger, as a substitute for Gehlen's method of separating peroxide of iron by means of succinate of ammonia. Drop a solution of benzoate of ammonia into the saturated liquid. A buff coloured precipitate falls, and the liquid becomes transparent and colourless. The benzoate of iron (which is the buff coloured precipitate) falls more speedily if we heat the liquid, after adding the benzoate of ammonia.

The benzoate of iron is allowed to subside, the clear liquor is to be withdrawn by a sucker, and its place supplied by an equal quantity of water, taking care to stir the mixture with a glass rod. When the benzoate of iron has subsided to the bottom, if the supernatant liquid be colourless, the process has been properly conducted; but if the liquid be coloured, we may conclude that the benzoate of iron contains an excess of acid. This must be removed by dropping ammonia into the liquid (stirring it after each addition) till the colouring matter precipitates. It is needless to observe that great caution must be observed in adding the ammonia, lest we precipitate any manganese which may be in the liquid, together with the benzoate of iron.

Instead of ammonia we may pour into the coloured liquid a solution of sal ammoniac. The benzoate of iron will be precipitated, while the manganese will be held in solution. We now collect the benzoate of iron on a filter, wash it with a solution of sal ammoniac, dry it, and expose it to a heat sufficiently strong to sublime the benzoic acid.

The peroxide of iron* thus obtained has a red colour, is tasteless, and dissolves in muriatic acid. The solution is a deep yellow, or almost a red. It has a very harsh astringent inky taste, and strikes a deep blue almost black with the infusion of nutgalls, and a deep blue with the prussiate of potash.

The iron being thus separated, the liquid (previously reduced by evaporation to a convenient bulk) is raised to the boiling point, and carbonate of soda being added, the manganese is thrown down in the state of a white powder, (the carbonate,) which when ignited becomes black, or, if the heat be strong, red.

It is of importance to ascertain beforehand whether the solution contain any manganese in solution. The appearance of the matter before it is dissolved in muriatic acid gives us some information. If it is dark brown, or almost black, we may suspect manganese. If it is a fine red, it consists chiefly of peroxide of iron. There is a valuable test of manganese which I frequently employ, namely, bleaching powder or chloride of lime. But care must be taken that it does not contain any excess of lime, otherwise it would throw down iron as well as manganese. A drop of solution of bleaching powder being let fall into a liquid containing manganese, occasions an immediate precipitate of reddish or brownish-red flocks. Should the colour remain unaltered, we may be sure that no manganese is present in the liquid.

The white colour of carbonate of manganese, and the change of that colour to black or red when the powder is ignited, is a sufficient character to enable us to distinguish manganese from other bodies.

If alumina and magnesia occur together in the mineral, the precipitate, together with alumina and oxides of iron and manganese, will likewise contain magnesia, which will be precipitated by the ammonia along with the alumina. In such cases we have a solution of magnesia, protoxide of manganese, and peroxide of iron in muriatic acid. The best way of

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* Benzoate of ammonia does not precepitate protoxide of iron. We must, therefore, take care to ensure the peroxidizement of the iron by *digesting it, if necessary,* with nitric acid.

separating these bodies from each other is the following:—Make the solution nearly neutral by evaporating it almost to dryness, and then diluting it with water till its bulk amounts to ten or twelve cubic inches. Dissolve bicarbonate of potash in water, and drop the solution into the liquid till the peroxide of iron is completely thrown down. Then filter. The liquid which passes through the filter will retain all the magnesia and oxide of manganese held in solution by the carbonic acid of the bicarbonate. These two substances, supposing them to exist together in solution, may be separated from each other, or at least the amount of each ascertained in the following manner:—

Divide the liquid into two equal portions. Into the one pour a solution of neutral chloride of lime. The whole manganese falls in the state of a red powder. Separate this powder, wash it, and expose it when dry to a red heat. Every six grains of it in this state indicate 4½ grains of protoxide of manganese. Let the weight of the precipitate be a, then the protoxide of manganese in the half of the liquid employed $= \frac{3}{4}a = b$, and the whole oxide of manganese in the portion of the mineral examined $= \frac{3a}{2}$.

Raise the other half of the liquid to the boiling temperature, and add an excess of carbonate of soda, boil for some time, then evaporate the whole liquid to dryness in a porcelain basin, pour water on the dry residue, and digest it till every thing soluble be taken up, then throw the whole upon a filter, wash the white matter remaining on the filter, dry it and expose it to a red heat, and then weigh it. The weight will indicate one half of the magnesia contained in the original precipitate, together with one half of the manganese in the state of red oxide.

By the first step of the process we determined the half of the manganese in the state of protoxide. Now protoxide of manganese is to red oxide as 4·5 to 4·833. To find the weight of red oxide of manganese contained in our second precipitate, we say $4{\cdot}5 : 4{\cdot}833 :: b : x =$ the quantity of red oxide in the powder, and $x = \frac{4{\cdot}833b}{4{\cdot}5}$. This quantity being subtracted will leave the quantity of magnesia; and twice this weight will obviously be the whole magnesia contained in the quantity of mineral under examination.

If we are not in possession of neutral chloride of lime, we may separate the manganese and magnesia from each other in the following manner:—Saturate the potash in the liquid with muriatic acid, and then concentrate somewhat by evaporation. Pass a current of chlorine gas through the liquid till the manganese is peroxidized. Add bicarbonate of potash in slight excess. The whole manganese falls in the state of deutoxide. Wash it, dry it, and expose it to a dull red heat. It will become perfectly black, and every five grains of it indicate 4·5 grains of protoxide of manganese. Let the weight of black powder obtained in this manner be a, the protoxide of manganese in the liquid will be $\frac{9a}{10}$.

Instead of throwing down the magnesia by carbonate of soda, we may add to the liquid thus freed from manganese, phosphate of soda and caustic ammonia, or biphosphate of ammonia. The magnesia is precipitated in the state of ammonia-phosphate of magnesia. When this salt is exposed to a red heat, it loses its ammonia and its water of crystallization, and there remains biphosphate of magnesia, every 11½ grains of which are equivalent to 2½ grains of magnesia. Let the weight of biphosphate of magnesia obtained be a, then the whole magnesia contained in the precipitate $= \frac{5a}{23}$.

VIII. There are certain minerals which contain yttria, zirconia, and oxides of cerium and uranium. Now, when these bodies happen to be present, they will be thrown down by the caustic ammonia, together with the alumina, iron, and manganese, the mode of separating which has just been pointed out. It may be proper therefore to make a few observations on the mode of detecting yttria, zirconia, and oxides of cerium and uranium, when they occur.

1. Yttria has been hitherto met with only in about eight minerals (as may be seen in the first part of this work), the specific gravity of which (if we except *orthite* and *pyrorthite*), is not less than 4·15, nor greater than 5·88. Yttria is most commonly accompanied by oxide of cerium; and the characters of these bodies are so nearly alike, that it is not easy to separate them from each other. Let us suppose that the precipitate after digestion in caustic potash, consists of a mixture of yttria, oxide of cerium, and oxide of iron. Dissolve it in muriatic acid, and into the solution place a mass of sulphate of potash, so that a portion of it shall stand higher than the

surface of the liquid, and the quantity of which is so great that the liquid is incapable of dissolving it. Leave the mixture in this state for twenty-four hours. Oxide of cerium has the property of forming a compound salt with sulphate of potash, which is insoluble in a saturated solution of sulphate of potash, whether the liquid contain an excess of acid or not. The oxide of cerium will be precipitated in the state of this compound salt. Let it be collected on a filter, and washed with a saturated solution of sulphate of potash. The liquid by this process is freed from oxide of cerium.

It still contains yttria and peroxide of iron; let it be neutralized and the iron thrown down by benzoate of ammonia by the method already explained.

Nothing now remains in solution but the yttria, which is to be precipitated by caustic potash or soda.

The oxide of cerium thrown down in the state of potash-sulphate of cerium is a granular powder, white if the cerium be in the state of protoxide, but lemon-yellow when the peroxide of cerium is present. Dissolve it in water, add an excess of caustic potash or soda, and digest for some time on the sand-bath. The oxide of cerium is thrown down. When washed, dried and ignited, it is always in the state of peroxide of cerium, and has a cinnamon-brown or tile-red colour.

2. Protoxide of cerium, while in the state of an hydrate, is white, but when dried in the air it becomes yellow. By ignition it is peroxidized. The protoxide dissolves readily in acids and the solution is colourless. The solution of the peroxide is yellow or reddish-yellow. When muriatic acid is digested on peroxide of cerium, chlorine is exhaled, and the solution becomes gradually colourless by the conversion of the peroxide into protoxide.

The solution of protoxide of cerium exhibits the following phenomena with re-agents:

(1.) Potash or soda throws down a bulky white precipitate, which does not re-dissolve though the potash be added in excess.

(2.) Ammonia acts precisely as potash does.

(3.) Carbonate of potash, bicarbonate of potash, and carbonate of ammonia throw down a white bulky precipitate which is soluble in an excess of the precipitating medium; but the whole of the precipitate is again thrown down when the liquid is raised to the boiling temperature.

(4.) Phosphate of soda throws down a white precipitate, easily soluble in acids.

(5.) Oxalic acid throws down a white bulky precipitate, (provided there be not too great an excess of acid in the liquid,) which dissolves in a great excess of muriatic acid.

(6.) If the solution be not too dilute, sulphate of potash throws down a crystalline precipitate,* very difficultly soluble in water and not at all in a solution of sulphate of potash.

(7.) Prussiate of potash throws down a white precipitate.

(8.) Sulphuretted hydrogen occasions no precipitate, but sulphohydrate of ammonia throws down a white powder.

(9.) Before the blowpipe, in the outer flame, oxide of cerium melts with borax or biphosphate of soda into a *red* bead, but the colour diminishes as the bead cools and at last it vanishes. In the inner flame the glass formed is colourless.

It is unnecessary to state the phenomena of the solution of peroxide of cerium, because the peroxide by solution in muriatic acid and digestion can easily be brought into the state of protoxide.

3. Yttria, while in the state of a hydrate is white, but by ignition its colour is changed into a dirty yellowish white. It dissolves readily in acids, and the solution is colourless. It exhibits the following appearances with re-agents:—

(1.) Caustic potash, or soda, throws down a white bulky precipitate, not redissolved by adding an excess of the alkali.

(2.) Ammonia exhibits the same phenomena.

(3.) The alkaline carbonates throw down a bulky precipitate which is redissolved in an excess of the precipitant. The bicarbonate of potash redissolves the precipitate more readily than the carbonate. Carbonate of ammonia does not redissolve yttria so easily as it does glucina.

(4.) Phosphate of soda throws down a white precipitate, which is redissolved by muriatic acid; but the precipitate appears again when the liquid is boiled.

(5.) Oxalic acid throws down a bulky white precipitate soluble in muriatic acid.

(6.) Sulphate of potash occasions, after a considerable interval of time, a white precipitate, which is redissolved by the addition of water, even when undissolved sulphate of potash is present.

(7.) Prussiate of potash throws down a white precipitate.

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* The precipitate does not fall immediately, but after an interval of time.

(8.) Sulphuretted hydrogen occasions no precipitate, but sulphohydrate of ammonia throws down yttria.

(9.) Yttria can scarcely be distinguished from the other earthy bodies by the blowpipe.

4. Zirconia is nearly as scarce as yttria. Hitherto (as may be seen in the first part of this work) it has been found only in five species of minerals, all of which, except the *zircon* or *hyacinth*, are very rare. It has a yellowish colour while in the state of a hydrate and dissolves readily in acids; but when it is deprived of its water by ignition it assumes a white colour and becomes insoluble in acids, though by long digestion in concentrated sulphuric acid we may obtain a solution of it.

The solution of zirconia in nitric or muriatic acid is colourless, and however carefully neutralized, always reddens vegetable blues. It exhibits with reagents the following phenomena:

(1.) Potash, or soda, throws down a bulky white precipitate, which is not redissolved by adding the alkali in excess.

(2.) Ammonia produces exactly the same effect.

(3.) The alkaline carbonates or bicarbonates throw down bulky white precipitates, which are redissolved by an excess of the precipitant. Carbonate of ammonia seems to be most powerful in redissolving such precipitates.

(4.) Phosphate of soda throws down a bulky white precipitate.

(5.) Oxalic acid throws down a bulky white precipitate, redissolved by adding muriatic acid to the liquid.

(6.) Sulphate of potash throws down in a short time a white precipitate, which is redissolved by the addition of a considerable excess of muriatic acid; but if the precipitate has been thrown down from a hot solution; it is insoluble both in water and in acids.

(7.) Prussiate of potash throws down a white precipitate.

(8.) Sulphuretted hydrogen occasions no change, but sulphohydrate of ammonia throws down a bulky white precipitate.

Thus zirconia is distinguished from alumina and glucina by its insolubility in potash: from yttria, because after being precipitated hot by sulphate of potash, it is insoluble in water and even in acids; whereas the precipitate of yttria by the same reagent is soluble in a considerable quantity of water. It may be distinguished also from yttria by this property: after ignition it is insoluble in muriatic acid, whereas yttria after ignition dissolves readily in that acid. Zirconia is easily distinguished from oxide of cerium, because the latter when ignited becomes tile red, whereas zirconia becomes white. Before the blowpipe zirconia does not form a coloured glass with borax or biphosphate of soda, unless it be contaminated with iron.

I shall, in a subsequent part of this treatise, give an example of the mode of analyzing a mineral containing zirconia. There is considerable difficulty in separating zirconia and oxide of iron from each other, when they happen to be present in the same mineral.

5. Thorina is so rare that there is little chance of any mineral containing it coming in the way of the young analyst. I shall therefore pass it over at present, and give hereafter an example of the mode of analyzing a mineral containing this substance.

6. Oxide of uranium is easily recognised by the yellow colour which it gives to solutions containing it. Prussiate of potash throws it down of a dark brown colour. If the solution of uranium be neutral, the infusion of nutgalls gives the same dark reddish-brown precipitate; but if there be an excess of acid in the liquid, no effect is produced by this reagent. Oxide of uranium dissolves in an excess of carbonate of ammonia; the solution of it is yellow, and if concentrated it deposits abundance of crystals of ammonia-carbonate of uranium. These characters will enable the young analyst to recognise this oxide when it happens to be present in any mineral, which, however, is a rare occurrence. I shall hereafter give an example of the mode of analyzing a mineral containing this oxide.

CHAP. III.

METHOD OF DETECTING AND SEPARATING FIXED ALKALIES.

THE three fixed alkalies, *potash*, *soda*, and *lithia*, are pretty frequent ingredients of minerals, as may be seen by inspecting the table prefixed to the first part of this work. Potash was first discovered in the mineral kingdom by Klaproth, in his analysis of the *Leucite*, published in 1795. Soda was soon after detected by Dr. Kennedy in basalt, and lithia was discovered in *petalite* by Arfvedson in 1818. The two first of these are found in the mineral kingdom much more frequently than the third. Various methods have been contrived to detect and separate these bodies. We have reason to suspect their existence when, after having made an analysis of a mineral, the weight of the constituents detected comes considerably (more than 2 per cent.) short of the mineral subjected to analysis.

The method which I employ in such cases to detect and separate potash and soda, is the following:—Reduce a quantity of the mineral (25 grains for example) to powder. By a previous analysis the quantity of silica contained in this portion is known. For every grain of such silica weigh out 2·375 grains of fluor spar, previously reduced to a fine powder. Mix the fluor spar and the pounded mineral intimately in a platinum crucible, and pour upon the mixture a quantity of strong sulphuric acid sufficient to convert the whole into a pulp. Put the crucible on a sand bath, and expose it to a heat gradually raised to 400°. Then heat it to redness, and keep it red hot till the whole excess of sulphuric acid is driven off. Digest the residue in water till every thing soluble is taken up. Concentrate this aqueous solution on the sand-bath, and while it is hot add a little oxalate of ammonia to decompose a little sulphate of lime which it contains. Separate the clear liquid from the oxalate, and for the greater security add a little carbonate of ammonia to it. After the precipitate has been removed, evaporate the liquid to dryness in a platinum basin, and expose the residue to a red heat to drive off the ammoniacal salts. The matter remaining will be an alkaline sulphate.*

Dissolve this sulphate in water, and let fall into it a few drops of an alcoholic solution of chloride of platinum. If the alkali be potash a yellow coloured precipitate falls, but no precipitate will appear if the alkali be soda.

Should a precipitate appear, but indicating only a portion of the alkali and not the whole, then the conclusion to be drawn is, that the alkali in the mineral is a mixture of potash and soda. To determine how much of each is present we must proceed in the following way:—The alkaline sulphates are to be dissolved in water, and by means of chloride of barium cautiously added they are to be converted into

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* If the mineral contain magnesia, some of that substance may be present. It must be separated by the methods already detailed, before we obtain the alkaline sulphate.

chlorides. Evaporate these chlorides to dryness and determine their weight. Mix them with 3¼ times their weight of soda-muriate of platinum in crystals. Dissolve the mixture in a very small quantity of water, and evaporate to dryness in a very gentle heat, and digest the dry residue in alcohol of the specific gravity 0·896. This dissolves every thing but the potash-muriate of platinum which remains in the state of a yellow powder. Bring the undissolved portion upon a weighed filter, and wash it with weak alcohol. Dry it in a gentle heat till it ceases to lose weight. The weight of this salt gives the potash which it contains, every 26 grains of it indicating 6 grains of potash. If we convert this potash into chloride, recollecting that 6 potash is equivalent to 9½ chloride, and subtract the amount from that of the whole chloride originally weighed, the remainder gives us the chloride of sodium, from which the quantity of soda is easily determined by calculation.

Should no precipitate fall when the tincture of chloride of platinum is dropt into the solution of alkaline sulphate, we may then add a little alcohol to the solution, and set it aside for twenty-four hours. If it contains sulphate of soda, that salt will shoot out into crystals, and the shape of the crystals will readily indicate the nature of the salt.

If we suspect the alkali in the sulphate to be lithia, or to contain lithia, the easiest mode of proceeding, is to add a little sulphuric acid, so as to convert the sulphate into bisulphate. This bisulphate is to be digested in alcohol. If it be bisulphate of lithia it will be wholly dissolved, while the bisulphate of potash or of soda, should either be present, will remain undissolved. The alcoholic solution of bisulphate of lithia burns with a red coloured flame which is characteristic of this alkali.*

Evaporate the alcoholic solution to dryness, and expose it to a red heat, having previously neutralized the excess of acid by ammonia. We thus convert it into sulphate of lithia composed of

Sulphuric acid	5
Lithia .	1·75
	6·75

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* Dr. Turner has shown that the presence of lithia in a mineral may be detected by the blowpipe, by fusing it with a little alkali to set the lithia at liberty. It then *betrays itself* by giving a red tinge to the flame.

Let its weight be a, the weight of lithia which it contains is $\frac{1{\cdot}75\,a}{6{\cdot}75}$, or $\frac{7a}{27}$.

Should any doubt exist about the lithia, we may remove it by converting the sulphate into muriate. For this purpose weigh it, and add as much chloride of barium as will throw down all the sulphuric acid, on the supposition that it is sulphate of lithia. Let the weight of the sulphate of lithia be a, then $6{\cdot}75 : 13 : : a : \frac{13\,a}{6{\cdot}75} =$ the quantity of anhydrous chloride of barium required. Or if we take crystals of chloride of barium the weight will be 15·25 instead of 13, and the quantity $\frac{15{\cdot}25\,a}{6{\cdot}75}$, or $2{\cdot}44\,a$. Now filter the liquid, and let a drop of sulphate of soda fall into it. If the salt was sulphate of lithia no precipitate will fall, but if it was sulphate of soda, or contained sulphate of soda, a precipitate will still appear. Determine by cautious addition how much sulphate of soda is requisite to throw down the whole barytes which has been added in excess. If the salt was pure sulphate of soda, the quantity of sulphate of soda necessary to throw down the whole excess added, will be such that the sulphate of barytes thrown down by this second dose of sulphate of soda will form a salt weighing 0·248 of the sulphate of barytes first thrown down.

It is easy from the weight of sulphate of barytes obtained to deduce the proportion of soda and lithia in the original sulphate.

Let the weight of the alkaline sulphate be a, and let the sulphuric acid obtained be ten or two atoms. Then $a - 10 =$ alkali in sulphate $= m$.

1. $m = 4\,x + 1{\cdot}75\,y$

$x =$ atoms soda,
$y =$ atoms lithia.

2. $x + y = 2$ as the acid was 2 atoms.

$$x = \frac{m - 1{\cdot}75\,y}{4}$$

$$x = 2 - y$$

$$\frac{m - 1{\cdot}75\,y}{4} = 2 - y \text{ and } y = \frac{8 - m}{2{\cdot}25}$$

y being thus found gives us x, and the weight of the lithia in the sulphate is $1{\cdot}75\,y$, while that of the soda $4\,x$.

Muriate of lithia is a deliquescent salt. Lithia is thrown down from any of its saline solutions by means of carbonate of ammonia, in the state of a white powder.

If lithia and potash exist together in a mineral, they may be separated from each other exactly in the way by which potash and soda were separated in page 387.

Another mode of detecting an alkali in minerals, which is very frequently employed by mineralogists, is to make use of carbonate of barytes. The pulverized mineral is mixed with five or six times its weight of carbonate of barytes, and exposed to a red heat for an hour or an hour and a half in a platinum crucible. The whole is then dissolved in muriatic acid, and the silica separated in the usual way. The earths and metallic oxides (including the barytes) are then thrown down by carbonate of ammonia. The filtered liquid is evaporated, and when concentrated and hot, a little oxalate of ammonia may be added to throw down any lime which might accidentally remain in the liquid. The whole is now evaporated to dryness, and the residual salt is to be cautiously heated till the whole of the ammoniacal salt is driven off. What remains is an alkaline muriate, or a sulphate if the barytes (as is often practised) had been thrown down by sulphuric acid.*

Another method, first proposed by M. Berthier, is to mix the pounded mineral with twice its weight of nitrate of lead, and its own weight of carbonate of lead, both in the state of a fine powder. This mixture is put into a small platinum crucible covered with a lid. This crucible is enclosed in another also covered with a lid.† The crucibles are heated in an ordinary furnace, and kept red hot only for a quarter of an hour. Before it is quite cold, the crucible is reversed above water, and the fused mass by tapping the bottom is made to fall into that liquid. It falls down into numerous fragments which makes it easily attackable by acids. Boil it in nitric acid, taking care to reduce all the fragments to fine powder. Every thing is dissolved except the silica, which is separated in the usual manner. The oxide of lead is thrown down by sulphuric acid, and we ensure its complete separation

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* If the mineral contain magnesia, a portion of it might remain in the state of sulphate, as carbonate of ammonia is not a good precipitant of it. In such a case the sulphate must be weighed, and the magnesia being separated in the usual manner and weighed, we must deduct the weight of anhydrous sulphate of magnesia from the original quantity, the remainder will be the alkaline sulphate.

† All these precautions are to guard against the reduction of the lead, which would occasion the destruction of the platinum crucible.

by the addition of a little sulphuretted hydrogen. The earths and metallic oxides are then thrown down by carbonate of ammonia. The residual liquid is evaporated to dryness, and being treated as already described, the alkaline sulphates are obtained in a separate state.*

CHAP. IV.

METHOD OF DETERMINING THE ACIDS IN MINERALS.

In the preceding chapters the methods of detecting the different bases which occur in stony bodies has been pointed out. But with the exception of silica nothing has been said about the acids. By inspecting the table at the commencement of the first part of this work, it will be seen that minerals are in fact salts, composed of one or more acids in combination with one or more bases. By far the most common acid in minerals is silica, and the method of detecting and separating it has been already described. But there are at least twelve other acids which may occasionally be present, and we shall in this chapter point out the methods of detecting their presence.

To determine whether a mineral contain any acid, reduce a portion of it to powder, and fuse it either in a platinum crucible or by the blowpipe with twice its weight of carbonate of potash or carbonate of soda. Digest the fused mass in water till every thing soluble be taken up. Fusion with the carbonates of the fixed alkalies decomposes all the salts containing a fixed acid. Hence the water employed to digest the fused mass will contain an acid (if any was present) combined with the alkali employed. Saturate this alkali with acetic acid, and add to the neutral liquid a few drops of acetate or nitrate of lead. If an acid be present a white precipitate will appear.† Hence the absence of every precipitate when the salt of lead is added, is a proof that the mineral under examination contains no other acid than silica. Suppose that by this method the existence of an acid is detected, the next thing to be done is to determine what that acid is.

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[*] Ann. de Chim. et de Phys. xvii. 28.

[†] Nitric acid occasions no precipitate. The method of detecting it will be shown afterwards.

1. Fuse a portion of the alkali containing the acid on charcoal by the blowpipe, and put the fused bead in a drop of water placed on a piece of polished silver. If the acid was the *sulphuric*, a black spot of sulphuret of silver will be produced. Bright copper will also serve for the same purpose. If we place the globule of the fused salt on cudbear paper it will change its colour to purple.

If we suspect the acid to be the *muriatic* or *chlorine*, we put upon a plate of polished silver a drop of the solution of sulphated peroxide of iron, or of the sulphate of copper; into this drop we let fall a little of the alkali containing the acid in question. If it be the muriatic or chlorine, a spot of black chloride of silver will be produced.[*]

3. If the acid be the *phosphoric*, the alkali containing it, after saturation with acetic acid, gives a sulphur yellow precipitate with nitrate of silver, which no other acid does.[†]

The precipitate which it gives with lead crystallizes before the blowpipe.

Fuchs remarks that if a mineral containing phosphoric acid be reduced to powder, immersed in sulphuric acid, and then exposed to the action of the blowpipe, it will tinge the flame of a bluish-green colour. The phosphate of alumina communicates this colour without the assistance of sulphuric acid.[‡]

Berzelius gives the following method of discovering phosphoric acid in a mineral. Fuse the mineral in question with boracic acid before the blowpipe, and when the fusion is complete, plunge the end of a small steel wire, rather longer than the diameter of the globule, into it, and heat it in a good reducing flame. The iron becomes oxidized at the expense of the phosphoric acid; hence borate of iron and phosphuret of iron are produced. The latter fuses at a pretty high temperature, and at the same time the assay, which had spread itself over the whole length of the wire, resumes the globular form. As the globule cools, an appearance of ignition is generally seen near its base, arising from the crystallizing of the phosphuret of iron. Remove the globule from the charcoal, wrap it in a piece of paper, and strike it gently on the anvil

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[*] It is well known that chloride of silver is precipitated white, but it blackens on exposure to the light; but the black colour of chloride of silver produced in this way, is independent of the light.

[†] The arsenious, indeed, gives a yellow precipitate with nitrate of silver, but it can scarcely occur in stony minerals.

[‡] Schweigger's Jour., xxiv. 130.

with the hammer, to separate the phosphuret of iron, which we find in the form of a brittle metallic globule, attractable by the magnet, and having a steel-coloured fracture. Its brittleness depends upon the proportion of the iron; it may sometimes be a little flattened under the hammer. If the assay contain no phosphoric acid, the steel wire will burn only at the ends which project beyond the globule, preserving elsewhere its form and brilliancy. Since four or five per cent. of phosphoric acid are insufficient to fuse a mass of iron as large as the experiment requires, it follows that a proportion not exceeding that quantity cannot be discovered by the blowpipe.*

4. *Arsenic acid* constitutes one of the ingredients of several minerals, as may be seen by inspecting the table at the beginning of the first part of this work. The presence of this acid is easily detected, by exposing a small portion of the mineral containing it, mixed with carbonate of soda, to the reducing flame of the blowpipe on charcoal; a white smoke is exhaled, having the well known smell of arsenic.

The arseniates resemble the phosphates in almost all their properties. Like them the alkaline arseniates are soluble in water, while the arseniates of the alkaline earths, and of the earths and metallic oxides, are insoluble. A little sulphuretted hydrogen dropt into a solution of a soluble arseniate strikes a a yellow colour, and the addition of a few drops of muriatic acid occasions a yellow precipitate of sulphuret of arsenic. The insoluble arseniates are easily soluble in muriatic or nitric acid, and the solution, when acted on by sulphuretted hydrogen, gives the same yellow colour and precipitate.

Chlorides of barium and calcium, and barytes, or lime water, occasion a white precipitate when dropt into a solution of an arseniate. These solutions are soluble in nitric and muriatic acid. They dissolve also in sal ammoniac, as is the case with the same precipitates induced in the phosphates. But the arsenical precipitates are more easily dissolved in sal ammoniac than the phosphates; on the contrary, they are more difficultly soluble than the phosphates when the solution contains free ammonia.

The yellow precipitate produced in solutions of arseniates by sulphuretted hydrogen, is soluble in sulpho-hydrate of ammonia. The same thing happens with the precipitate produced by the same reagent in solutions of peroxide of tin:

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* Berzelius on the Blowpipe, p. 129.

hence it is possible that the two may be confounded by a careless experimenter.

5. The presence of *boracic* acid in minerals is indicated by the green colour which they give during fusion to the flame of the lamp or candle employed. Gay-Lussac has observed that a solution of boracic acid changes the colour of turmeric paper to red, like an alkali.* Borax, to which sulphuric acid has been put, does so; and the same holds with a bead of soda containing boracic acid.

The most certain test of boracic acid in a soda bead, &c., is to add sulphuric acid to it, and then spirit of wine, the flame of which will be coloured green if boracic acid be present.

Professor C. G. Gmelin of Tubingen, who devoted several years to the analysis of the tourmalin, has adopted the following method of separating boracic acid from those minerals which contain it. The mineral must be reduced to a fine powder, mixed and ignited with an alkaline carbonate. The ignited mass is to be digested in water to separate the alkaline which now holds the boracic acid in combination. The alkaline liquid thus obtained is to be exactly saturated with muriatic acid. Muriate of lime, and then caustic ammonia, being added to the neutral liquid, the boracic acid precipitates in combination with lime.

The quantity of boracic acid in combination with the lime may be determined in the following manner:—Expose the borate of lime to a red heat, and then ascertain its weight. Mix it with its own weight of pure fluor spar in a platinum crucible, and reduce the whole mixture to a pulp by the addition of a sufficient quantity of sulphuric acid. Digest this mixture for some time on the sand-bath, then expose it to a red heat, and keep it at that temperature till all the excess of sulphuric acid be driven off. Nothing will remain but sulphate of lime. The boracic acid having been driven off in combination with the fluoric acid, leaving the lime formerly in combination with both these acids in the state of an anhydrous sulphate.

Now 9·5 fluor spar, when decomposed by sulphuric acid, becomes 17 sulphate of lime; we can, therefore, easily find how much of the sulphate of lime obtained by our process was derived from the fluor spar. Let the weight of fluor spar

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* Ann. de Chim. et de Phys. xvi. 75.

employed $=a$. We have $9{\cdot}5 : 17 :: a : \frac{17a}{9{\cdot}5} =$ sulphate of lime derived from the fluor spar $= b$.

If we subtract b from the total weight of the sulphate of lime, the remainder ($= c$) will be the sulphate of lime derived from the borate of lime. But sulphate of lime is composed of

Sulphuric acid, . .	5
Lime, . . .	3·5
	8·5

Consequently, $8{\cdot}5 : 3{\cdot}5 :: c : \frac{3{\cdot}5\,c}{8{\cdot}5} = d =$ the weight of the lime derived from the borate of lime examined. Now, if we subtract d from the quantity of borate of lime employed in the experiment, the remainder will be the weight of boracic acid originally combined in this borate.

6. The presence of *chromic acid*, or *chromium*, in any state, is easily discovered by the yellow colour which carbonate of potash, or soda, acquires when fused with it. If this alkaline solution be saturated with acetic acid, it gives a fine orange precipitate with acetate of lead, and a red precipitate with nitrate of silver.

Chromate of potash, or soda, fused on a plate of clay, leaves green oxide of chromium.

When a mineral, or salt, containing chromic acid, is fused with borax, or biphosphate of soda, before the blowpipe on charcoal, a glass bead is obtained, of a fine emerald green colour, whether the fusion be performed by means of the outer or inner flame. This colour appears to most advantage when the bead is cold. It is obvious that if the chromic acid be in combination with a metallic oxide capable of giving a deep colour to the glass, the colour of the bead may be considerably modified. Thus, when chrome-iron ore is fused with borax, or biphosphate of soda, the characteristic colour of iron is only apparent while the assay is hot; but when, on cooling, its colour disappears, then the fine grass green of the chromium is developed.

If a chromate and a chloride be ground together, mixed with concentrated sulphuric acid, and heated, an effervescence takes place and beautiful red fumes are disengaged, constituting, when condensed, the chlorochromic acid of Dr. Thomson.

When a chromate is mixed with muriatic acid and heated, chlorine gas is disengaged, easily recognised by its smell and also by its colour. The experiment may be made in a crystal glass tube shut at one end. The muriatic acid assumes during the process, a dark green colour, because oxide of chromium is formed and dissolved.

When chromic acid exists in solution, it may be precipitated by nitrate of lead, which throws it down in the state of chromate of lead, even when the liquid contains an excess of acid. Every 20·5 grains of this chromate when dried by ignition, is equivalent to 6·5 grains of lead. Or the chromic acid is 0·317 of the weight of the chromate of lead obtained.

7. *Molybdic* acid scarcely occurs in the mineral kingdom, except in combination with oxide of lead, constituting molybdate and trismolybdate of lead.

This mineral before the blowpipe on charcoal, decrepitates and acquires a brown yellow colour, which disappears on cooling. It then fuses and is absorbed, leaving on the surface globules of reduced lead. By washing the absorbed part, we obtain a mixture of globules of lead and metallic molybdenum, which has the metallic lustre, but is neither malleable nor fusible. With borax, in the exterior flame, it fuses readily into a colourless glass. In the interior flame we obtain a transparent glass, which all of a sudden becomes dark brown and opaque. With biphosphate of soda it fuses readily, and we obtain a green glass if the quantity of molybdate be small, a black opaque glass if the quantity be considerable.

To separate the molybdic acid from oxide of lead, or indeed any oxide with which it may be combined, we must dissolve the molybdate in any acid except the nitric. To the solution an excess of ammonia is added, and the whole is digested in sulphohydrate of ammonia. The oxide is precipitated in the form of a sulphuret, while the molybdic acid is retained in solution by the sulphohydrate. The sulphurets are filtered off, and the bisulphuret of molybdenum precipitated by muriatic acid. This sulphuret contains $\frac{3}{5}$ths of its weight of molybdenum, and every 10 grains of it are equivalent to 9 grains of molybdic acid; or the molybdic acid is equivalent to $\frac{9}{10}$ths of the bisulphuret of molybdenum obtained.

The sulphuret may be converted into molybdic acid by cautious roasting and subsequent solution in caustic ammonia, from which it may be thrown down by muriatic acid.

When this acid is heated in a close vessel, it fuses, and the fused mass on cooling assumes a light yellow colour and a crystallized texture. In an open vessel it smokes and sublimes in a moderate temperature.

It is very little soluble in water, though the aqueous solution reddens litmus paper. But it dissolves readily in solutions of the fixed alkalies or of their carbonates. The solution is transparent and colourless, and the resulting salts readily soluble in water. But all the earthy and oxide salts of molybdic acid are insoluble. Hence the solution of an alkaline molybdate is precipitated by almost all the earthy or metallic acid salts.

Nitrate of lead throws down a *white* precipitate, nitrate of mercury, a *yellow*, nitrate of silver, a *white* precipitate, soluble in a great deal of water, and still easier in nitric acid or ammonia. In like manner, the salts of peroxide of iron throw down a yellow precipitate, which dissolves in a great excess of water. The chlorides of calcium and barium throw down white precipitates also soluble in much water, especially that caused by the former of the two. But if we neutralize the excess of acid present with ammonia, a precipitate appears which is not rendered soluble by adding more water.

Molybdic acid is easily soluble in acids unless it has been ignited, by which process it is rendered insoluble in most acid bodies. But if we boil a mixture of cream of tartar and ignited molybdic acid in water, a solution is obtained.

8. *Tungstic acid*, occurs in the mineral kingdom united to lime and to oxide of lead. The tungstic acid may be detected in either of these minerals, by fusing a globule of them with biphosphate of soda before the blowpipe. The tungstate of lime when so treated in the interior flame, assumes a green colour which it retains while hot, but which turns to a fine blue on cooling. With tungstate of lead treated in the same way, we obtain at once a blue glass, sometimes with a shade of green.

Tungstic acid may be separated from those oxides with which it is combined, by dissolving the salt in an acid and then adding an excess of sulphohydrate of ammonia. The base is thrown down in the state of sulphuret, but the sulphuret of tungsten remains in solution. The sulphuret of tungsten is thrown down by muriatic or nitric acid. It is washed and roasted, which converts it into tungstic acid.

The tungstic acid is separated from lime by fusing the mineral with carbonate of soda. The tungstic acid combines *with the* soda. It may be washed off and neutralized with muriatic acid added in excess. The tungstic acid precipitates and may be washed, dried, and weighed.

Tungstic acid has a yellowish colour, and when heated becomes lemon yellow. It is fixed, and does not dissolve in water, yet it reddens moist litmus paper.

It forms with the alkalies, salts which are colourless and soluble in water. After ignition it is much more difficult to dissolve it in alkalies, than it is to dissolve molybdic acid in the same state.

Acids when dropt into solutions of the alkaline tungstates occasion precipitates. Sulphuric, nitric, and muriatic acids throw down white precipitates, which are combinations of tungstic acid with the precipitating acid. Phosphoric acid throws down a precipitate soluble in an excess of phosphoric acid. Oxalic, tartaric, and citric acids, occasion no precipitates. Acetic acid throws down a precipitate which is not soluble in an excess of the acid.

The compounds of tungstic acid, with the earths and metallic oxides (tungstate of magnesia excepted) are insoluble in water. Hence it happens that the alkaline tungstates are precipitated by most of the earthy and oxide salts. Chloride of barium, chloride of calcium, nitrate of lead, and nitrate of silver, throw down white precipitates which are not re-dissolved by the addition of much water.

If we put a little alkaline tungstate, with a fragment of tin, into a drop of muriatic acid, white flocks at first make their appearance, which gradually acquire a blue tinge, and a deep blue colour surrounds the tin globule.

9. To detect the presence of *fluoric acid* is attended with considerable difficulty, and yet is very important, because this acid enters as a very frequent constituent into the composition of minerals, as may be seen by inspecting the first part of this work.

Reduce the mineral to powder, and moisten it in a watch glass with muriatic acid; let it remain a few seconds, and then rub a piece of brazil wood paper with the mixture. If fluoric acid be present, the paper assumes a fine yellow colour.* But this method does not always answer.

When fluoric acid exists in a mineral in small quantity, in

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* Bonsdorff, to whom we owe this fact, found that fluoric, phosphoric, and oxalic acids, render brazil wood paper yellow. Some of the other acids, when dilute, give a yellow tinge to this paper, but less lively, and much more slowly.

combination with a weak base and a minute portion of water, we have only to put a little of it into a tube closed at one end, and having a small slip of paper suspended in it, moistened with the infusion of brazil wood. Heat being applied, disengages fluosilicic acid, an unpolished ring of silica makes its appearance on the glass at a little distance from the assay, and the lower end of the paper becomes yellow.

If the mineral contain a great deal of fluoric acid, let it be mixed with biphosphate of soda, previously fused and put into an inclined open tube, near the lower end, so that a part of the current of air which feeds the flame may enter the tube. Heat the mixture by means of a spirit lamp. Fluoric acid vapour is formed, which fills the tube, and may be distinguished both by its peculiar odour, and by its corroding the glass, which becomes dull through its whole length, and particularly in those places where the vapour condenses.

To determine the quantity of fluoric acid, or fluorine, in a mineral, composed of fluorine and a metal, as in fluor spar, the best method is to reduce a determinate weight of the mineral to powder, and to make it into a paste with concentrated sulphuric acid in a platinum crucible. Heat is then applied and gradually raised to ignition. When the whole fluoric acid, and the excess of sulphuric acid, has been driven off, nothing remains but a sulphate of lime. From the weight of this sulphate the weight of the calcium which it contains is easily deduced, and subtracting this weight from that of the original mineral employed the remainder gives the fluorine in the mineral.

10. *Iodic acid* and *hydriodic acid* have scarcely yet been found in the mineral kingdom. They may be detected when they do occur by the following method:—Fuse oxide of copper with biphosphate of soda into a dark green globule, then add the assay, and heat the whole before the blowpipe. The flame (if the acids be present) is coloured with a *superb deep green*, quite different from the pale green communicated by boracic acid.

When the same process is followed with a muriate, the flame has a fine *blue inclining to purple.*

Most of the compounds formed by iodic acid with bases, except the alkaline iodates, are insoluble, or very sparingly soluble in water. When an iodate is heated in a small retort, oxygen is given out, and the iodate is converted into an *iodide.*

When an iodide is heated with concentrated sulphuric acid in a glass tube closed at one end, it gives out iodine, which fills the cold part of the tube, and is easily recognised by its violet colour. This process conducted in a porcelain vessel, will enable us to determine the quantity of iodine disengaged. The iodide is converted into a sulphate combined with the oxide of the base. The quantity of this oxide, and consequently the weight of the base in the iodide may be determined, and this weight, subtracted from that of the original iodide, gives the weight of iodine disengaged.

11. Neither *selenic* nor *selenious* acid has hitherto been met with in the mineral kingdom. Should a selenite, or seleniate, or a seleniet, occur, it is easy to recognise the presence of selenium in them by the blowpipe. For when such a compound is heated before the blowpipe in the reducing flame, it emits an exceedingly strong odour of decayed horse radish. By this odour a very minute quantity of selenium may be detected.

When selenium is contained in a solution, as selenious acid, the best way of determining its quantity is by means of sulphurous acid. We first acidulate the liquid by adding some muriatic acid, then a solution of sulphite of ammonia is mixed with it. The selenium precipitates in the form of a cinnabar red powder which remains long suspended. But if the liquid be made to boil, the selenium unites into a very small bulk, and becomes black. If the addition of a fresh portion of sulphite of ammonia occasions no farther precipitation, we may conclude that the whole selenium is thrown down. We have then only to collect and wash it on a weighed filter, in order to determine its weight.

If nitric acid exist in a solution containing selenious acid, the selenium cannot be precipitated till the whole of that acid is destroyed. To accomplish this, place the solution on the sand bath, and add muriatic acid as long as chlorine continues to be disengaged. When the nitric acid has been destroyed in this way, we may proceed as above directed to separate the selenium.

12. *Nitric acid* is not a frequent ingredient in the mineral kingdom. It exists however in a few salts, as nitrate of soda and nitrate of potash. All fusible nitrates detonate with charcoal. Those which do not fuse are to be heated till they are rendered quite dry, and then being put into a glass tube shut at one end, they are to be gradually raised to a red heat.

The tube soon becomes filled with the orange yellow vapour of nitric acid.*

CHAP. V.

METHOD OF DETERMINING THE WEIGHT OF THE FIXED CONSTITUENTS OF STONY MINERALS.

Since the introduction of the atomic theory into chemistry, the number of individuals who have occupied themselves with the analysis of minerals has become very considerable, and it has sometimes happened that persons little accustomed to precise experiments have deceived themselves by the application of this theory to inaccurate results. It is necessary to be on our guard against this mode of proceeding, and never to attempt to determine the atomic constituents of a mineral till we are quite sure of the accuracy of our results, both as regards the nature and quantity of each constituent. We should also be at great pains in selecting our specimens for analysis. How accurate soever our experiments may be, we can deduce no valuable consequences from them, if the specimens selected for analysis were impure, or consisted of more than one mineral species mechanically mixed together. The specimens selected for analysis should be quite pure, and if possible in crystals.

Klaproth, to whose labours we are chiefly indebted for contriving and systematizing the methods of analyzing minerals, usually subjected 100 grains of the mineral to experiment; but now that our apparatus is simplified and improved, and our methods brought to precision, we can obtain exact results though we analyze a much smaller quantity. By employing a small quantity of mineral for analysis instead of a large, we save a good deal of time and expense, both of which, to the practical chemist, are objects of considerable importance. When the mineral is free from combined water, and other volatile matter, 20 grains of it are sufficient for an exact analysis, provided its constituents be substances with whose

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* The reader will find some good observations on the method of detecting acids by Smithson, in the *Annals of Philosophy* (second series), v. 385. And in Berzelius on the Blowpipe, p. 125.

properties we are already familiar. When the water or volatile matter amounts to between ten and twenty per cent., we should employ 25 or 30 grains of it. When we employ 50 or 100 grains, the process is more tedious, and the results scarcely so much to be depended on. Mr. Smithson, who was a very accurate experimenter, never employed more than 10 grains, and he assured me that when he took a greater quantity he could not rely so much upon his results. Berzelius, the accuracy of whose analyses is sufficiently known to chemists, employs from 1 to 2 grammes; that is, from 15·4 to 30·8 grains.

I have already explained the method of separating the silica, which is so general a constituent of stony minerals. After the filter containing it has been washed till the water ceases to be affected by nitrate of silver, it is to be placed between two folds of blotting paper, and dried in a temperature of at least 212°. As much of the dry silica as possible is taken off the filter, put into a platinum crucible, ignited, and weighed. The filter, with what silica may still adhere to it, is burnt in a platinum crucible, and the weight of the residual ashes ascertained.

A given weight of the filtering paper employed must have been previously burned, and the weight of the ashes left ascertained. Thus, 40 grains of the filtering paper which I employ at present, when burnt leave 0·165 grains of ashes. The weight of the filter employed having been determined before we began to use it, the ashes which it would leave are known by an easy calculation, and deducting this weight from the ashes left when the filter was burnt, we have the weight of the silica which adhered to it. This portion being added to the former quantity of silica, weighed separately, we have obviously the whole silica contained in the mineral.

Some attention is necessary in weighing a filter, because it is apt to vary something in weight according to the moisture or dryness of the atmosphere. I employ a glass tube of such a size as to contain the filter easily. One end is shut with a slip of cork, the surface of which is covered with sealing-wax; to the other end a cork, the outer end of which is also coated with sealing-wax, is fitted. This tube, with its corks, is weighed, and the weight marked upon it with a diamond. The filter to be weighed is rendered as dry as possible, by heating it before the fire, and when still warm it is enclosed in the tube and weighed, deducting from the whole weight that of the tube in which the filter is enclosed.

In some cases, as in weighing sulphur, iodine and selenium, which cannot be ignited, it is requisite to cut two filters of the same size, from the same sheet of filtering paper. These two filters are balanced against each other, and made of equal weights, by cutting small portions from the one which of the two is heaviest. When the sulphur, &c., contained on the filter is to be determined, the two filters are dried in a gentle heat, and then put into opposite scales, the additional weight necessary to counterpoise the filter containing the sulphur gives us the weight of the filter. When this method is pursued with the requisite care, it gives results very near the truth.

It is proper to wash the filters before using them, by steeping them for some time in water, acidulated by nitric or muriatic acid. Our filtering paper made in Great Britain generally contains a little lime, which is removed by these acids. I think it likely that this lime is introduced by the chloride of lime employed in bleaching the rags, of which the paper is made. The quantity is very small, but in general quite sensible.

After the silica has been separated, its purity must always be tested by the rules already laid down.

It remains now to separate the substances held in solution by the muriatic acid. As the processes necessarily vary according to the substances to be separated, and as a general method applicable to all would be too complicated for use, the best way of communicating the requisite information seems to be to give different examples of the analyses of minerals differently constituted.

I. *Minerals soluble at once in Muriatic Acid.*

There are a considerable number of minerals which, when reduced to powder, and digested in muriatic acid, undergo decomposition. In many the silica exists in such quantity that when the acid is concentrated, the whole is speedily converted into a jelly. The following minerals are decomposed and gelatinize with muriatic acid:—

1. Natrolite,
2. Mesolite,
3. Scolezite,
4. Lomonite,
5. Chabazite,
6. Levyine,

7. Comptonite,
8. Analcime,
9. Potash harmatome,
10. Apophyllite,
11. Leucite,
12. Elœolite,
13. Sodalite,
14. Hauyne,
15. Cronstedtite,
16. Ilvaite,
17. Gehlenite,
18. Scapolite or Meionite,
19. Table spar,
20. Nepheline,
21. Gadolinite,
22. Allophane,
23. Helvine,
24. Datholite,
25. Botryolite,
26. Lazulite,
27. Eudyalite,
28. Orthite,
29. Silicate of zinc,
30. Dioptase,
31. Meerschaum.

The following minerals are decomposed by muriatic acid, but do not gelatinize with it:—

32. Stilbite,
33. Heulandite,
34. Anorthite,
35. Silicate of copper,
36. Sphene,
37. Pyrosmalite,
38. Cerite,
39. Allanite,
40. Pitchblende, or pitch-ore.

Most of these minerals, though not the whole of them, withstand the action of acids, after having been ignited. Probably other minerals may exist besides those above named, which are decomposed by muriatic acid, but the preceding are those that have been tried with sufficient accuracy.

To the above list might have been added all the carbonates, but the action of muriatic acid upon them must be so obvious to every person, that I thought it unnecessary to include them in the list.

EXAMPLE I.

Analysis of Carbonate of Strontian, from Strontian.

The method of determining the quantity of carbonic acid in a mineral is the following:—Procure a small Wolfe's bottle, with two mouths; one of these mouths has a ground crystal stopper fitted to it; into the other a bent glass tube filled with fragments of chloride of calcium is luted. Put into the bottle the requisite quantity of nitric acid, sufficiently diluted with water to act as a good solvent of the carbonate; then balance the bottle, with all its appendages, and note down the weight. Take out the glass stopper, and introduce as speedily as possible 100 grains of the carbonate to be analyzed, not in powder, but in fragments. Replace the stopper, and allow the bottle to remain till the whole carbonate has dissolved, and till the carbonic acid has had time to make its escape from the bottle; for this purpose I generally allow an interval of twenty-four hours. Now weigh the bottle again, putting into the opposite scale not only the original counterpoise, but also the weight of the carbonate employed. The amount of weight necessary to balance the bottle again will represent the weight of the carbonic acid that has made its escape. If the carbonate of strontian were perfectly pure, the loss of weight would be 29·73 grains from the 100, and it usually approaches that number pretty nearly.

Evaporate the solution of strontian till the salt crystallizes, and till all the excess of acid is driven off; then re-dissolve in water. Almost always a little black powder remains, consisting of earthy matter, which I suppose to have been mechanically mixed with the carbonate, for it cannot be observed before the solution. Its weight never exceeds, in well-selected specimens, 0·2 or 0·3 grain.

The crystals of nitrate of strontian obtained are usually tinged slightly yellow, and when the solution of them is mixed with caustic ammonia red flocks separate, consisting of peroxide of iron, sometimes though very rarely slightly mixed with alumina. These flocks may be collected in a weighed filter, and the weight determined by burning the filter in the way formerly described.

The solution thus freed from iron is crystallized again, and the crystals are exposed in a platinum crucible to a heat sufficient to drive off and decompose the nitrate of ammonia, but not to injure the nitrate of strontian, and the quantity of nitrate of strontian in this anhydrous state is determined. It is then digested in absolute alcohol, which dissolves any nitrate of lime that may be present, but leaves untouched the nitrate of strontian. By weighing the residual nitrate of strontian we determine the loss of weight, and consequently the quantity of nitrate of lime dissolved. By evaporating the alcoholic solution we get the nitrate of lime, which deliquesces when exposed to the air. The nitrate of strontian indicates the quantity of strontian, as it is a compound of

Nitric acid	6·75
Strontian	6·5
	13·25

Hence $\frac{6 \cdot 5}{132 \cdot 5}$, or 0·49 of the nitrate of strontian is the weight of the strontian.

In general, the carbonate of lime in the green carbonate from Strontian amounts to about 6¼ per cent. That in the brown carbonate is greater.

EXAMPLE II.

Analysis of Scolezite.

Scolezite is a compound of water, silica, alumina, and lime. The method of analysis is abundantly simple.

1. Expose 25 grains of it to a red heat in a covered platinum crucible, it assumes the appearance of porcelain, and loses at an average about 3·375 of water, making about 13·5 per cent.

2. 25 grains of the mineral are reduced to powder, and digested with muriatic acid in a platinum basin. In a few minutes the mineral dissolves, and very speedily assumes the form of a jelly. Evaporate to dryness by a gentle heat, taking care with a platinum spoon to scrape the matter from the bottom, that it may not be exposed to a decomposing heat. When all smell of muriatic acid is gone, pour upon it water acidulated with muriatic acid, and allow it to digest upon the sand-bath for half an hour. Then throw the whole upon a filter previously weighed. The silica is retained by the filter. It must be washed in the way already described, and when dry ignited in a platinum crucible and weighed. What remains attached to the filter is determined by burning the filter in the way formerly explained. The amount of the ignited silica is about 11·625, or 46·5 per cent.

The silica if pure ought to be perfectly white, and it ought to melt with effervescence with carbonate of soda into a transparent colourless glass.

3. The liquid freed from silica, together with all the washings of the silica, is to be concentrated by evaporation till it is reduced to about ten cubic inches. It is then to be nearly neutralized by carbonate of ammonia, stirring the whole well after each addition, in order to drive off the carbonic acid. Into the liquid thus nearly, but not quite, neutralized, pour caustic ammonia in slight excess, or till the liquid smells distinctly of ammonia. The alumina and oxide of iron (should any be present) are thrown down, while the lime

remains in solution. Separate the alumina upon a weighed filter, and wash it carefully with distilled water till every thing soluble is carried off. This is known to be the case when the liquid which passes through the filter is not affected by nitrate of silver. Then dry the filter containing the alumina, take off as much of the alumina as possible, heat it to redness, and weigh it. By burning the filter the quantity left on the paper is determined, and it must be added to the quantity ignited and weighed by itself. The weight of the alumina should be about 6·425, or 25·7 per cent.

4. To determine whether it be pure alumina, put that portion which had been ignited into a flask, and boil it with muriatic acid. The whole will dissolve except a few flocks of silica, the quantity of which will be the smaller, the more care was taken to dry the original solution before the silica was removed. In general its weight does not amount to 0·1 grain, and sometimes it is not more than 0·02, or 0·01 grain.

The muriatic solution is evaporated nearly, but not quite to dryness, to get rid of the excess of muriatic acid. It is then mixed with a considerable excess of caustic potash, or soda, till the precipitate which at first appears, be re-dissolved. If the alumina be pure the whole will re-dissolve in the caustic alkaline ley. In general a mere trace of oxide of iron remains, too little to admit of being weighed. But should the scolezite be impure the quantity of iron may be greater. Should it amount to an appreciable quantity, let it be collected on a balanced filter, washed and dried, and its weight determined by burning the filter. I never saw a specimen of scolezite in which the peroxide of iron from 25 grains of the mineral, amounted to so much as 0·01 grain.

Should any doubt be entertained whether the alumina be really alumina, or whether it may not be rather glucina, take a small particle of it, moisten it with solution of nitrate of cobalt, and expose it to a red heat before the blowpipe. If the substance be alumina it will assume a deep and fine blue colour, but this will not be the case if it was glucina.

5. The ammoniacal liquid from which the alumina had been separated is to be saturated with muriatic acid, and concentrated on the sand-bath to ten cubic inches. While still hot, it is to be mixed with oxalate of ammonia till all the lime is thrown down. The oxalate of lime is collected on a weighed filter, and washed till the liquid which passes through ceases to be affected by nitrate of silver. It is then dried, and as much

of the oxalate of lime as possible is put into a platinum crucible, and exposed to a red heat. The oxalic acid is decomposed, and the lime converted into carbonate. Mixed with this carbonate of lime there is a little charry matter which renders the colour grey. But if the heat has been raised to ignition, this charcoal just compensates for a little carbonic acid driven off, so that the whole of it may be estimated as carbonate of lime. What remains on the filter is determined by burning the filter, and from the weight of its ashes deducting that of the weight of the ashes of the filter supposed clean. From the whole carbonate of lime obtained, it is easy to deduce the lime. For carbonate of lime is composed of

Carbonic acid, . .	2·75
Lime, . . .	3·5
	6·25

Let the weight of the carbonate of lime be *a*, the lime which it contains is $\frac{3{\cdot}5a}{6{\cdot}25}$, or $0{\cdot}56a$. It will be found on an average to amount to 3·55 grains.

6. The liquid from which the lime was precipitated may be tested for magnesia. But as scolezite contains none of that alkaline earth, none of course would be found.

Having finished the analysis, the next step is to collect all the constituents found together, and observe whether their weight amounts to as much as that of the mineral analyzed. In the present case we have

Water, . . .	3·375
Silica, . . .	11·625
Alumina, . .	6·425
Lime, . . .	3·550
	24·975

The quantity of mineral employed was 25 grains, and the weight of the constituents obtained 24·975 grains. So that the two numbers agree as nearly as can be expected in such an analysis. Had the loss amounted to 1 or 2 grains, there would be a presumption that the mineral contained an alkali, which would require to be sought for by the methods indicated in the next example.

EXAMPLE III.

Analysis of Natrolite.

The constituents of natrolite are water, silica, alumina, soda, and sometimes a little oxide of iron. The method of proceeding is almost the same as in the last example.

1. The water, the silica, the alumina, and the oxide of iron, are separated precisely as in the case of scolezite.

2. The liquid remaining after the separation of the alumina may be tested for lime and magnesia, but none will be found. Let it be evaporated to dryness, and the residual salt being put into a platinum crucible, let it be heated almost to ignition till all the ammoniacal salts are driven off. Care should be taken not to fuse the matter in the crucible, because when that is the case a portion is apt to be driven out of the crucible and lost. What remains (if the processes have been conducted with the requisite care) is common salt. Let it be weighed and then dissolved in a little water. Into the concentrated solution let fall a few drops of an alcoholic solution of chloride of platinum. No precipitate will fall, showing that the alkali in the salt is soda. Every seven and a half grains of common salt are equivalent to 4 grains of soda. Let the weight of common salt obtained be a, the soda is equal to $\frac{4a}{7{\cdot}5}$, or $0{\cdot}533a$. If we have employed 25 grains of natrolite in the analysis, we shall obtain at an average about 7·855 grains of common salt, equivalent to 4·19 grains of soda, or 16·76 per cent.

EXAMPLE IV.

Analysis of Ilvaite.

This mineral contains five ingredients; namely, silica, alumina, protoxide of iron, protoxide of manganese, and water.

1. When ilvaite is heated to incipient ignition, it gives out water. The mineral by this treatment assumes a shining black colour, and becomes attracted by the magnet, which is not the case with it before this roasting. 25 grains of ilvaite give out at a medium, about 0·317 grain of water, which makes the water in this mineral to amount to 1·268 per cent.

2. When 25 grains of ilvaite, in the state of fine powder, are digested in muriatic acid, a solution is soon effected, and the whole is speedily converted into a jelly. The solution is

evaporated to dryness, and the residue digested in water acidulated with muriatic acid, and thrown on a weighed filter in order to separate the silica. It is washed, dried, ignited, and weighed, exactly in the way already described. The quantity of silica from 25 grains of ilvaite, is at an average about 7·319 grains, which is equivalent to 29·276 per cent.

3. To peroxidize the iron which constitutes so great a proportion of ilvaite, a little nitric acid is added, and the liquid is digested for some time. The peroxide of iron, together with the alumina, are then precipitated by dropping bicarbonate of soda into the cold liquid. The precipitate, while still moist, is digested with caustic potash ley to dissolve off the alumina. The peroxide of iron is then collected on the filter, washed, dried, ignited, and weighed. From 25 grains of ilvaite, we obtain 14·595 grains, equivalent to 13·1355 grains protoxide, or 52·542 per cent. For 10 parts of peroxide of iron are equivalent to 9 parts of protoxide.

4. Sal ammoniac being poured into the potash ley which had been digested over the peroxide of iron, a quantity of alumina falls, which after being washed, dried, and ignited, weighs at an average 0·1535 grain, or 0·614 per cent.

5. The liquid (No. 3) from which the iron had been precipitated, still retains lime and oxide of manganese in solution. It is raised to a boiling temperature, and completely precipitated by carbonate of soda. The precipitate is washed and dried, and exposed in an open vessel to a temperature sufficiently high to expel the carbonic acid from the lime, and convert the manganese into black oxide. From this mixture dilute nitric acid dissolved out almost all the lime, leaving the oxide of manganese, still contaminated with a little lime. This residue is again exposed to a red heat, and afterwards digested in dilute nitric acid, which dissolves out all the lime, and leaves the manganese in the state of sesquioxide, every 5 grains of which are equivalent to 4·5 grains of protoxide of manganese. The average quantity of sesquioxide of manganese from 25 grains of ilvaite, is 0·441, equivalent to 0·397 grain of protoxide, which amounts to 1·587 per cent.

6. The lime is precipitated from the nitric acid solution by neutralizing it with carbonate of soda, raising it to the boiling temperature, and throwing it down in the state of carbonate of lime. The average weight of carbonate of lime from 25 grains of ilvaite, is 6·15 grains, equivalent to 3·444 grains of lime, which amounts to 13·776 per cent.

Having thus finished the analysis, we must collect all the ingredients, and see whether their weights correspond with the weight of the mineral analyzed. We have,

Water, . . .	0·317
Silica, . . .	7·319
Protoxide of iron, .	13·1355
Alumina, . . .	0·1535
Protoxide of manganese,	0·3970
Lime, . . .	3·4440
	24·766

The loss being only 0·234, or less than one per cent., we conclude that the analysis has been rightly conducted, and none of the constituents overlooked.

EXAMPLE V.

Analysis of Eudyalite.

The constituents of this mineral, which was first analyzed by Stromeyer, are silica, zirconia, lime, soda, peroxide of iron, protoxide of manganese, muriatic acid, and water.

1. The quantity of water is determined in the usual way by ignition in a platinum crucible. 25 grains of the mineral lose, at an average, 0·45 grain, or about 1·8 per cent.

2. Being reduced to a fine powder, it is to be digested in muriatic acid. It speedily gelatinizes. Being evaporated to dryness, and the residue digested in water acidulated with muriatic acid, the silica is to be separated in the way already explained. 25 grains of the mineral yield, at an average, 13·331 grains of silica, or 53·325 per cent.

2. The liquid thus freed from silica, is neutralized as exactly as possible with ammonia, and then mixed with succinate or benzoate of ammonia. The precipitate is separated, washed, dried, and ignited, in a covered crucible. It is then fully calcined in an open vessel. In this state it is a mixture of peroxide of iron and zirconia. It is weighed and then digested in muriatic acid. The peroxide of iron is dissolved, and the zirconia left behind is washed and dried. The peroxide of iron from 25 grains of eudyalite, weighs at an average 1·69 grains, or 6·754 per cent. The zirconia remaining behind, weighs at an average 2·775 grains, or 11·1 per cent.

3. The liquid thus deprived of its iron and zirconia, is treated with sulpho-hydrate of ammonia to throw down the

manganese. The precipitate thus obtained, is dissolved in nitric acid, and the manganese again precipitated by means of carbonate of soda. The precipitate after being washed, dried, and ignited, is red oxide of manganese, every 4·833 grains of which is equivalent to 4·5 grains of protoxide of manganese, or the protoxide is equal to 0·931 of the red oxide obtained. The quantity of protoxide from 25 grains of the mineral, amounts at an average to 0·515 grain, or 2·062 per cent.

4. The liquid thus freed from manganese, is mixed with oxalate of ammonia to throw down the lime. The oxalate of lime is treated as already explained, aud the weight of lime deduced from it by the rules formerly laid down. 25 grains of eudyalite yield at an average 2·446 grains of lime, or 9·785 per cent.

5. The residual liquid is now evaporated to dryness, and the dry residue exposed to heat in a platinum crucible to drive off the ammoniacal salts. The saline matter remaining is dissolved in water. A little platinum derived from the crucible sometimes remains behind. The solution being treated with oxalate of ammonia, a little oxalate of lime is separated, the lime of which is included in the preceding estimate. When the carbonate of lime obtained from this oxalate is dissolved in nitric acid, a few flocks of red oxide of manganese generally remain undissolved.

6. The saline solution is again evaporated to dryness, and the residual salt ignited. It is now weighed and then dissolved in water. A very minute quantity of carbonate of lime may remain behind. The solution being sufficiently concentrated, crystallizes in cubes, which have all the properties of common salt. From the weight of this common salt, that of the soda contained in the mineral may be deduced. It amounts to 3·455 grains from 25 of eudyalite, or to 13·822 per cent.

7. To determine the amount of muriatic acid which eudyalite contains, a quantity of the mineral in powder may be digested with nitric acid, in a close vessel till it gelatinizes. The silica is then separated by the filter, and the nitric acid liquid is treated with nitrate of silver. A precipitate of chloride of silver falls, which is separated by the filter, washed, dried, and fused upon a piece of glass. From the weight of this chloride, it is easy to deduce the weight of muriatic acid in the mineral. For 18·25 grains of chloride of silver are

equivalent to 4·625 grains of muriatic acid. Let the weight of chloride of silver be a, the muriatic acid $= \frac{4·625a}{18·25}$ or $= 0·253a$. The muriatic acid from 25 grains of eudyalite, amounted to 0·258 grain, equivalent to 1·034 per cent.

The constituents of eudyalite obtained by the preceding analysis, being collected, amount to

Water, . . .	0·450
Silica, . . .	13·331
Peroxide of iron, . .	1·688
Zirconia, . . .	2·775
Protoxide of manganese,	0·515
Lime, . . .	2·446
Soda, . . .	3·455
Muriatic acid, . .	0·258
	24·918

Here the loss does not exceed 0·328 per cent., a quantity so small, that we may conclude that no constituent has been overlooked.

Example VI.

Analysis of Orthite.

This mineral contains, like the preceding, no fewer than six different constituents; namely, lime, alumina, yttria, protoxide of iron, protoxide of manganese, and oxide of cerium.

1. The mineral being reduced to powder, 25 grains of it are to be dissolved in aqua regia, and the silica separated and estimated by the methods already described.

2. The acid solution, together with the washings of the silica, are concentrated to the bulk of about 10 cubic inches. Caustic ammonia being added in slight excess, every thing is thrown down except the lime, which still remains in solution. The liquid being poured into a cylindrical glass vessel, is covered with a glass plate, and left at rest to allow the precipitate to sink to the bottom, while at the same time, the carbonic acid of the atmosphere is prevented from having access to the ammonia, which would occasion a precipitate of carbonate of lime. The clear liquid is then drawn off with a sucker, and the sediment being diluted with hot water, is thrown upon a balanced filter. The filter and its contents are washed with distilled boiling hot water, in the way already described, till the precipitate is perfectly clean.

3. The water thus employed to wash the filter, together with the portion drawn off with a sucker, is concentrated to about 10 cubic inches, neutralized with muriatic acid, and then precipitated while hot with oxalate of ammonia. The oxalate of lime thrown down is collected on a weighed filter, washed and ignited. It indicates the quantity of carbonate of lime, from which the pure lime is to be deduced by the method already explained.

4. The precipitate collected on the filter (in No. 2) is put into a flask while still moist, and boiled for a couple of hours in a caustic ley of potash or soda. By this process the alumina is dissolved, while the other constituents remain unacted upon.

As it is impossible to take the whole precipitate off the filter, we must proceed as follows:—We remove as much as we can conveniently, without injuring the texture of the filter. We then put the filter into a porcelain dish, and pour over it water acidulated with muriatic acid. If we leave the filter for some time in this liquid, the whole remainder of the precipitate will be dissolved. The solution being neutralized, is poured into the flask containing the potash ley and the rest of the precipitate. The filter is to be washed with a little distilled water, which is poured also into the ley. Care must be taken not to injure the texture of the filter, nor to convert any of it into pulp. Should such pulp appear, it is best to get rid of it by passing the muriatic solution through a filter, taking care to concentrate it sufficiently before pouring it into the flask.

To know whether the muriatic liquor (supposing we do not saturate it) may not saturate too much of the potash, let a drop of muriatic acid be let fall into the ley. A precipitate will at first appear, but it will dissolve again upon the least agitation of the liquid, if the potash present be in sufficient quantity. Should this precipitate not dissolve again, it is a sign that the quantity of potash employed is too small. In that case, the portion of precipitate not dissolved in the ley, must be again digested in a new portion of potash ley.

5. The alkaline ley having thus taken up the alumina, is drawn off, and the undissolved matter washed clean upon a filter, taking care to add the washings to the potash ley, and to concentrate till the bulk be reduced to a convenient quantity for use. Then sal ammoniac being added in sufficient quantity to saturate the alkali with muriatic acid, the alumina

is precipitated. It is collected on a double filter, washed with hot water, dried, ignited, and weighed.

The alumina obtained in this way is almost always mixed with a little silica. To separate this portion, the alumina is boiled in a flask with muriatic acid till every thing soluble be taken up; the white residue remaining is the silica, which must be separated, washed, ignited, and weighed, and its weight added to that of the silica previously obtained.

When the alumina constitutes the greatest part of the matter thrown down by the ammonia, the best method of proceeding is this:—After washing the precipitate, dry it and expose it to a red heat.* Let it then be dissolved by digestion in muriatic acid; the silica remains undissolved. To the solution add a sufficient quantity of caustic potash or soda; the alumina will be retained in solution, but the other constituents will be thrown down. Let the undissolved portion be collected, washed, dried, and ignited. Its weight deducted from that of the original quantity of ignited precipitate, gives the true quantity of alumina which the mineral contains. This mode of proceeding is advantageous, because alumina is bulky and difficult to wash, and consequently occupies a good deal of time; we save a troublesome washing, and are thus enabled to finish the analysis in a shorter time. But we must be careful to ascertain, before having recourse to it, that no other constituent be present besides alumina, which is soluble in caustic potash ley.

6. The matter not dissolved by the potash still remains to be examined. It is a mixture of yttria, oxide of cerium, oxide of iron, and oxide of manganese. It is dissolved in muriatic acid, and into the solution a crust of sulphate of potash is put, of such a size that it rises up higher than the surface of the liquid, and it is left in this state for twenty-four hours, to give the liquid time to be saturated with the salt. As oxide of cerium has the property of forming a compound salt with sulphate of potash, which is insoluble in a saturated solution of sulphate of potash (no matter whether any uncombined acid be present or not), it will be all precipitated in the

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* The portion that adheres to the filter is determined by burning the filter, and allowance must be made for that portion when the precipitate is analyzed. Suppose the portion of the precipitate ignited to be 10 grains, and the portion which remains in the filter to weigh 0·2 grain. It is obvious that we must augment the weight of each constituent found, by a *fiftieth part*, to allow for the portion lost on the filter.

state of this compound salt. The clear liquid is drawn off, and the white precipitate is washed with water saturated with sulphate of potash, till it is clean. It is then dissolved in water, and the oxide of cerium precipitated by caustic potash or soda. If we precipitate it by ammonia, the oxide of cerium still retains sulphuric acid. The precipitate is collected on a filter, washed, dried, and ignited. It is now peroxide of cerium.

The atom of peroxide of cerium weighs 7, and that of protoxide 6·5. Let the weight of peroxide obtained be a, the weight of protoxide of cerium corresponding is $\frac{6{\cdot}5\,a}{7}$, or $0{\cdot}9286a$.

7. The liquid thus freed from oxide of cerium is rendered as neutral as possible by ammonia, and then benzoate of ammonia is added in sufficient quantity to throw down the whole of the peroxide of iron which it contains. The precipitate after being washed, dried, and ignited in an open crucible is peroxide of iron, the weight of which must be determined.

If we dry the benzoate of iron in a temperature not under 212°, it is anhydrous, and when weighed in that state one-fourth of its weight indicates the quantity of peroxide of iron which it contains.

It is necessary, in order to throw down iron by benzoate of ammonia, that the metal should be in the state of peroxide. This is accomplished by adding a few drops of nitric acid to the liquid before it is neutralized by ammonia, and digesting it for some time on the sand-bath.

If the liquid be not completely neutralized by ammonia, the benzoate of ammonia will still throw down the peroxide of iron. But we cannot wash the precipitate with pure water, because that liquid would dissolve a little of it, and acquire a red colour. In such a case we must wash the precipitate with water, holding salammoniac in solution, because the presence of that salt prevents the water from dissolving benzoate of iron, even when there is a slight excess of acid present.

The iron in the mineral was in the state of protoxide, but by the above process we obtained it in the state of peroxide. Now the atom of protoxide of iron is 4·5, and that of peroxide 5. Hence the protoxide amounts to nine-tenths of the corresponding quantity of peroxide.

If succinate of ammonia be employed instead of benzoate, the process is the same. In this country the high price of succinic acid precludes its employment in chemical analyses.

8. Nothing now remained in the liquid but yttria and protoxide of manganese. Ammonia being added, the yttria is precipitated, while the oxide of manganese remains in solution in the state of a double ammoniacal salt. The yttria being collected on a filter, washed, dried, and ignited, the amount of its weight is determined.

9. To the liquid now freed from every thing except oxide of manganese, an excess of carbonate of soda is to be added, and the whole evaporated to dryness, to drive off the ammonia. The dry residue being digested in water, every thing dissolves except the carbonate of manganese. It is washed, dried, moistened with nitric acid, and heated to incipient ignition. It is now sesquioxide of manganese, the atom of which weighs 5, while that of protoxide weighs 4·5. Hence the protoxide constitutes nine-tenths of the sesquioxide obtained.

When oxide of manganese is exposed to a strong red heat, its colour becomes reddish brown. In this state it is a compound of one atom protoxide and two atoms sesquioxide of manganese. Its atom weighs 4·833. In this case to find the amount of protoxide from that of the red oxide, we say

$$4·833 : 4·5 : : a \ (= \text{weight of red oxide}) : \frac{4·5a}{4·833}, \text{ or } 0·931a.$$

Another mode of separating yttria from oxide of manganese is to add carbonate of soda to the liquid containing both, and then to evaporate the whole to dryness. When the dry residue is washed with water, a mixture of yttria and carbonate of manganese remains. If we digest this mixture while still moist, in a large quantity of carbonate of ammonia, the yttria will be dissolved, while the oxide of manganese will be left behind. By boiling the ammoniacal liquid we throw down the yttria, which is collected, washed and determined as before explained. The oxide of manganese is treated exactly as has just been described.

The constituents thus obtained are now to be collected, and it will be found that they nearly amount to the weight of the mineral analyzed. Hence it may be inferred that no constituent has been overlooked.

II. *Minerals requiring to be heated with Carbonate of Soda.*

The preceding examples are sufficient to enable the young analyst to analyze those minerals which dissolve in muriatic acid. The remaining stony bodies, in order to become soluble in muriatic acid, require to be reduced to a fine powder, to be intimately mixed with twice or thrice their weight of anhydrous carbonate of soda, and to be ignited for an hour in a platinum crucible. The following table exhibits the names of some of the most remarkable minerals that require this treatment:—

1. Felspar.
2. Albite,
3. Petalite,
4. Spodumene,
5. Labradorite,
6. Andaluzite,
7. Barytes harmotome,
8. Chrysolite,
9. Prehnite,
10. Mica,
11. Lepidolite,
12. Talc,
13. Chlorite,
14. Pinite,
15. Achmite,
16. Amphibole,
17. Pyroxene,
18. Anthophyllite,
19. Diallage,
20. Epidote,
21. Idocrase,
22. Garnet,
23. Dichroite,
24. Staurolite,
25. Emerald,
26. Euclase,
27. Tourmalin,
28. Axinite,
29. Topaz,
30. Chondrodite,
31. Picrosmine,
32. Carpholite,
33. Steatite,
34. Serpentine,
35. Nacrite,
36. Obsidian,
37. Pitchstone,
38. Bytownite,
39. Plinthite,
40. Schiller spar,
41. Hyperstene,
42. Retinalite,
43. Bucholzite,
44. Cyanite,
45. Zoisite,
46. Hydrolite.

I shall give examples of the mode of analyzing these minerals, according to their constituents.

EXAMPLE I.

Analysis of Albite.

The constituents of this mineral are silica, alumina, and soda, with a very little lime, and peroxide of iron. It differs from felspar merely in containing soda instead of potash, which is the constituent in felspar.

This mineral containing an alkali, and being insoluble in muriatic acid, we may adopt the following process for ascertaining its constituents:—

1. Let 25 grains of it in the state of fine powder be intimately mixed with four times its weight of nitrate of barytes, in a platinum crucible, and the mixture exposed for two hours to a strong red heat. The fused mass is to be dissolved in muriatic acid, and the silica separated in the way already described. It will amount, at an average, to 17·669 grains.

2. The remaining liquid freed from silica is to be concentrated to a manageable quantity, and mixed with sulphate of ammonia, to throw down the barytes. The sulphate of barytes must be separated by the filter, and the liquid, reduced to a manageable quantity, is to be heated to the boiling point, and mixed with carbonate of ammonia in excess, which will throw down the alumina, together with the lime and oxide of iron.

3. The liquid thus freed from every thing except the alkali is to be evaporated to dryness, and the residual matter heated to drive off the ammoniacal salts. A small quantity of saline matter remains, which after fusion is to be dissolved in water and evaporated. It will yield cubic crystals to the very last drop, having all the properties of common salt, and will not be precipitated either by an alcoholic solution of chloride of platinum, or by tartaric acid. It weighs at an average 4·245 grains, indicating 2·264 grains of soda, or 9·056 per cent.

From the method employed to throw down the barytes it may happen that the common salt may be mixed with a little sulphate of soda. To determine this point the common salt obtained must be dissolved in water, and the solution tested by chloride of barium. The precipitate, if any fall, must be collected, washed, ignited, and weighed. Let it weigh a, the sulphuric acid in it will be $\frac{5a}{14\cdot5}$, or $\frac{a}{2\cdot9}$, or $0\cdot3448a$. The soda united to this sulphuric acid will be $\frac{4a}{14\cdot5}$, or $0\cdot2758a$. This gives us the weight of the sulphate of soda present $= 0\cdot6206a$. This quantity must be subtracted from the common salt. We must determine the soda equivalent to the remainder, and adding to this the soda in the sulphate, we obtain the whole soda in the mineral.

3. The precipitated alumina, with the lime and oxide of iron, are to be dissolved in a little muriatic acid, and the solution neutralized and mixed with caustic ammonia in slight

excess. The alumina and oxide of iron will be precipitated, while the lime remains in solution.

4. Let the liquid containing the lime be precipitated hot with oxalate of ammonia, and let the precipitate be collected, washed, dried, and ignited. It is carbonate of lime, weighing at an average 0·105 grain, indicating 0·059 grain of lime, or 0·235 per cent.

4. Let the precipitated alumina, &c., while still moist, be digested in caustic potash ley; the whole will dissolve, except a minute quantity of reddish-brown matter. This matter being tested will be found to be peroxide of iron, with a slight trace of protoxide of manganese; the weight is only about 0·028 grain, or 0·111 per cent. To analyze with accuracy so minute a quantity of matter is impossible, but the quantity of manganese in it may barely be made appreciable by the blowpipe.

5. The potash ley may now be mixed with sal ammoniac. The alumina will be precipitated. Let it be washed, dried, ignited, and weighed: its weight at an average amounts to 4·95 grains, or 19·801 per cent. Being digested in muriatic acid, it generally leaves a minute quantity of silica, which is to be estimated and added to the weight of the silica originally found, while its amount is to be subtracted from the alumina.

Having finished the analysis, we collect as usual all the constituents together, that we may see their amount.

Silica, . . .	17·669
Soda, ...	2·264
Alumina, . . .	4·950
Lime, . . .	0·059
Peroxide of iron, .	0·028
	24·970

As the quantity nearly coincides with the weight of the mineral employed, we may consider it as certain that we have not omitted any of the constituents.

EXAMPLE II.

Analysis of Garnet.

There is a variety of minerals at present confounded together under the name of garnet; but the kind of garnet which I employ here as an example is the dark red variety, having a specific gravity of 4·236. Its constituents are silica, alumina, protoxide of iron, and protoxide of manganese.

1. 25 grains of this garnet, reduced to a fine powder, are to be mixed with thrice their weight of anhydrous carbonate of soda, and exposed to a red heat for an hour and a half in a platinum crucible. The matter, if melted, will have assumed a dark green colour. It must be dissolved in muriatic acid, and the solution evaporated to dryness. The dry residue being digested for an hour in water acidulated with muriatic acid, the whole is thrown on a weighed filter, and the silica which remains upon the filter must be washed, dried, ignited, and weighed. It amounts, on an average, to 9·965 grains, or 39·86 per cent.

2. The liquid from which the silica had been separated is to be concentrated to a manageable quantity, and then mixed with caustic ammonia in slight excess. The mixture may be allowed to remain for half an hour in a covered vessel to give time to the precipitate to subside. It is then to be collected on a filter, washed, dried, ignited, and weighed. Being again dissolved in muriatic acid, a little silica will remain behind, which is to be separated and weighed.

3. The solution is now to be mixed with a great excess of caustic soda, and boiled for some time that all the alumina may be dissolved. The undissolved portion is then separated by the filter, washed, dried, ignited, and weighed. Its weight, together with that of the silica (in No. 2.) being subtracted from the original weight of the ignited precipitate, will give the weight of the alumina dissolved by the caustic soda ley. It amounts at an average to 4·915 grains, or 19·66 per cent.

4. The oxide of iron, &c., (of No. 3.) is to be dissolved in a boiling heat in aqua regia. A little silica remains behind, which must be separated, washed, dried, ignited, and weighed. Its weight is to be added to that of the silica obtained in No. 1.

5. The solution being neutralized as nearly as possible with caustic ammonia, the peroxide of iron is to be thrown down by benzoate of ammonia. The precipitate, washed with cold water, and afterwards with water containing a little ammonia, is to be heated to redness and weighed. The weight at an average amounts to 11·02 grains, equivalent to 9·92 grains of protoxide of iron, or 39·68 per cent.

6. The liquid thus freed from iron is to be mixed with carbonate of soda in excess, and evaporated to dryness. The

residue being digested in water to dissolve the saline constituents, a quantity of white matter remains, which becomes brown by ignition, and is the red oxide of manganese, together with a very minute portion of silica, and a trace of lime. Its weight at an average amounts to 0·456 grain, equivalent to 0·425 grain of protoxide, or 1·7 per cent.

We now as usual collect all the constituents together.

Silica, ...	9·965
Alumina, ...	4·915
Protoxide of iron, . .	9·920
Protoxide of manganese, .	0·425
	25·225

In this case the constituents rather surpass the original weight of the mineral. We may be satisfied, therefore, that no constituent has been overlooked.

EXAMPLE III.

Analysis of Hornblende.

The constituents of this mineral are numerous; namely, silica, magnesia, lime, protoxide of iron, alumina, protoxide of manganese, fluoric acid, and water. As it contains magnesia as a constituent, several precautions are necessary in order to obtain that substance in a state of purity. It has a great tendency to form double salts, and from this it happens that we are apt to get the magnesia contaminated with some foreign matter which increases its quantity beyond the truth, so that in analyzing magnesia minerals we often obtain a greater weight when we add the constituents together, than the amount of the whole mineral submitted to analysis. To put the young analyst on his guard against these mistakes, it will be requisite to enter somewhat into detail. The present example will show the general method of managing minerals which contain magnesia as a constituent.

1. The mineral reduced to a fine powder, is to be mixed with three times its weight of anhydrous carbonate of soda, and exposed for an hour to a red heat in a platinum crucible. The matter whether it has been fused or only made to cohere by the heat, is to be dissolved in muriatic acid. In general a few white flocks remain undissolved, easily distinguished by their lightness from the undecomposed powder of the mineral.

2. The muriatic acid solution is evaporated to dryness, care

being taken to make the heat equable, and to break all the little knots that may remain, that every portion of the residue may be equally dried. The dry residue is then mixed with water acidulated with muriatic acid, and allowed to digest for an hour. The whole is then thrown on a weighed filter, and the silica washed, dried, ignited, and weighed.

3. The liquid thus freed from silica, is precipitated by caustic ammonia, taking care to add as small an excess as possible, lest a portion of the alumina should be kept in solution. The precipitate is to be collected on a weighed filter, washed with hot water, put while still moist into a caustic soda ley, and boiled in it for an hour in order to dissolve the alumina. Or, instead of this, we may ignite the precipitate and dissolve it in muriatic acid. A little silica will remain, which is separated, washed, ignited, and weighed. The solution is mixed with an excess of potash or soda ley, boiled with it an hour, and then what remains undissolved, is separated from the alkaline ley by the filter.

4. The alkaline liquid (of No. 3.) is saturated with muriatic acid, added in such quantity, that the alumina at first thrown down is re-dissolved. It is then thrown down by carbonate of ammonia. The alumina is collected on a filter, washed with hot water, dried, ignited, and weighed. If it be dissolved in dilute sulphuric acid, a little silica usually remains behind; and if to the solution sulphate of potash or sulphate of ammonia be added, crystals of alum are gradually deposited.

5. The portion of the precipitate (of No. 3.) not dissolved by boiling it in an alkaline ley, is dissolved in muriatic acid, a little nitric acid is added, and the whole boiled a little while to peroxidize the iron. The solution is diluted with water, neutralized by caustic ammonia, and precipitated by succinate or benzoate of ammonia. The iron is thrown down in the state of peroxide, and in combination with the acid of the salt employed as a precipitant. The benzoate of iron must be collected in a filter, washed with cold water, dried, and ignited. The acid is dissipated and pure peroxide of iron remains, provided the ignition has been continued long enough in an open vessel. From the weight of peroxide of iron thus obtained, that of the protoxide of iron, which is the state in which iron exists in hornblende, is easily deduced by the method already explained at full length in a preceding example.

6. The liquid thus freed from iron, may be tested by the addition of a little carbonate of ammonia, to see whether it

may not still retain a trace of alumina, which may have escaped the action of the alkaline ley. Should any precipitate appear, it must be separated, washed, dried, and ignited, and its weight added to that of the alumina already obtained. What liquid remains after these processes, may be added to the liquid No. 2., from which the alumina and iron have been thrown down by means of caustic ammonia.

7. The liquid of No. 2. contains still the lime, magnesia, and oxide of manganese. It must be heated to drive off all the excess of caustic ammonia which it contains. It is then diluted with hot water and precipitated by oxalate of ammonia. When the oxalate ceases to produce any more effect, the oxalate of lime is collected on the filter, washed, dried, and ignited. It is converted into carbonate of lime, from which the lime contained in the mineral is to be deduced in the way already explained.

For greater security, we may saturate the lime with sulphuric acid, and after igniting the sulphate of lime, determine its weight. Supposing the sulphate anhydrous, as it is rendered by ignition, every $8\frac{1}{2}$ grains of it contain 3·5 grains of lime. Let the weight of sulphate be a, the lime contained in it is $\frac{3{\cdot}5a}{8{\cdot}5}$ or $0{\cdot}412a$.

8. The liquid thus freed from lime is to be evaporated, but to prevent the precipitation of any oxalate of magnesia during the evaporation, which would happen if an excess of oxalate of ammonia had been added, a few drops of muriatic acid is added to it. The concentrated solution is mixed with carbonate of soda, added at first cautiously, till the sal ammoniac in the liquid is decomposed and its ammoniac driven off, then more carbonate of soda is added, the liquid being kept boiling hot till the magnesia is precipitated. These precautions are requisite to prevent the double magnesian salt from forming. The employment of carbonate of soda instead of carbonate of potash, has also a tendency to prevent the formation of the double salt, for soda-carbonate of magnesia does not form nearly so readily as potash-carbonate.

When the precipitated magnesia concretes together into a heavy, fine, granular powder, we may conclude that it is all precipitated and that no double salt is present. We may then collect it on the filter. But when it is bulky and light like alumina, we must not attempt to filter, but continue the boiling. To make it certain that all the magnesia is thrown down, the best way is to evaporate to dryness, taking care to stir the mixture from the bottom with a glass rod, to prevent the matter from agglutinating together. The dry residue is digested in hot water. The carbonated magnesia is now collected on a filter and washed. The process of washing is easy, not requiring more than half an hour. It is now to be dried, ignited strongly, to drive off the carbonic acid, and weighed. If we dissolve the magnesia thus obtained in muriatic acid or dilute sulphuric acid, a little silica usually remains undissolved.

9. The solution neutralized by ammonia, is mixed with a little sulphohydrate of ammonia, to throw down the oxide of manganese. The precipitated manganese is dissolved in muriatic acid, filtered, precipitated by carbonate of soda at a boiling temperature, washed, dried, ignited, and weighed. It is in the state of red oxide, every 4·833 grains of which are equivalent to 4·5 grains of protoxide of manganese.

10. The solution thus freed from manganese, is heated to drive off the sulphuretted hydrogen, saturated with sulphuric acid and evaporated to dryness. By dissolving the residual salt in water, we satisfy ourselves whether any lime has remained united to the magnesia. Should any gypsum remain, it must be separated, washed with a little water applied at intervals, dried, ignited, and weighed. The lime contained in it amounts to $\frac{3\cdot5}{8\cdot5}$ or 0·412 of the whole gypsum.

This portion of lime, together with the small quantity of silica and oxide of manganese obtained, being subtracted from the whole weight of the precipitate, the remainder gives the quantity of magnesia contained in the mineral.

It deserves attention, that the silica obtained when the precipitated magnesia is dissolved in sulphuric acid, however carefully washed, and though its weight is not greater than when the magnesia has been dissolved in muriatic acid, possesses however some peculiar properties. It is more bulky and seems composed of scales, coheres together before the blowpipe, and gives a light blue colour when heated with nitrate of cobalt. Bonsdorff, to whom we owe these observations, examined this silica with the utmost care, and could find nothing in it except a trace of lime, so small as not to be capable of being appreciated.* This singular variety of silica

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* Köng. Vet. Acad. Handl., 1821, p. 205.

always occurs whenever the magnesia from a mineral holding magnesia is dissolved in sulphuric acid.

11. To determine the quantity of water in the mineral, a given weight of it is exposed to a red heat in a platinum crucible for a quarter of an hour. A spirit lamp may be very conveniently employed for this trial. If we now expose the same portion of mineral to a white heat for half an hour, it will be found to lose an additional weight, amounting in hornblende, generally to from half a per cent. to 3 per cent.*

EXAMPLE IV.

Analysis of Emerald.

The constituents of this mineral are silica, alumina, glucina, oxide of iron, and according to Vauquelin, oxide of chromium, and according to Berzelius, columbic acid.

1. 25 grains of it in the state of fine powder are well mixed with thrice their weight of carbonate of soda, and heated for an hour in a platinum crucible. Towards the end of the process I usually raise the heat sufficiently high to fuse the mixture. The fused mass is digested in dilute muriatic acid, which dissolves every thing except a few flocks of silica. The solution is gradually evaporated to dryness in a porcelain dish, and the dry residue being digested for an hour in dilute muriatic acid, the silica is collected on a filter, and its quantity determined in the way already described.

2. The liquid which has passed through the filter being concentrated to a manageable quantity, and almost neutralized with carbonate of ammonia, taking care to agitate well in order to expel the whole carbonic acid, is then precipitated by caustic ammonia.

3. The precipitate, while still moist, is put into a bottle with a crystal stopper, and a large quantity of solution of carbonate of ammonia being poured over it, the whole is well agitated, and the bottle left for twenty-four hours, agitating occasionally during the interval. The undissolved portion being allowed to subside, the clear solution is drawn off by a sucker, and an additional quantity of carbonate of ammonia being poured into the bottle, the whole is well agitated and left for twenty-four hours more, agitating

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* The reader will find an excellent set of directions for analyzing magnesian minerals, in Bonsdorff's paper on Amphibole. Kōng. Vet. Acad. Handl., 1821, p. 197.

occasionally during that interval. The whole is now to be poured upon a filter, and the residue washed with solution of carbonate of ammonia till every thing soluble is removed.

4. The carbonate of ammonia solution contains the glucina. This earth is precipitated by boiling the liquid in a glass flask till the excess of ammonia is driven off. As the liquid could not be free from muriatic acid, it may be proper to add a few drops of caustic ammonia, in case the muriatic acid may have taken up any of the glucina, in order in that case to throw it down again. The precipitated glucina is collected on the filter, washed, dried, ignited, and weighed.

5. It will be proper to examine the glucina thus obtained, in order to ascertain its purity, or whether it be really glucina.

(1.) Pure glucina has a white colour, and is tasteless and insoluble in water. But it dissolves in acids, even after ignition, though not without difficulty. The saturated acid solutions of glucina have a sweet taste.

(2.) No acid occasions a precipitate when poured into a solution of a glucina salt.

(3.) When potash ley is poured into a solution of glucina, a bulky precipitate falls, which is completely dissolved in an excess of potash. If to this solution containing potash and re-dissolved glucina you add sal ammoniac, the glucina is again precipitated.

(4.) Ammonia produces in solutions of glucina a bulky precipitate, which does not re-dissolve in an excess of ammonia. The presence of sal ammoniac in this solution does not prevent the appearance of the precipitate.

(5.) Carbonate of potash throws down a bulky precipitate from solutions of glucina, which is re-dissolved by an excess of the precipitant.

Carbonate of soda, carbonate of ammonia, and the bicarbonates of these alkalies, and of potash, act precisely in the same way.

(6.) Phosphate of soda throws down a bulky precipitate from solutions of glucina.

(7.) Oxalate of ammonia occasions no precipitate.

(8.) When potash is added to a solution of glucina containing an excess of sulphuric acid, no crystals of alum are produced.

(9.) Prussiate of potash occasions no precipitate.

(10.) Sulphohydrate of ammonia throws down a precipitate in neutral solutions of glucina, which is soluble in solutions of potash.

But sulphuretted hydrogen gas occasions no precipitate.

(11.) Litmus paper is reddened by neutral solutions of glucina.

(12.) The salts of glucina in general are decomposed by a red heat.

(13.) Many of the salts of glucina are insoluble in water.

(14.) When glucina, moistened with nitrate of cobalt, is heated before the blowpipe it does not become blue, but dark grey or black.

6. When the glucina obtained in the above described mode was dissolved in muriatic acid in Berzelius' analysis a small portion of white matter remained which had the following properties:—

(1.) When heated before the blowpipe with carbonate of soda it did not form a glass.

(2.) With borax it fused into a transparent glass, which by flaming became milk white.

From these two characters he concluded that the substance was columbic acid. But the evidence seems hardly sufficient to determine its identity with that acid.

7. The undissolved portion of No. 3., collected on the filter is to be dried, ignited, and weighed. It is then dissolved in muriatic acid, and the solution mixed with potash ley in great excess. This alkali dissolves the alumina which is at first precipitated, and leaves peroxide of iron, which is to be separated, washed, dried, ignited, and weighed. Its weight being subtracted from that of the whole precipitate dissolved in the muriatic acid gives that of the alumina.

8. Vauquelin, in his analysis of the emerald of Peru, found no oxide of iron but oxide of chromium. After separating the silica, he added caustic potash in great excess to the solution. It re-dissolved the glucina and alumina at first thrown down, but precipitated a lilac-coloured powder, which became green before the blowpipe; and when fused with borax or biphosphate of soda, it gave a fine green glass quite similar in colour to the emerald. When boiled with nitric acid to dryness, and potash poured upon the residue, a lemon-yellow coloured solution was obtained, which being mixed with a solution of nitrate of lead, gave a fine yellow precipitate, and with nitrate of mercury, a red precipitate.* From these

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* Jour. des Mines, vii. 94.

occasionally during that interval. The whole is now to be poured upon a filter, and the residue washed with solution of carbonate of ammonia till every thing soluble is removed.

4. The carbonate of ammonia solution contains the glucina. This earth is precipitated by boiling the liquid in a glass flask till the excess of ammonia is driven off. As the liquid could not be free from muriatic acid, it may be proper to add a few drops of caustic ammonia, in case the muriatic acid may have taken up any of the glucina, in order in that case to throw it down again. The precipitated glucina is collected on the filter, washed, dried, ignited, and weighed.

5. It will be proper to examine the glucina thus obtained, in order to ascertain its purity, or whether it be really glucina.

(1.) Pure glucina has a white colour, and is tasteless and insoluble in water. But it dissolves in acids, even after ignition, though not without difficulty. The saturated acid solutions of glucina have a sweet taste.

(2.) No acid occasions a precipitate when poured into a solution of a glucina salt.

(3.) When potash ley is poured into a solution of glucina, a bulky precipitate falls, which is completely dissolved in an excess of potash. If to this solution containing potash and re-dissolved glucina you add sal ammoniac, the glucina is again precipitated.

(4.) Ammonia produces in solutions of glucina a bulky precipitate, which does not re-dissolve in an excess of ammonia. The presence of sal ammoniac in this solution does not prevent the appearance of the precipitate.

(5.) Carbonate of potash throws down a bulky precipitate from solutions of glucina, which is re-dissolved by an excess of the precipitant.

Carbonate of soda, carbonate of ammonia, and the bicarbonates of these alkalies, and of potash, act precisely in the same way.

(6.) Phosphate of soda throws down a bulky precipitate from solutions of glucina.

(7.) Oxalate of ammonia occasions no precipitate.

(8.) When potash is added to a solution of glucina containing an excess of sulphuric acid, no crystals of alum are produced.

(9.) Prussiate of potash occasions no precipitate.

(10.) Sulphohydrate of ammonia throws down a precipitate in neutral solutions of glucina, which is soluble in solutions of potash.

But sulphuretted hydrogen gas occasions no precipitate.

(11.) Litmus paper is reddened by neutral solutions of glucina.

(12.) The salts of glucina in general are decomposed by a red heat.

(13.) Many of the salts of glucina are insoluble in water.

(14.) When glucina, moistened with nitrate of cobalt, is heated before the blowpipe it does not become blue, but dark grey or black.

6. When the glucina obtained in the above described mode was dissolved in muriatic acid in Berzelius' analysis a small portion of white matter remained which had the following properties:—

(1.) When heated before the blowpipe with carbonate of soda it did not form a glass.

(2.) With borax it fused into a transparent glass, which by flaming became milk white.

From these two characters he concluded that the substance was columbic acid. But the evidence seems hardly sufficient to determine its identity with that acid.

7. The undissolved portion of No. 3., collected on the filter is to be dried, ignited, and weighed. It is then dissolved in muriatic acid, and the solution mixed with potash ley in great excess. This alkali dissolves the alumina which is at first precipitated, and leaves peroxide of iron, which is to be separated, washed, dried, ignited, and weighed. Its weight being subtracted from that of the whole precipitate dissolved in the muriatic acid gives that of the alumina.

8. Vauquelin, in his analysis of the emerald of Peru, found no oxide of iron but oxide of chromium. After separating the silica, he added caustic potash in great excess to the solution. It re-dissolved the glucina and alumina at first thrown down, but precipitated a lilac-coloured powder, which became green before the blowpipe; and when fused with borax or biphosphate of soda, it gave a fine green glass quite similar in colour to the emerald. When boiled with nitric acid to dryness, and potash poured upon the residue, a lemon-yellow coloured solution was obtained, which being mixed with a solution of nitrate of lead, gave a fine yellow precipitate, and with nitrate of mercury, a red precipitate.* From these

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* Jour. des Mines, vii. 94.

properties there could be no doubt that the matter was oxide of chromium.

EXAMPLE V.

Analysis of the Topaz.

This mineral is a compound of silica, alumina, and fluoric acid. No good method of determining the weight of fluoric acid has been hitherto discovered. In the third example I described the method employed by Bonsdorff; in this I shall give the way in which Berzelius attempted to determine it.

1. The topaz, reduced to a fine powder, is to be mixed with four times its weight of anhydrous carbonate of soda, and exposed for an hour in a platinum crucible to a strong red heat. From the matter thus treated, the alkali is to be washed off completely, and dissolved in water, so that nothing remains but a white powder. Berzelius was of opinion that the alkaline solution would contain the whole fluoric acid. But as it might contain also a little silica and some alumina, carbonate of ammonia was added to it as long as any precipitate fell. The precipitate being separated by the filter, the liquid was slowly concentrated by placing it in a warm place to drive off the excess of ammonia. During this concentration a little more earthy matter fell.

2. The white powder of No. 1. not dissolved in water, together with the portion separated from the alkaline solution, was collected on a filter and well washed. It was then dissolved in dilute muriatic acid. The solution, which was complete, was evaporated to dryness, and the dry residue being digested for some time in dilute muriatic acid, the silica was collected on a filter and treated in the way already described.

3. From the liquid thus freed from silica, and rendered previously nearly neutral by carbonate of ammonia, the alumina was precipitated by caustic ammonia. It was washed, dried, ignited, and weighed. Being dissolved in muriatic acid, it left no silica behind. We see from this, that when the original solution is evaporated, and the residue made sufficiently dry, the silica may be rendered quite insoluble. This is a case which never occurred to me in any of my analyses, though I am always at considerable pains in drying the residue. But I state it, that the reader may see the possibility of rendering the silica insoluble in muriatic acid.

4. The carbonate of soda solution, containing the fluoric acid, was evaporated in a silver basin till its quantity was reduced sufficiently to make it convenient for examination. It was then saturated with muriatic acid, and left for twenty-four hours in a temperature of 86°, to give time for the carbonic acid to escape. The liquid was then raised to the boiling temperature, and neutralized with caustic ammonia, added slightly in excess. It was then put into a flask, mixed with a solution of muriate of lime, and the vessel being corked as quickly as possible, it was left to become clear. The clear liquid was drawn off, and a new portion of boiled water added. It was again left to become clear, and the fluor spar produced by mixture of the muriate of lime with the fluate of soda was collected on the filter, washed, dried, and ignited. To this substance a little muriatic acid was added to ascertain whether any carbonate of lime was mixed with the fluor spar.

From the weight of fluor spar thus obtained, it was easy to determine the quantity of fluoric acid contained in the mineral. For fluor spar is a compound of

Fluorine, . . .	2·25
Calcium, . . .	2·5
	4·75

So that every 4·75 grains of fluor spar are equivalent to 2·25 grains of fluorine, or 2·375 grains of fluoric acid. Or if we multiply the fluor spar obtained by 0·474, we obtain the weight of fluorine.

This method of Berzelius is probably capable of considerable exactness, when the mineral containing fluoric acid is free from lime, as is the case with the topaz. But when lime is present it is obvious that the fluoric acid must be in combination with the lime, and carbonate of soda does not seem capable of decomposing fluor spar completely.

Klaproth's method of determining the quantity of fluoric acid in the topaz was nearly the same as that of Berzelius. The liquid from which the silica and alumina had been separated was neutralized by nitric acid, evaporated to a small quantity, and then mixed with lime water. Fluor spar precipitated, from the quantity of which he deduced the weight of fluoric acid in the mineral.*

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* Beiträge, iv. 176.

EXAMPLE VI.

Analysis of Chrysoberyl.

The constituents of this mineral are silica, glucina, alumina, and protoxide of iron. Seybert detected a little oxide of titanium in the specimens which he analyzed, but I could detect none of that substance in the chrysoberyls from Brazil which I examined, though I repeated the analysis three times, and Dr. Thomas Muir, at my request, made a fourth analysis of the same mineral, with the same object in view.

1. The chrysoberyl reduced to the finest possible powder is mixed with four times its weight of anhydrous carbonate of soda, and the mixture exposed to a strong red heat for at least an hour in a platinum crucible.* The mixture was dissolved in muriatic acid. In general a portion of the mineral remains undecomposed. It is best to pound it again, and mixing it with four times its weight of carbonate of soda, repeat the ignition for at least an hour. The mixture is again treated with muriatic acid. By three or four repetitions of these processes (always pounding the undecomposed residue) I succeeded in obtaining a complete solution of the chrysoberyl in muriatic acid.

2. The muriatic solution is evaporated to dryness, and the silica separated in the way already described. The quantity found by Seybert varied from 4 to 6 per cent., but in my analysis I got no silica whatever.†

2. The muriatic acid solution freed from silica (should any be present) is reduced to a quantity sufficiently small for conveniently experimenting on; it is then precipitated by caustic ammonia, and the whole is left at rest in a stoppered bottle till the precipitate has subsided to the bottom. The clear liquid is then drawn off by a sucker, and the bottle filled up with a solution of carbonate of ammonia; the mixture is to be well shaken and left for twenty-four hours, agitating it occasionally. The carbonate of ammonia is then to be drawn off, and a new portion poured on, and treated in the same way. Thus the glucina is dissolved in the carbonate

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* Caustic potash has been commonly used for rendering chrysoberyl soluble in muriatic acid, but I found that carbonate of soda answered the purpose when the chrysoberyl was sufficiently pounded.

† The portion of silica which I obtained was just equivalent to what had been rubbed off the agate mortar during the pounding of the mineral.

of ammonia, while the alumina and oxide of iron remains undissolved.

3. The alumina and oxide of iron being thoroughly washed are to be dissolved in muriatic acid, and the solution mixed with potash ley in great excess. Alumina is kept in solution, while the peroxide of iron remains undissolved. This peroxide is then to be separated, washed, ignited, and weighed.

4. The potash solution of alumina is mixed with sal ammoniac, which throws down the alumina. It is collected on a balanced filter, washed with hot water, dried, ignited, and weighed.

5. Mr. Seybert, in his analysis of chrysoberyl, employed caustic potash to render the mineral soluble in muriatic acid. After four successive fusions with caustic potash, 0·17 of the quantity originally employed remained unacted on, and was not diminished by a subsequent fusion; he therefore had recourse to nitrate of barytes. Six parts of this salt were mixed with one part of the undecomposed residue. By four successive operations, the residue was reduced to $\frac{1}{100}$th part of the original quantity of chrysoberyl employed.

This matter was not acted on by alkalies or acids, when used separately, but after having been previously calcined with caustic potash, it readily dissolved in muriatic acid, yielding a solution of a pale yellow colour, which gave a reddish precipitate with infusion of galls, a deep green precipitate with sulphohydrate of potash, and a white precipitate with alkalies. From these properties he considered it as titanic acid.*

Example VII.

Analysis of Red Tourmalin, or Rubellite.

The constituents of this mineral are, boracic acid, silica, alumina, protoxide of iron, protoxide of manganese, lime, potash, lithia, and water. It is therefore a very complex substance. But the method of separating all the constituents, except the boracic acid and the lithia, has been given in the preceding examples.

1. The method employed by M. C. G. Gmelin to estimate the boracic acid, is the following:—The tourmalin reduced to a fine powder, is mixed with carbonate of barytes in the requisite quantity, and exposed in a platinum crucible to a

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* Silliman's Jour., viii. 108.

strong red heat for an hour and a half. The matter thus treated, is dissolved in muriatic acid, and the acid solution evaporated to dryness in a gentle heat. If the evaporation be conducted on the water bath, the portion of boracic acid which is driven off is quite inconsiderable. From this dry residue, the silica is to be separated in the usual way.

The residual liquid is to be precipitated by carbonate of ammonia, separated by the filter from the precipitated matter, evaporated to dryness, and the residual salt heated to incipient redness. No boracic acid can be driven off by this treatment, because that acid is in combination with ammonia, and because, during the heating no acid vapour escapes, as happens when sulphate of ammonia is treated in the same manner. The weight of the residue, after ignition, is to be carefully determined. It is then to be drenched with alcohol containing a little muriatic acid, and the alcohol is to be set on fire. This operation is to be repeated as long as the alcoholic flame shows the least tinge of green. In this way all the boracic acid which existed in the salt, under the form of borate of ammonia, is driven off. The residue is ignited again and weighed. The difference between the weight before and after the burning of the alcohol, gives the weight of the boracic acid thus given off.*

A better mode of determining the quantity of boracic acid in such a residue, would be to mix it with the requisite quantity of fluor spar and sulphuric acid, and then to raise the temperature gradually to ignition. The boracic acid would be driven off in the state of fluoboric gas, and the loss of weight would indicate its quantity. The amount of the sulphate of lime from the fluor spar could easily be estimated. The difficulty would be to determine the quantity of sulphuric acid which had united with the other ingredients in the matter under examination. But it might be determined by dissolving that residue (except the sulphate of lime) in muriatic acid, throwing down the sulphuric acid by muriate of barytes, and determining its quantity from the weight of the sulphate of barytes. Every 14·5 grains of sulphate indicating 5 grains of sulphuric acid.

Dr. Turner, some years ago, pointed out a very easy method of discovering the presence of boracic acid in minerals by means of the blowpipe. Mix the assay in powder

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* Poggendorff [illegible] n, ix. 175.

with a flux composed of one part of pulverized fluor spar and four and a half parts of bisulphate of potash. The mixture moistened with a little water is attached to the extremity of a platinum wire, and exposed to the apex of the inner plane. Shortly after the fusion there appears a green colour round the flame, which soon disappears however, and is not again seen.*

The mode of separating lithia practised by C. G. Gmelin has been given in a former part of this work, and need not be repeated here.

When no other alkali but lithia exists in a mineral, the lithia may be obtained in the state of a sulphate by fusing the mineral with carbonate of barytes, separating the silica and the barytes in the way already explained: precipitating all the earthy matter from the residual liquid, filtrating, evaporating to dryness, and exposing the residual salt to heat to drive off the ammoniacal salts. The residual salt being mixed with sulphate of ammonia and ignited, nothing remains but sulphate of lithia.

When a mineral contains only a small quantity of lithia mixed with potash, or soda, or both together, Berzelius has proposed the following method of separating the lithia:—To the solution containing these alkalies add some phosphoric acid, and also a quantity of phosphate of soda, and then evaporate the whole to dryness. When the concentration has advanced to a certain point, the liquid becomes muddy, and when the dry residue is dissolved in water a white powder remains. It is the lithia-phosphate of soda. It is insoluble in a strong solution of phosphate of soda. Let it be collected in a filter, and washed with a little cold water. Dry this salt, expose it to a red heat, and weigh it. Every 100 grains of it are equivalent to 11·86 grains of lithia. The soda contained in it is equivalent to 27·12 per cent. This method will not succeed for a very obvious reason, if the solution contains any base whatever besides the alkalies. From phosphates of lime or magnesia, it may be distinguished by the blowpipe. If we mix it with carbonate of soda, and fuse it on platinum foil, it forms a transparent mass, which on cooling becomes opaque, whereas the earthy salts do not fuse at all.

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* Poggendorff's Annalen, vi. 490.

EXAMPLE VIII.

Analysis of Zircon.

When this mineral is pure it contains nothing but silica and zirconia. It is very difficult to decompose it so as to render it soluble in muriatic acid. I have succeeded by means of carbonate of soda, but the process is difficult, and requires too many repetitions to be advisable. The objection to the caustic alkaline hydrates is the ease with which they melt when heated. The consequence is, that when the crucible containing the mixture is put into the fire, its contents speedily fuse, boil, sputter up, and a portion is very apt to be lost. We succeed pretty well in preventing any such loss by covering the crucible with a close lid. But in that case it should be so small that the whole crucible, lid and all, may be exposed to a strong heat, otherwise a portion of the zircon escapes decomposition.

Berzelius adopted the following method, which is easy of execution:—Mix the zircon powder with thrice its weight of carbonate of soda, putting it in so that a hollow portion remains in the central part. Expose it for a quarter of an hour to incipient ignition, taking care not to fuse the mixture. Then put a quantity of hydrate of soda equal to the weight of the zircon into the central hollow, replace the crucible in the fire, and heat it slowly. The hydrate as it fuses is absorbed by the mixture. The consequence is, that it gives out its water slowly, and without sputtering. Raise the temperature to a white heat, and keep the mixture in that heat for half an hour. The fused mass is colourless if the zircon was pure, and the crucible when the process is conducted in this way is not acted upon.*

The whole is now dissolved in muriatic acid, and the solution treated as before described, in order to separate and obtain the silica. The liquid thus freed from silica is neutralized, and the zirconia thrown down by ammonia. It is washed, dried, ignited, and weighed.

Should the zircon contain iron, as is often the case, it is exceedingly difficult to free the zirconia completely from all admixture of that metal.

The characters of zirconia, by which it may be distinguished from other bodies, are as follows:—

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* Köng. Vet. Acad. Handl. 1824, p. 307.

(1.) When precipitated from a solution, washed, and dried without the application of artificial heat, it is a pale yellow horny-looking matter, which dissolves readily in muriatic acid. When this hydrate of zirconia is ignited it glows at the moment of ignition, becomes white and insoluble in acids, with the exception of the concentrated sulphuric in which it dissolves by slow digestion. When the solution of zirconia in muriatic acid is concentrated, it shoots into needle-form crystals.

(2.) The solution of these crystals in water is colourless. It has an astringent and disagreeable taste.

(3.) Potash throws down a bulky white precipitate, which is not re-dissolved by adding the potash in excess. Soda and ammonia behave in the same way.

(4.) A solution of carbonate of potash throws down a bulky white precipitate, which is slightly soluble in a great excess of the carbonate. Carbonate of soda and the bicarbonates of potash and soda act in precisely the same way. So does carbonate of ammonia, only that the zirconia is more soluble in an excess of that carbonate than of carbonate of potash or soda.

(5.) Phosphate of soda throws down a bulky white precipitate.

(6.) Oxalic acid throws down a bulky precipitate, which is soluble in a great excess of muriatic acid.

(7.) A concentrated solution of sulphate of potash throws down, after a short interval, a white precipitate, which is soluble in a large quantity of muriatic acid. When this precipitate is produced in a warm solution, it is nearly insoluble in water and acids.

(8.) Prussiate of potash throws down a white precipitate.

(9.) Sulphohydrate of ammonia throws down the zirconia, but sulphuretted hydrogen gas occasions no precipitate.

(10.) The salts of zirconia are decomposed by ignition. They all redden litmus paper.

The blowpipe does not enable us to distinguish zirconia from other earthy bodies.

EXAMPLE IX.

Analysis of Thorite.

Thorina, when pure, is colourless, and after ignition is soluble in no other acid but the sulphuric, diluted with its own weight of water. Even heating it with caustic fixed alkalies, or their carbonates, does not render it soluble in muriatic or nitric acid, as is the case with all the other earths, which become insoluble by ignition. These acids merely remove from thorina the foreign bodies with which it may be mixed. The hydrate of thorina dissolves readily in these acids while moist, but after it has been dried the solution takes place much more slowly.

When *potash* is dropt into a solution of thorina in an acid, a gelatinous precipitate falls, which is insoluble in an excess of the precipitant.

Carbonate of potash and *ammonia* also occasion a precipitate, which is re-dissolved in an excess of the precipitant. If the carbonate of potash be concentrated, the solution is effected very rapidly, but more slowly if it be dilute.

Phosphate of soda throws down a white flocky precipitate, insoluble in an excess of phosphoric acid.

Oxalic acid throws down a white heavy precipitate, insoluble in an excess of the acid.

Sulphate of potash occasions no change at first, but if it be concentrated and added in sufficient quantity, it gradually throws down the whole of the thorina.

Prussiate of potash throws down a white heavy precipitate, soluble in acids. Of course no precipitate appears unless the liquid be nearly neutral.

Sulphuretted hydrogen occasions no change, but sulphohydrate of ammonia throws down thorina.

Thorite consists essentially of silica, thorina, and water, but it contains also lime, peroxide of iron, oxide of manganese, peroxide of uranium, and minute quantities of magnesia, oxide of lead, oxide of tin, potash, soda, and alumina. It was analyzed by Berzelius in the following manner:—

1. The portion to be analyzed was ignited in a small retort to which a glass tube, containing chloride of calcium, was luted. The water was retained by the chloride of calcium, while a minute quantity of fluosilicic acid made its escape.

2. The portion thus treated was afterwards heated to ignition in a glass bulb, through which a current of hydrogen gas passed. The colour was changed from brownish-red to grey, water was evolved, and the mineral lost a certain portion of its weight.

3. The mineral thus treated was reduced to a fine powder, and digested with muriatic acid. The colour became yellow,

and a weak smell of chlorine was given out. Heat being applied, the smell of chlorine became stronger, and the whole was converted into a jelly. Being dried in the water bath, and afterwards digested in water acidulated with muriatic acid, it left a quantity of silica which was estimated in the usual manner.

4. The liquid thus freed from silica was mixed with caustic ammonia, and the precipitate well washed with boiling water. The filtered liquid was mixed with oxalic acid, and heated till the liquid at first muddy became clear. The oxalate of lime thus separated was ignited, and the lime estimated from it in the usual way. It contained mixed with it some manganese. To separate it the carbonate of lime was dissolved in muriatic acid. The solution was first mixed with bromine water, and then in a close flask with very dilute caustic ammonia till the acid was rather more than saturated. In twenty-four hours it had deposited a small quantity of yellow matter, which was oxide of manganese.

5. The liquid, freed from lime and manganese by oxalic acid, was evaporated to dryness, the ammoniacal salt was driven off by heat, and the residue being digested in water, left a little magnesia, not quite free from oxide of manganese.

6. The residual liquid being evaporated to dryness left a small quantity of chloride of potassium and chloride of sodium, which were separated from each other by chloride of platinum.

7. The precipitate obtained in paragraph 4, became dark coloured during the washing, on account of the oxide of manganese which it contained. It was dissolved while still moist in muriatic acid. A current of sulphuretted hydrogen was passed through the solution, which threw down a black precipitate. This precipitate was well washed, and then digested in sulphohydrate of ammonia which dissolved a little sulphuret of tin, too inconsiderable to be weighed. The remainder was treated with nitric acid till it was fully oxydized, a little sulphuric acid was then added, and the matter was heated till the excess of sulphuric acid was driven off. Water dissolved a metallic salt, from which ammonia threw down white flocks, which when examined by the blowpipe appeared to be oxide of tin.

8. The liquid which had been treated with sulphuretted hydrogen was evaporated to dryness in a gentle heat. It gelatinized, and left when dissolved in water a little silica.

9. The solution was mixed with an excess of caustic

alkali, which threw down a precipitate, but retained a small quantity of alumina in solution.

10. The precipitate dissolved readily in dilute muriatic acid, leaving a little oxide of manganese. It contained a trace of oxide of iron and of alumina.

11. The muriatic solution was neutralized by caustic ammonia, and concentrated by evaporation. After this sulphate of potash was added to it as long as it would dissolve it. A fine white precipitate fell, which was collected on a filter and washed with a saturated solution of sulphate of potash. It was then dissolved in boiling water, and precipitated by caustic potash. The precipitate was white, and did not acquire a yellow colour while drying, showing the absence of cerium. It was thorina, mixed with a very minute quantity of oxide of manganese, as was shown by heating it on platinum foil mixed with carbonate of soda.

12. The liquid which had been precipitated by sulphate of potash, was now precipitated by caustic potash. The precipitate was well washed, and then digested in carbonate of ammonia.

13. The matter insoluble in carbonate of ammonia was ignited and weighed. It was then dissolved in muriatic acid, and by means of succinate of ammonia, was decomposed into peroxide of iron and red oxide of manganese.

14. The solution in carbonate of ammonia was evaporated to dryness. The residue was digested in dilute acetic acid. This acid assumed a yellow colour, and caustic ammonia threw down a beautiful yellow precipitate, which became dark green by ignition, and was oxide of uranium.

15. The matter undissolved by the acetic acid, was yellowish grey. It gave a colourless solution in muriatic acid. The solution was mixed with tartaric acid and then with ammonia, without any precipitate appearing. Sulphuretted hydrogen threw down a minute quantity of sulphuret of iron.

16. The residue was evaporated to dryness in a weighed platinum crucible. The ammoniacal salts were driven off and the tartaric acid burnt. A small quantity of yellowish matter remained, which contained no yttria or titanic acid, but was thorina, mixed with some oxide of manganese.*

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* Köng. Vet. Acad. Handl., 1829, p. 3.

BOOK II.

OF THE ANALYSIS OF METALLIC ORES.

In the preceding book I have explained the methods of separating from each other the constituents of the first twelve genera of the second class of minerals, described in the first part of this work. The metallic ores, though they do not constitute so numerous, yet form a more difficult class; because the analyses of the different sorts being conducted upon different principles, will require a greater variety of illustrations before the young analyst can be made acquainted with the method of proceeding in the different cases which may present themselves to him. It will be the simplest mode of proceeding, to divide these ores into different groups, classing together those which bear the greatest resemblance to each other in the mode of analyzing them. Perhaps the ores may, without impropriety, be arranged (so far as their analysis is concerned) under the ten following heads:—

1. Alloys,
2. Seleniets,
3. Tellurets,
4. Arseniets,
5. Antimoniets,
6. Iodides,
7. Sulphurets and sulphur salts,
8. Oxides,
9. Chlorides,
10. Salts.

We shall treat of the methods of analyzing these different groups, in the ten following chapters.

CHAP I.

METHOD OF ANALYZING METALLIC ALLOYS.

There are twelve metals which occur in the mineral kingdom, either pure or only alloyed with other metals. These are iron, lead, bismuth, copper, mercury, silver, palladium, gold, platinum, iridium, titanium, arsenic, and antimony.

Sect. 1. *Iron.*

There are two species of minerals in which this metal occurs, either pure or merely alloyed with small quantities of other metals. These are, *native iron* and *meteoric iron*.

Iron in the metallic state, has a light grey colour with the metallic lustre, and is easily recognised by the effect which it produces upon the magnetic needle. It is hard and malleable; when cold, difficultly so, but when heated red hot it is very malleable, and can readily be hammered into any shape. When kept in a moist place, or when exposed to acid fumes, even in a dry place, it speedily rusts. When kept red hot in the open air, it is gradually converted into a red powder, distinguished by the name of peroxide of iron.

It dissolves with great facility in dilute sulphuric or muriatic acid, with the evolution of hydrogen gas. The saturated solution has a light green colour, an astringent taste, similar to that of ink, and when sufficiently concentrated, forms fine light green crystals.

In nitric acid, iron dissolves rapidly, and the solution assumes a dark reddish brown colour, in consequence of the nitrous gas evolved being absorbed by the acid.

Iron forms two oxides by combining with oxygen, the *protoxide* is a dark blue, and forms green-coloured solutions in acids; the *peroxide* is a fine red, and forms reddish or yellowish-brown solutions in acids. It will be proper to point out the action of re-agents upon solutions of each of these oxides, in sulphuric or muriatic acid.

1. *Protoxide of Iron.*

The solution, as has been already stated, is green, and has an astringent and inky taste.

(1.) Potash throws down a bulky precipitate in flocks. It is at first white, then becomes grey, and in an instant or two green; and this green colour deepens as the precipitate subsides to the bottom. If we attempt to dry it on a filter, it becomes yellow, and at last reddish-brown, by absorbing oxygen from the atmosphere. An excess of potash does not re-dissolve this precipitate. Soda acts precisely as potash does.

(2.) Ammonia produces the same effect as potash, when poured into a neutral solution of protoxide of iron in sulphuric or muriatic acid. But if the muriatic solution contains an excess of acid, or if we mix some sal ammoniac with it, then ammonia either throws down no precipitate, or precipitates imperfectly. By degrees, however, a small green precipitate falls, if the liquid be exposed to the air, and this precipitate becomes gradually reddish-brown, like that thrown down by *potash* or soda.

(3.) Carbonate of potash or soda, throws down a white precipitate without any effervescence ensuing from the evolution of carbonic acid gas. Sal ammoniac dissolves this precipitate, but on exposure to the air, a small greenish deposit appears and changes to reddish-brown.

Carbonate of ammonia produces the same precipitate, but more slowly.

The bicarbonates of these alkalies throw down the same precipitate, but an effervescence takes place at the same time from the escape of one-half of the carbonic acid in the state of gas.

(4.) Phosphate of soda throws down a white precipitate from a neutral solution of protoxide of iron, which after being sometime exposed to the air becomes green.

(5.) Oxalic acid, or binoxalate of potash, strikes a yellow colour when poured into a solution of protoxide of iron, and after some time a yellow precipitate falls, which is oxalate of iron. This precipitate is re-dissolved by the addition of muriatic acid. The oxalate of ammonia produces a similar precipitate.

(6.) Prussiate of potash throws down a precipitate, at first white, but instantly assuming a light blue colour, which gradually acquires a deeper shade in proportion as it absorbs oxygen from the atmosphere.

(7.) The infusion, or tincture of nutgalls, strikes a deep blue with the solutions of iron, so deep indeed, that it appears to the eye black, and constitutes common writing ink.

(8.) Sulphuretted hydrogen occasions no precipitate, but sulphohydrate of ammonia throws down a black precipitate. When this precipitate is exposed to the air, it becomes reddish-brown.* No excess of sulphohydrate of ammonia re-dissolves this precipitate.

(9.) The salts of protoxide of iron redden litmus paper.

(10.) The salts of protoxide of iron which do not dissolve in water, almost all dissolve in muriatic acid, and are again precipitated by ammonia.

(11.) In general we may detect the salts of protoxide of iron by the blowpipe. When fused with borax or biphosphate of soda, by the outer flame, a deep red bead is obtained, the

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* This enables us to distinguish iron from nickel and cobalt. The precipitate from these two last metals, by sulphohydrate of ammonia, remains black in the air.

colour of which becomes much lighter on cooling. When the bead is fused in the interior flame, a green-coloured bead is obtained, which colour disappears altogether when the glass cools, unless the proportion of iron be too great.

2. *Peroxide of Iron.*

The peroxide when pure, has a reddish-brown colour. It dissolves with facility in acids before it has been exposed to a red heat, but after ignition the solution takes place slowly. By far the best solvent of this oxide is muriatic acid.

(1.) Potash throws down a reddish-brown precipitate from the solution of peroxide of iron in acids. No excess of potash re-dissolves this precipitate.

Soda and ammonia produce the same effect.

(2.) The alkaline carbonates and bicarbonates, throw down a similar precipitate, but of a rather lighter colour.

(3.) Phosphate of soda throws down a white precipitate. If ammonia be added, the precipitate becomes brown, and after some time it totally disappears.

(4.) Oxalic acid occasions no precipitate in neutral solutions of peroxide of iron, but the liquid assumes a yellow colour.

(5.) Prussiate of potash throws down a very deep blue precipitate, which is insoluble in muriatic acid.

(6.) Sulphuretted hydrogen renders a neutral solution of peroxide of iron milky. Sulphur is precipitated, and the iron is reduced to the state of protoxide.

(7.) Sulphohydrate of ammonia throws down a black precipitate, insoluble in an excess of the re-agent. When this precipitate is exposed to the air, it becomes reddish-brown.

(8.) The salts of peroxide of iron, which are insoluble in water, dissolve in muriatic and dilute sulphuric acid, and are again thrown down from these solutions by ammonia.

(9.) The salts of peroxide of iron exhibit the same phenomena before the blowpipe, as those of protoxide.

Native iron was analyzed by Klaproth, and found to contain some lead and copper, with a trace of sulphur. It may be analyzed in the following manner:—

1. Dissolve 100 grains of it in muriatic acid. The solution should be effected in a small tubulated retort, from the beak of which there passes a glass tube, bent so as to pass to the bottom of a glass jar, containing a weak solution of nitrate of *lead.* Along with the hydrogen gas evolved, passes the sul-

phur of the iron, in the state of sulphuretted hydrogen gas. It is decomposed by the oxide of lead, the oxygen of that oxide uniting with the hydrogen of the sulphuretted hydrogen, and forming water, while the sulphur and lead combine to form sulphuret of lead, composed of

Lead, . . .	13
Sulphur, . . .	2
	15

So that every 15 grains of it contain 2 grains of sulphur. Collect the sulphuret of lead, wash, dry, ignite it, and weigh. From the weight of it we easily deduce that of the sulphur, which is $\frac{1}{7\frac{1}{2}}$ of the sulphuret.

2. Concentrate the muriatic acid solution, and set it aside for some time, the chloride of lead will be deposited in white silky needles, which may be separated, washed, fused, and weighed. It is composed of

Lead, . . .	13
Chlorine, . .	4·5
	17·5

Hence the lead is 0·743 of the weight of the fused chloride.

3. Add a little nitric acid to the liquid thus freed from lead, and digest to peroxidize the iron. Concentrate, neutralize by ammonia, and throw down the iron by benzoate of ammonia. From the precipitate the quantity of iron is to be deduced in the way formerly explained.

4. Pour caustic potash into the solution thus freed from iron and lead; the copper is thrown down in the state of black oxide. Let it be washed, dried, ignited, and weighed. Four-fifths of its weight constitute the quantity of copper in the mineral analyzed.

Meteoric iron is distinguished from native iron by containing nickel, which appears to exist in a great variety of proportions. It may be analyzed in the following manner:—

1. Dissolve the meteoric iron in nitric acid. Concentrate the solution to make it as neutral as possible, dilute it with water, add sal ammoniac in sufficient quantity to form a double salt with the oxide of nickel; then throw down the iron by ammonia. Collect the precipitate on a filter, wash it, dry it, and ignite. It is peroxide of iron, every 5 grains of which is

equivalent to 3·5 grains of iron, or the iron constitutes $\frac{7}{10}$ths of the oxide.

2. Pour caustic potash into the liquid freed from iron, to precipitate the oxide of nickel. Should the nickel not be easily thrown down from the double salt, the liquid may be evaporated to dryness, and the ammoniacal salts driven off; then the residue must be dissolved in muriatic acid, and the oxide of nickel thrown down by caustic potash or soda. This oxide after ignition weighs 4·25, while the weight of the metallic nickel is 3·25. Hence $\frac{13}{17}$ths, or 0·765 of the oxide of nickel obtained is metallic nickel.

Sect. 2. *Titanium.*

It can scarcely be said that this mineral occurs native in the metallic state, but it was found at Merthyr Tydvil, at the bottom of the furnace in which iron had been long smelted, in fine metallic cubes; and I have a specimen of iron found in the same position at Muirkirk, in which a great deal of metallic titanium also occurs in small cubes. It has been observed also in a similar situation in other iron smelting houses. It is proper, therefore, that the young analyst should be aware of the mode of examining it.

Titanium is a fine red metal nearly of the colour of copper. It is brittle, and very hard, and crystallizes in cubes. It combines with two proportions of oxygen, and forms oxide of titanium, which is blue, and titanic acid, which is white. It is in the state of titanic acid that it is always obtained after solution.

In the metallic state titanium is scarcely soluble in acids; but when heated with caustic potash or soda it is readily oxidized, and converted into titanic acid.

(1.) Titanic acid, when precipitated from its solution in muriatic acid by an alkali, washed, and ignited, forms small lumps of a light brown colour, and a great deal of lustre. When the colour is reddish, the titanic acid contains some iron. When titanic acid is heated to redness it becomes lemon yellow, but loses this colour on cooling, and becomes white.

(2.) Titanic acid after ignition is insoluble in all acids. When in this state, if we mix it with carbonate of potash or soda, and heat the mixture to redness, the carbonic acid is driven off, and the titanic acid unites with the alkali. When such a mixture is fused, it assumes a crystallized form. Water dissolves the excess of the alkali, and leaves a supertitaniate of potash, insoluble in that liquid; but it dissolves in muriatic acid when assisted by a gentle heat. If we dilute the solution with water and boil it, the greatest part of the titanic acid falls down in the state of a white precipitate. If we throw the whole upon the filter, and attempt to wash the titanic acid, the liquid passes through transparent and colourless as long as it is acid, but as soon as the water becomes nearly pure it passes through the paper quite milky, so that by degrees all the titanic acid is washed away.

When titanic acid is precipitated from its solution in muriatic acid by boiling, it is very little soluble in acids; but if it be precipitated by an alkali, it may be washed in the filter, and dissolves completely in acids.

(3.) When potash, soda, or ammonia, or the carbonates or bicarbonates of these alkalies are dropt into a solution of titanic acid in muriatic acid, a white bulky precipitate falls, which does not dissolve on the addition of an excess of the precipitating medium; but if we add an excess of muriatic acid, the precipitate is again redissolved. The alkaline carbonates dissolve a very little of the precipitated titanic acid; but the quantity is so small that we cannot employ them to separate titanic acid from other bodies with which it may be mixed.

(4.) When the muriatic acid solution of titanic acid does not contain too much acid, as, for example, when it is added in such quantity as not to dissolve the whole of the titaniate of potash exposed to its action, if we drop into the solution dilute sulphuric acid, arsenic acid, phosphoric acid, tartaric acid, and especially oxalic acid, a white precipitate falls. This precipitate is again dissolved if we add an excess of the precipitating acid, or of muriatic acid. The oxalic acid precipitate, however, requires the addition of a little muriatic acid before it is completely redissolved.

Nitric acid, acetic acid, and succinic acid occasion no precipitate when they are employed.

(5.) When the muriatic acid solution contains as little excess of acid as possible, the tincture of nutgalls throws down an orange-red precipitate.* If titanic acid thrown down by boiling be mixed with the tincture of nutgalls, it also strikes an orange-red or brownish-yellow colour.

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* Prussiate of potash gives a similar precipitate, as far as colour is concerned.

(6.) Sulphuretted hydrogen throws down no precipitate from the muriatic acid solution of titanic acid.

Sulphohydrate of ammonia, added in excess, throws down a white precipitate, while sulphuretted hydrogen gas is disengaged. If the solution contain even a trace of iron, the precipitate is grey or black.

(7.) If a zinc rod is put into a solution of titanic acid in muriatic acid the liquid assumes a blue colour, and continues for some time clear, while at the same time hydrogen gas is evolved in consequence of the action of the free acid upon the zinc. By degrees a blue precipitate falls, which at last assumes a white colour. If we take out the zinc while the blue-coloured liquid remains transparent, and pour into it an excess of potash or ammonia, a blue precipitate falls, which gradually assumes a white colour, while at the same time hydrogen gas is evolved. When titanic acid thrown down by boiling is placed in contact with zinc, it assumes also a blue colour. If the quantity of titanic acid in the solution be very small, no blue colour appears. Iron and tin produce the same phenomena as zinc.

(8.) The compounds of titanic acid with bases are all, so far as is known, soluble in concentrated muriatic acid, even after having been exposed to a red heat. The solution is hastened by the application of heat; but we must take care not to apply too much, for if we throw down the titanic acid by heat it becomes insoluble in muriatic acid.

(9.) The appearances which characterize titanic acid before the blowpipe have been already described in a former part of this treatise.*

M. H. Rose has shown that the old method of precipitating titanic acid from its solutions by boiling does not give good analytical results. The best method is to throw it down by ammonia, taking care to use as small an excess of ammonia as possible. The difficulties attending the separation of titanic acid from other substances are so great, that chemists are not able at present to overcome them completely. The following observations, chiefly deduced from the researches of Rose, are all that I can offer:—

From the oxides of tin, mercury, silver, copper, bismuth, lead, and cadmium, titanic acid is readily separated by dissolving the mixture in muriatic acid, and passing a current of

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* See page 376.

sulphuretted hydrogen through the solution. The oxides are thrown down in the state of sulphurets, while the titanic acid remains in solution, and may be afterwards thrown down by ammonia.

The oxides of cobalt, nickel, zinc, and manganese, which, though not precipitated by sulphuretted hydrogen, are precipitated by sulphohydrate of ammonia, may be separated from titanic acid in the following way:—To the solution add a considerable quantity of tartaric acid, and then supersaturate with ammonia. The tartaric acid prevents any precipitate from appearing. Add a quantity of sulphohydrate of ammonia; the oxides precipitate, but the titanic acid remains in solution. Evaporate the solution to dryness, and expose the residue to a red heat in an open platinum crucible till every thing combustible is destroyed. The residual matter is now pure titanic acid. This process succeeds also when we wish to separate titanic acid from iron, with which it is frequently found in combination.

No good method has yet been discovered of separating titanic acid from zirconia, when they happen to be united, as is sometimes the case.

When titanic acid occurs along with oxides of cerium and yttria, we must dissolve the whole in sulphuric acid, and boil the solution. The titanic acid falls down, while the other two substances remain in solution. They are to be separated from each other by the processes already described.

From lime titanic acid is thrown down by ammonia; the solution must be filtered as much as possible in a covered vessel, to prevent the lime from being thrown down during the process in the state of a carbonate. From barytes and strontian we easily separate titanic acid by throwing down the former substances by means of sulphuric acid; ammonia precipitates the titanic acid from the fixed alkalies.

In dissolving titanic acid, or the compounds of it, in muriatic acid, the process is best conducted without applying heat; for if we raise the temperature too high the titanic acid is precipitated again, and the whole process stopped.

Sect. 3. *Lead.*

Lead has been found native in the mineral kingdom, though only in small quantity. The characters of this metal are so striking and so well known that it is easily recognised. It is a soft, heavy, malleable metal, having a bluish-white colour, and very soon tarnishing when exposed to the air. It dissolves readily in nitric acid. The solution is colourless, and readily yields octahedral crystals, having a sweet and astringent taste.

Lead forms three oxides, but only one of these, the protoxide, is soluble in acids. Hence it is the only one which occurs when native lead is dissolved in acids.

(1.) Protoxide of lead has a yellow colour, or sometimes a reddish-yellow. When heated to redness it melts readily, and in a white heat in open vessels sensibly evaporates. It is insoluble in water, but dissolves readily in nitric acid. The neutral solution of nitrate of lead has the following characters.

(2.) Potash or soda throws down a white precipitate, which is re-dissolved in an excess of the precipitating substance.

(3.) Ammonia throws down a white precipitate not soluble in an excess of the reagent.

(4.) The alkaline carbonates and bicarbonates throw down white precipitates not re-dissolved by an excess of the reagents.

(5.) Phosphate of soda throws down a white precipitate, which is soluble in a solution of pure potash or soda.

(6.) Oxalic acid throws down a white precipitate.

(7.) Prussiate of potash throws down a white precipitate.

(8.) Sulphuretted hydrogen and sulphohydrate of ammonia throw down a dark brown or black precipitate of sulphuret of lead.

(9.) A rod of zinc throws down the lead in the metallic state.

(10.) Sulphuric acid, or an alkaline sulphate, throws down a white precipitate, insoluble in acids, but soluble in caustic potash or soda. This last property enables us to distinguish precipitated sulphate of lead from sulphate of barytes, strontian, or lime.

(11.) Common salt, or any soluble chloride, occasions a white silky precipitate in concentrated solutions of lead. This precipitate is again dissolved by diluting the liquid with a sufficient quantity of boiling water.

(12.) Hydriodate of potash, or any soluble hydriodate, throws down a fine yellow-coloured precipitate, soluble in a great excess of the hydriodate.

(13.) Chromate of potash throws down a fine yellow precipitate, insoluble in dilute nitric acid, but soluble in pure potash or soda.

(14.) Most of the insoluble salts of lead dissolve in nitric acid, and sulphuric acid throws down a white precipitate from the solution. Sulphate of lead is not soluble in dilute nitric acid; but if we moisten it with sulphohydrate of ammonia, it becomes black, and when fused with carbonate of soda on charcoal, a globule of metallic lead is obtained.

Native lead has never been analyzed. But I have repeatedly made experiments to determine the foreign metals contained in metallic lead. The only metals found were iron, copper, and silver; all in very minute quantity.

The iron was detected by dissolving 500 grains of lead in nitric acid, evaporating the solution till the excess of acid was driven off, and then precipitating the oxide of lead by sulphate of ammonia. The residual liquid when tested by prussiate of potash, sometimes indicated the presence of oxide of iron. This I attempted to separate by means of benzoate of ammonia. But in general the quantity from 500 grains of the lead was too small to be weighed.

Copper is a much more frequent constituent of lead than iron. After the lead has been thrown down from the nitric solution by sulphate of ammonia, if we concentrate the solution, and add a little ammonia, the presence of the copper is indicated by the blue colour which the liquid assumes. The copper may be thrown down by caustic potash, collected, ignited, and weighed. Every 5 grains of it are equivalent to 4 grains of metallic copper. I have found as much copper as 0·1 grain in 500 grains of lead.

Silver exists in such minute quantity in lead, that I have never been able to detect its presence by any other method than cupellation. A pound of lead is usually taken and kept at a red heat, in a muffle, on a test till the lead is all absorbed. The silver remains, and may be easily weighed, if its quantity be appreciable. But as the lead is usually deprived of its silver by cupellation before it is exposed to sale, it is not surprising that it seldom contains an appreciable quantity of that metal.

Sect. 4. *Bismuth.*

Bismuth occurs in a native state, and indeed constitutes its most common ore. It is requisite therefore that the young analyst should be acquainted with the characters of this metal.

The only oxide of bismuth likely to come in the way of the analyst is the yellow oxide, formed when nitrate of bismuth is exposed to a red heat.

(1.) This oxide dissolves in nitric acid, and forms a colourless solution, which when sufficiently concentrated yields crystals. When these crystals are put into water they undergo decomposition; a supersalt is dissolved, while a subsalt remains in the form of a white powder. An addition of nitric acid dissolves the whole by converting it into a supersalt.

(2.) Potash or soda throws down a white precipitate in solution of bismuth, which is not re-dissolved in an excess of the potash.

(3.) Ammonia acts in the same way.

(4.) The alkaline carbonates and bicarbonates throw down white precipitates, not dissolved in an excess of the precipitant.

(5.) Phosphate of soda throws down a white precipitate.

(6.) Oxalic acid occasions no change at first, but after some time a crystalline precipitate falls.

(7.) Prussiate of potash throws down a white precipitate not soluble in muriatic acid.

(8.) Sulphuretted hydrogen, or sulphohydrate of ammonia, throws down a dark brown or black precipitate which is a sulphuret of bismuth.

(9.) A rod of zinc precipitates bismuth in the metallic state.

(10.) Iodide of potassium throws down a brown precipitate, easily soluble in an excess of the precipitant.

(11.) Chromate of potash throws down a yellow precipitate, soluble in dilute nitric acid.

(12.) Before the blowpipe on charcoal a salt of bismuth mixed with carbonate of soda is easily reduced, and globules of metallic bismuth are obtained. These are white and brittle, breaking in pieces under the hammer, while globules of lead or silver are flattened. The charcoal becomes coated with yellow oxide of bismuth.

I am not aware that native bismuth has hitherto been subjected to analysis. But the principal impurity in the bismuth of commerce, which is merely native bismuth melted down, is sulphur. Native bismuth contains almost always traces of silver and arsenic. The mode of determining the sulphur will be given in a subsequent chapter. The silver is easily separated by the addition of a little muriatic acid. The silver is thrown down in the state of chloride, every 18·25 grains of which contain 13·75 grains of silver.

Arsenic is obtained when the bismuth is dissolved in nitric acid, and the solution being first rendered alkaline by the addition of ammonia is mixed with sulphohydrate of ammonia in excess. The whole is digested on the sandbath in a flask with a cork. The bismuth is precipitated in the state of sulphuret, while the arsenic remains in solution. Separate the sulphuret of bismuth by the filter, render the liquid that passes through acid by means of muriatic acid, and digest in a gentle heat till all smell of sulphuretted hydrogen is dissipated. The sulphuret of arsenic precipitates. Let it be collected on a filter and weighed. The mode of determining the quantity of arsenic which it contains will be given in a subsequent chapter, when treating of the sulphurets.

The best precipitant of oxide of bismuth is carbonate of ammonia. According to Liebig, carbonate of lime throws down bismuth from a cold solution of the nitrate, but not lead. We may employ this method of separating bismuth and lead.*

Sect. 5. *Copper.*

Native copper is a pretty common inhabitant of the mineral kingdom, usually in crystals, strings, or plates. All the specimens of it which I have examined were remarkably pure.

Copper has a well known red colour, and is malleable. It dissolves readily in nitric acid, forming a fine blue solution, yielding deliquescent crystals, which possess considerable causticity. In sulphuric acid and muriatic acid it does not dissolve, unless the solution be aided by the presence of nitric acid. But the black oxide of copper dissolves readily both in sulphuric and muriatic acid. The sulphuric solution is blue, the muriatic green. The salts of copper however neutral redden vegetable blues.

(1.) Potash or soda poured into a neutral solution of copper in an acid throws down a bulky blue precipitate, which is hydrated black oxide. When this precipitate is boiled with an excess of potash it becomes black, and quickly subsides. But if the quantity of potash be insufficient to decompose the salt completely, the precipitate is green, being a subsalt of copper.

(2.) A little ammonia being added to a solution of copper, a green precipitate falls, which speedily dissolves in an excess of ammonia, and the solution assumes a blue colour. This blue colour is much deeper than that produced by ammonia in a solution of nickel, and is characterized besides by

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* Ann. de Chim. et de Phys. xlviii. 293.

a shade of red which the nickel solution wants. If we boil the ammoniacal solution of copper with potash, a black precipitate falls and the liquid becomes colourless.

(3.) Carbonate of potash throws down a blue precipitate which boiling renders black and dense. Bicarbonate of potash throws down a green precipitate, easily dissolved by an excess of the precipitant. The solution then has a light blue colour.

(4.) Carbonate of ammonia in small quantity throws down a greenish white precipitate, which is re-dissolved by the addition of more carbonate. The solution has the same blue colour as that given by caustic ammonia, and when boiled with potash a black dense precipitate falls.

(5.) Phosphate of soda throws down a greenish white precipitate, which dissolves in ammonia, and forms a blue liquid. Potash boiled with this solution throws down a heavy black precipitate.

(6.) Oxalic acid throws down a greenish white precipitate.

(7.) Prussiate of potash throws down a reddish brown precipitate insoluble in muriatic acid.

(8.) Sulphuretted hydrogen, or sulphohydrate of ammonia, throws down a dark brown or black precipitate, which is bisulphuret of copper. It is not soluble in an excess of the sulphohydrate.

(9.) A rod of zinc throws down copper in the metallic state, so does a rod of iron.

(10.) Iodide of potassium throws down a white precipitate. It is re-dissolved in an excess of the precipitant.

(11.) Chromate of potash throws down a reddish brown precipitate, which dissolves in ammonia, forming an emerald green solution. It dissolves also in dilute nitric acid.

(12.) The salts of copper are easily detected by the blowpipe. When fused with borax, or biphosphate of soda, they communicate a fine green colour to the outer flame, and a dirty brownish red to the interior flame. When fused with carbonate of soda on charcoal, the copper is reduced to the metallic state.

The best precipitant of copper when alone in a solution is caustic potash or soda. It may be separated from iron by a current of sulphuretted hydrogen, which throws down the copper without acting on the iron.

Sect. 6. *Mercury.*

Mercury occurs occasionally in the earth in the metallic state, in small drops scattered through the rock in which it is found. It is usually pure. The presence of any foreign metal would be detected by the mercurial drop wanting its usual fluidity, or dragging a tail, as it is called. In such case the foreign body is easily obtained by distilling off the mercury.

Mercury is so well characterized by its white colour and its fluidity, that it cannot be confounded with any other metal. The best solvent of it is nitric acid. The solution is colourless, and crystallizes when sufficiently concentrated. This is the solution of mercury usually formed. The action of reagents upon it is as follows:

(1.) Potash throws down a black precipitate, insoluble in an excess of the reagent. Soda and ammonia act in the same way.

(2.) Carbonate of potash throws down a dirty yellow precipitate, which boiling renders black. Bicarbonate of potash throws down a white precipitate, which boiling renders black.

The action of carbonate of ammonia is nearly the same as that of carbonate of potash.

(3.) Phosphate of soda throws down a white precipitate.

(4.) Oxalic acid throws down a white precipitate.

(5.) Prussiate of potash occasions a white gelatinous precipitate.

(6.) Sulphuretted hydrogen throws down a black precipitate. Sulphohydrate of ammonia throws down a black precipitate, insoluble in an excess of the precipitant, and also in ammonia. It dissolves partially in a solution of pure potash, leaving a black powder, which proves on examination to be running mercury. When the filtered alkaline solution is supersaturated with an acid a black precipitate falls, which is sulphuret of mercury.

(7.) Muriatic acid, or common salt, or any soluble chloride, throws down a white precipitate.

(8.) A bar of zinc or copper throws down the mercury in the metallic state.

(9.) Iodide of potassium forms a greenish-yellow precipitate, soluble in an excess of the precipitant.

(10.) Chromate of potash throws down a red precipitate.

(11.) If we mix a salt of mercury with carbonate of soda, and heat the mixture to redness in a glass tube, shut at one end, running mercury sublimes and coats the tube in the form of a grey powder, which assumes the form of globules when rubbed with a glass rod.

The best way of determining the quantity of mercury in any salt is to reduce it to the metallic state. Suppose the mercury to exist in solution in the state of suboxide. Pour muriatic acid or sal ammoniac into the solution; the metal is thrown down in the state of chloride. Put this chloride into a flask, pour upon it concentrated muriatic acid, and then add a concentrated solution of chloride of tin, to which a sufficient quantity of muriatic acid has been previously added to render it perfectly clear. Boil the mixture for two or three minutes and then cork it up; the mercury falls to the bottom in the state of a black powder, which gradually forms larger globules. When the flask is cold pour off the liquid and wash the mercury with water, acidulated with muriatic acid, till it is quite clean. It must then be dried and weighed.

When the mercury is in the state of peroxide, if in combination with nitric acid, that acid must be destroyed by muriatic acid, or if it be in combination with any other acid, the salt may be put into the flask and treated as above directed: the result will be the same.

Sect. 7. *Silver.*

Native silver occurs very frequently in the mineral kingdom; indeed a great proportion of the silver from the American mines exists originally in that state. Native silver is seldom pure, it almost always contains copper, and sometimes antimony or arsenic. Whatever be its constituents we must begin the analysis by dissolving the native silver in nitric acid. The solution, if the silver be pure, is colourless, crystallizes when concentrated, and is very corrosive. The action of reagents upon this solution is as follows:—

(1.) Potash throws down a light brown precipitate, insoluble in an excess of the precipitant, but soluble in ammonia.

(2.) Ammonia, when added in very small quantity, throws down a brown precipitate, instantly dissolved by the addition of more ammonia.

(3.) Carbonate of potash or soda throws down a white precipitate, soluble in ammonia. Bicarbonate of potash or soda acts in the same way.

(4.) Carbonate of ammonia produces a white precipitate, soluble in an excess of the carbonate.

(5.) Phosphate of soda throws down a yellow precipitate, soluble in caustic ammonia; but pyrophosphate of soda throws down a white precipitate.

(6.) Oxalic acid throws down a white precipitate, soluble in ammonia.

(7.) Prussiate of potash throws down a white precipitate.

(8.) Sulphuretted hydrogen or sulphohydrate of ammonia throws down a white precipitate.

(9.) Muriatic acid, or any chloride, throws down a heavy white curdy precipitate, soluble in ammonia, but insoluble in dilute acids.

(10.) Iodide of potassium throws down a white precipitate with a shade of yellow. It dissolves in an excess of the precipitant, and very sparingly in ammonia.

(11.) Chromate of potash throws down a dark reddish-brown precipitate, soluble in dilute nitric acid, and in ammonia.

(12.) A bar of zinc throws down silver in the metallic state. The sulphate of iron produces the same effect.

If the native silver contain no other foreign metal but copper, we may dissolve it in nitric acid, throw down the silver by common salt, and afterwards the oxide of copper by potash. From these precipitates the quantity of silver and copper is determined, by the methods already explained.

When silver is alloyed with antimony or arsenic, the compound is dissolved in nitric acid. The solution is put into a flask, and supersaturated with ammonia; then a quantity of sulphohydrate of ammonia is poured in, the flask is corked, agitated, and left for some time. The antimony or arsenic is kept in solution, while the silver is precipitated in the state of sulphuret. This sulphuret is to be washed, dried, and weighed. It is composed of

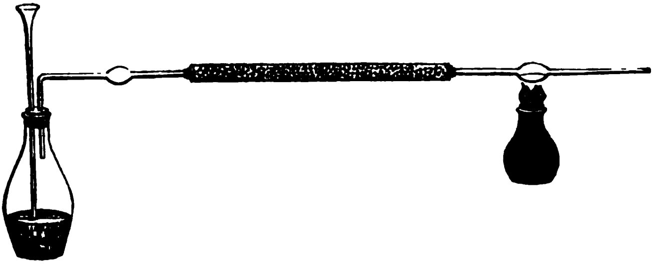
Sulphur, . .	2
Silver, . . .	13·75
	15·75

So that 0·873 of the sulphuret is silver.

From the solution the sulphides of antimony and arsenic are thrown down, in the way which will be immediately explained. The sulphuret of antimony always falls first, and the sulphuret of arsenic last.

The sulphides of arsenic and antimony intimately mixed are weighed, and then divided into two nearly equal portions. One portion is treated in a flask with fuming nitric acid cautiously added to acidify the sulphur, and muriatic acid is added to render the solution complete. Tartaric acid is now added to the solution, and the sulphuric acid precipitated by chloride of barium, and its weight ascertained. This gives the weight of the sulphur in the mixed sulphurets of antimony and arsenic obtained.

The other half of these sulphurets is put into a glass bulb, to which two glass tubes are soldered at opposite sides. A current of dry hydrogen gas is made to pass through the bulb, being generated in a flask connected with the bulb by a glass tube, in which a quantity of dry chloride of calcium is placed to dry the gas. When the tube and bulb are filled with hydrogen gas, heat is applied to the bulb, the sulphur and arsenic are driven off, and nothing remains but the antimony, which is to be weighed after the apparatus is cold. Knowing the weight of the sulphur and antimony in the mixed sulphurets, it is easy to deduce the weight of the arsenic.



Sect. 8. *Palladium.*

Native palladium occurs mixed with the platina grains from South America, and was first discovered and described by Dr. Wollaston. It consists of palladium alloyed with a little platinum and iridium. The metal seems to occur in considerable quantity in Brazil, though in what state I have never learned; but about twelve years ago large ingots of it were brought from that country to London, where they were exposed for sale.

The best solvent of palladium is aqua regia; the solution has a deep reddish-brown colour, and an astringent taste. The action of reagents on this solution, rendered as neutral as possible, is as follows:—

(1.) Potash or soda throws down a deep yellowish-brown

precipitate, insoluble in an excess of the precipitant, but soluble in muriatic acid.

(2.) Ammonia throws down a reddish-white precipitate, which gradually assumes a whiter colour. When heat is applied, the whole dissolves, with the exception of a small quantity of white matter.

(3.) Carbonate or bicarbonate of potash occasions no precipitate.

(4.) Carbonate of soda throws down a brown precipitate, but the solution retains a brown colour. Muriatic acid readily dissolves the precipitate.

(5.) Carbonate of ammonia destroys the colour, but produces no precipitate.

(6.) Phosphate of soda throws down a brown precipitate; the liquid continuing brown.

(7.) Oxalic acid throws down no precipitate.

(8.) Prussiate of potash occasions at first no precipitate, but after a considerable interval a thick stiff jelly of a green colour appears.

(9.) Cyanodide of mercury throws down a yellowish-white gelatinous precipitate.

(10.) Nitrated suboxide of mercury throws down a greenish-black precipitate.

(11.) Protochloride of tin throws down a dark brown precipitate.

(12.) Sulphuretted hydrogen or sulphohydrate of ammonia throws down a black precipitate.

(13.) A rod of zinc throws down a black powder.

It will be best to defer explaining the mode of separating palladium from platinum and iridium till we come to speak of platinum: the one description may serve for all.

Sect. 9. *Gold.*

This metal occurs most commonly in the metallic state, but seldom or never pure. It is almost constantly alloyed with silver, frequently with copper, and sometimes, though seldom, with iron.

Gold has a well known yellow colour, is soft, very malleable, and very heavy. It does not dissolve in sulphuric, nitric, nor muriatic acid; the best solvent of it is aqua regia; the solution is yellow and caustic. It consists of chloride of gold. The neutral chloride of gold is the only solution of that metal that can be conveniently obtained. It exhibits the following phenomena with reagents:—

(1.) Potash occasions no precipitate at first, but by degrees the liquid assumes a greenish tinge, and a small quantity of black matter falls down.

(2.) Ammonia throws down a dirty yellow precipitate, which is fulminating gold, and is re-dissolved by an excess of the ammonia.

(3.) Carbonate or bicarbonate of potash throws down nothing, but carbonate of ammonia throws down a yellow precipitate.

(4.) Phosphate of soda occasions no change.

(5.) Oxalic acid produces a greenish-black colour, owing to the separation of metallic gold, which gradually falls to the bottom.

(6.) Prussiate of potash strikes an emerald green colour, but occasions no precipitate.

(7.) Cyanodide of mercury throws down no precipitate, unless the chloride of gold be mixed with alcohol, when a slight reddish-yellow matter may be thrown down.

(8.) Nitrated suboxide of mercury throws down a black precipitate.

(9.) Sulphate of iron throws down a blue coloured precipitate, which is metallic gold.

(10.) Protochloride of tin, in diluted solutions of gold, produces a purple red colour; in concentrated solutions it throws down a dark purple precipitate.

(11.) Iodide of potassium strikes a black colour, and a yellowish-green precipitate falls.

(12.) Sulphuretted hydrogen throws down a black, and sulphohydrate of ammonia a dark brown precipitate.

(13.) A plate of zinc throws down the gold in the metallic state.

An alloy of gold and silver is to be beaten out into a thin plate, and digested in aqua regia. The gold is dissolved, but the silver remains behind in the state of chloride. It is to be separated, washed, dried, fused, and weighed. 18·25 grains of this chloride are equivalent to 13·75 grains of silver.

The gold solution being mixed with nitrated suboxide of mercury, the whole gold is precipitated, and the precipitate, when dried and ignited, leaves metallic gold.

Should the alloy contain copper, it will remain in solution after the gold has been precipitated, and its presence will be known by the green colour of the liquid. The copper may be thrown down in the state of black oxide by potash. Should a slight excess of nitrated suboxide of mercury remain in solution, it will not injure the accuracy of the result, because the red heat will dissipate the mercury and leave only the oxide of copper. Every 5 grains of black oxide of copper are equivalent to 4 grains of the metal.

If iron be present, it must be thrown down by benzoate of ammonia before precipitating the copper.

Sect. 10. *Platinum.*

This metal, like gold, has hitherto been found only in the metallic state, in small grains, or in lumps, sometimes of very considerable size. This native platinum is never pure. The metal is always alloyed with iridium, rhodium, palladium, osmium, copper, and iron; and the separation of all these metals from each other, is attended with very considerable difficulties. It will be requisite, before attempting to explain the methods which have been thought of for that purpose, to give the characters by which platinum, rhodium, iridium, and osmium, are distinguished, that the young analyst may be able to recognise these metals when he meets them.

Platinum, like gold, can be dissolved only in aqua regia. The solution is dark reddish-brown, and very astringent. It is in this solution that the peculiarities of platinum are best observed.

(1.) Potash throws down a yellow precipitate, consisting of potassium-chloride of platinum. This precipitate is not sensibly dissolved in acids, but when we add an excess of potash and apply heat, a solution is effected. When the excess of potash is saturated with muriatic acid, the precipitate again appears.

(2.) Ammonia produces the same effect as potash. The precipitate is not re-dissolved by acids, but it dissolves in an excess of ammonia when the action is assisted by heat; and when the excess of ammonia is saturated with muriatic acid, a white precipitate appears.

(3.) Carbonate of potash throws down the same precipitate, which is not re-dissolved by an excess of the precipitant. Bicarbonate of potash and carbonate of ammonia, act precisely in the same way.

(4.) Carbonate of soda occasions no precipitate.

(5.) Phosphate of soda throws down no precipitate.

(6.) Oxalic acid occasions no sensible change.

(7.) Prussiate of potash throws down a yellow precipitate, and the liquid assumes a deeper colour.

(8.) Cyanodide of mercury throws down nothing.

(9.) Nitrated suboxide of mercury throws down an abundant yellowish-brown precipitate.

(10.) Sulphate of iron throws down nothing.

(11.) Iodide of potassium gives the liquid a deep brownish-red colour, and occasions a lighter coloured brown precipitate. When heat is applied, the glass acquires a metallic coating.

(12.) Protochloride of tin gives the liquid a deep brownish-red colour, but precipitates nothing.

(13.) Sulphuretted hydrogen renders the liquid brown, and by degrees a brown precipitate falls, which at last becomes black. Sulphohydrate of ammonia produces the same effect, but the precipitate re-dissolves in an excess of the sulphohydrate.

(14.) A plate of zinc throws down a black powder.

(15.) When a red heat is applied to the chloride of platinum, the chlorine is driven off, and metallic platinum remains in grains or in a spongy state.

Rhodium.

Rhodium is a white metal, of so difficult fusion, that hitherto it has been obtained only in grains. In the metallic state it is insoluble in all acids, and even in aqua regia. But when in combination with another metal, as platinum, aqua regia is capable of dissolving it. When fused with bisulphuret of potassium it is oxidized, and may be dissolved. It may be dissolved also by fusion with phosphoric acid. It is oxidized also when fused with pure potash or with saltpetre. The solutions of oxide of rhodium and the chloride, have a rose-red or brownish-red colour, and exhibit the following phenomena with re-agents:

(1.) Potash occasions no precipitate, but when the mixture is boiled, a gelatinous brownish-yellow matter falls.

(2.) Ammonia occasions, after some time, a copious yellowish precipitate, which is completely soluble in muriatic acid. The solution has a yellow colour.

(3.) Carbonate of potash at first occasions no precipitate, but after some time a yellowish sediment falls. Carbonate of soda and carbonate of ammonia act in the same way.

(4.) Phosphate of soda throws down no precipitate.

(5.) Oxalic acid produces no sensible change.

(6.) Prussiate of potash throws down no precipitate.

(7.) Sulphate of iron occasions no change.

(8.) Protochloride of tin produces a dark brown colour, but throws down no precipitate.

(9.) Iodide of potassium deepens the colour, and occasions at last a slight precipitate.

(10.) Sulphuretted hydrogen produces at first no change, but by degrees a brown sediment falls, though the colour of the liquid continues. Sulphohydrate of ammonia throws down a brown precipitate, not soluble in an excess of the reagent.

(11.) A plate of zinc throws down the rhodium in the metallic state, under the form of a black powder.

Iridium.

Iridium is a white metal, like platinum, and requires so high a temperature to fuse it, that it has never been obtained in any other state than that of powder. It is very heavy, though its specific gravity has not yet been determined with accuracy. It is insoluble in nitric, muriatic, dilute sulphuric acid, and even in aqua regia. But it dissolves in this last liquid when alloyed with a sufficient quantity of platinum. By fusion with saltpetre, it may be converted into an oxide. It oxidizes spontaneously in fine powder when simply exposed to the atmosphere, as I have repeatedly observed. The chloride is the only solution of this metal whose action with reagents has been studied. Its colour is dark red, or dark reddish-brown.

(1.) Potash changes the colour of the liquid to a dirty green, and a very small quantity of a brownish-black precipitate falls. When heat is applied to this mixture, it gradually assumes a blue colour, which becomes deeper and deeper. When the blue liquid is evaporated, a slight bluish precipitate at first falls, but the dry mass is white with a tint of green. When it is digested in water, a blue powder remains undissolved, and the solution is colourless.

(2.) Ammonia added in excess destroys the colour as much as potash does, and throws down merely a trace of brownish-black deposit. When the liquid is long boiled, so that most of the excess of ammonia is driven off, it begins to assume a blue colour, but this colour is never so pure as when potash is employed. The colour is improved when the liquid is not boiled but left in a vessel exposed to the air.

(3.) Carbonate of potash throws down at first a copious light reddish-brown precipitate, but which gradually dissolves again, and the colour of the solution becomes much lighter. There remains a mere trace of a brownish-black precipitate. When the mixture is boiled it does not assume a blue colour. When we evaporate the whole to dryness, and treat the dry residue with water, a little blue coloured matter remains undissolved, and the solution after a time assumes also a blue colour.

(4.) Bicarbonate of potash produces at first no change, but by degrees the liquid loses its colour, just as when potash, or carbonate of potash is used, but no precipitate appears.

(5.) Carbonate of soda destroys the colour like the other carbonates. Boiling at first occasions no change, but if we continue the process, a blue colour at last appears. Carbonate of ammonia occasions the same phenomena.

(6.) Phosphate of soda at first produces no change, but after a considerable interval of time the liquid becomes nearly colourless.

(7.) Oxalic acid occasions at first no sensible alteration, but by degrees the colour of the liquid is destroyed.

(8.) Prussiate of potash produces the same effect.

(9.) Cyanodide of mercury occasions no change.

(10.) Nitrated suboxide of mercury throws down a light brown precipitate.

(11.) Sulphate of iron occasions no change at first, but after a considerable interval of time, a dirty greenish precipitate falls.

(12.) Protochloride of tin throws down a light-brown precipitate.

(13.) Iodide of potassium discolours the solution, but occasions no precipitate.

(14.) Sulphuretted hydrogen at first discolours the liquid. After a considerable time, a brown precipitate of sulphuret of iridium falls. Sulphohydrate of ammonia occasions a brown precipitate, dissolved by a small excess of the precipitating reagent. When muriatic acid is poured into this solution, sulphuret of iridium falls down.

(15.) A plate of zinc throws down the iridium in the metallic state, under the form of a black powder.

Osmium.

Osmium is usually obtained in the state of a black powder, but when in a compact state it has the metallic lustre. When heated in a close vessel it undergoes no change, neither melting nor volatilizing, but in the open air it flies off when heated under the form of an oxide, which has a strong and characteristic smell. Nitric acid dissolves it and converts it into osmium acid, and both acids are volatilized together. The change is more easily effected by aqua regia. The chloride of osmium is obtained, when osmium previously mixed with chloride of potassium is exposed to a current of chlorine gas while elevated to a red heat. The chloride of osmium has a red colour, but its solution in water is yellow. This chloride produces with reagents the following phenomena:

(1.) Potash occasions at first no change, but when the mixture is heated, it assumes a black colour, and a black precipitate falls, after which the solution becomes lighter coloured.

(2.) Ammonia occasions at first no alteration, but after some time the liquid becomes brown, and a brown precipitate falls.

(3.) Carbonate of potash produces no sensible change at first, but after a considerable interval a black precipitate falls, and the liquid assumes a bluish colour. Bicarbonate of potash acts in the same way.

(4.) Carbonate of soda acts as carbonate of potash, only the liquid has not quite so strong a blue colour.

(5.) Carbonate of ammonia acts as ammonia.

(6.) Phosphate of soda occasions no change.

(7.) Oxalic acid is equally inefficacious.

(8.) Prussiate of potash and cyanodide of mercury throw down no precipitate.

(9.) Nitrated suboxide of mercury throws down a yellow precipitate.

(10.) Sulphate of iron occasions no change.

(11.) Protochloride of tin throws down a brownish precipitate.

(12.) Iodide of potassium occasions no change at first, but after some time a black precipitate falls, and the liquid assumes a blue colour.

(13.) Sulphuretted hydrogen produces no change at first, but after a considerable interval, a yellow precipitate falls. Sulphohydrate of ammonia throws down a yellow precipitate which is soluble in an excess of the precipitant.

(14.) A plate of zinc throws down a black powder from solutions of osmium.

The analysis of platinum ore is attended with considerable difficulties. We must begin by separating all the foreign matter, and leaving nothing but the small plates of crude platinum.

After every thing that seems to be foreign has been removed, we must digest the purified ore in dilute muriatic acid. The object of this is to free it from the coating of peroxide of iron with which it is often covered, and to free it from any metallic iron with which it may be mixed.

The ore must now be ignited, but it should be previously weighed, because the ignition occasions an increase of weight by peroxidizing some of the iron.

The constituents of this complicated ore, arranged according to the relative amount of the constituents, are platinum, iron, iridium, copper, rhodium, palladium, and osmium.

1. Dissolve the portion of ore taken for analysis (30 grains are sufficient) in aqua regia, in a glass retort furnished with a receiver, which must be kept constantly cold. The liquid which distils over is yellow, and carries with it some of the ore, which, rising in a fine cloud during the effervescence, is driven over mechanically by the nitrous gas evolved. Distil off the acid till the liquid in the retort assumes the consistence of a syrup, and congeals on cooling. The saline mass is dissolved in the smallest possible quantity of water, and the solution poured off with the proper precaution. The acid which had distilled over is poured back upon the undissolved residue in the retort, and distilled again. This in general is sufficient to dissolve the whole of the ore. Distil as before to a syrup, re-dissolve, and pour off. If the liquid in the receiver be not colourless, it must be poured back into the receiver and re-distilled.

2. The colourless distilled liquid is diluted with water, and saturated with ammonia, or if this should be thought too expensive, with hydrate of lime, taking care however to leave a slight excess of acid. Put the solution into a flask, and add to it sulphuretted hydrogen water in excess. Then shut the mouth of the flask, (which ought to be nearly filled with the solution), and let it remain at rest till the precipitate formed in it have time to subside. The clear liquid is now drawn off with a syphon, and the precipitate, which consists of sulphuret of osmium, is collected on a weighed filter, washed,

dried, and weighed. It contains about 51 per cent. of osmium.

3. Should the liquid smell of chlorine after dissolving the saline mass, we must allow it to digest till this-smell vanishes. If a precipitate appear, it is oxide of palladium, which must be re-dissolved. The whole is then poured into a weighed filter, and the matter collected on this filter is to be washed and dried. It consists of grains of iridium ore and sand, which could not be separated previous to the analysis. Sometimes, besides these substances, a black powder appears, which looks like charcoal, and which passes through the filter during the washing of the other matter. It is peroxide of iridium, and it is produced when the aqua regia used for the solution contains too much nitric acid.

4. The filtered solution is mixed with twice its bulk of alcohol, of the specific gravity of 0·833, so that the mixture may contain about 60 per cent. of alcohol. A concentrated solution of chloride of potassium in water is now added, so long as it throws down a precipitate. This precipitate is a mixture of potassium-chloride of platinum, and potassium-chloride of iridium, contaminated with the same salt of rhodium, and even of palladium. The precipitate has a fine lemon-yellow colour, when it is free from iridium; but when iridium is present it assumes all the shades of red, from deep yellow to cinnabar. It is collected on a filter and washed with spirits of the specific gravity of 0·896, and holding in solution a little chloride of potassium. The washing is continued till the liquid which passes through the filter gives no precipitate with sulphuretted hydrogen water.

5. The washed double chlorides on the filter are dried and mixed as equably as possible with their own weight of carbonate of soda. The filter, with what of the precipitate cannot be removed, is burnt, and its ashes mixed with carbonate of soda, and added to the rest of the double salt. Put the whole into a porcelain crucible, and heat it gently till it is quite black throughout. This process could not be conducted in a platinum crucible, because the crucible would be corroded, and a portion of the metal mixed with the chlorides under investigation.

By this process the double salts are decomposed, and the platinum reduced to the metallic state. The iridium and rhodium become oxidized, and remain in such a state as to permit the separation of the platinum from them by solution.

The heated saline mass is washed with water till the greater part of the salt is dissolved. Dilute muriatic acid is then added to the remainder to extract the alkali combined with the oxides of iridium and rhodium. The mass is washed, dried, ignited, and weighed.

Now mix it with five or six times its weight of bisulphate of potash, and fuse the whole in a platinum crucible, covered with a lid. The rhodium is oxidized and sulphurous acid given out, and a solution of the oxidized rhodium takes place in the salt, which acquires a red or black colour, according to the portion of rhodium taken up. This operation is repeated several times; indeed as long as the salt acquires colour.

6. The quantity of rhodium may be estimated two ways: if we wash, ignite, and weigh the undissolved platinum, the loss of weight indicates the peroxide of rhodium, which contains 71 per cent. of metal; or we may mix the acid solution of rhodium with an excess of carbonate of soda, evaporate the mixture to dryness, and ignite the dry salt in a platinum crucible. Upon dissolving it again in water, the peroxide of rhodium remains behind; it is collected, washed, dried, and reduced by hydrogen gas in the way formerly explained. The rhodium thus obtained may contain palladium; this is extracted by aqua regia. The solution of palladium is neutralized, and then precipitated by cyanodide of mercury. The weight of the palladium thus obtained is of course abstracted from that of the rhodium.

7. After the separation of the rhodium, the metallic mass is next treated with dilute aqua regia by digestion, in which platinum is separated. The solution appears very dark in consequence of the presence of peroxide of iridium, but when this oxide has fallen to the bottom the colour will be found to be a pure yellow. The clear liquid is decanted; concentrated aqua regia mixed with common salt is now poured over the residue, and the mixture is evaporated to dryness. The common salt is added to prevent the formation of protochloride of platinum. The solution thus obtained consists chiefly of platinum, but it contains also a little iridium. Upon dissolving the dry mass the peroxide of iridium remains behind; as it is apt to pass through the filter when washed with pure water, we must wash it with a solution of common salt, and afterwards with a solution of sal ammoniac, to get rid of the common salt. It is now burnt with the filter, reduced by hydrogen gas, and weighed. The solution of soda salt, which contains

iridium, is mixed with carbonate of soda, evaporated to dryness, and heated to redness. The product is a mixture of platinum and peroxide of iridium, which being freed by washing from soluble salts and then treated with aqua regia, leaves the peroxide of iridium. Caustic ammonia still precipitates from the solution a trace of brown oxide of iridium, which, however, is not quite free from platinum. The peroxide of iridium is reduced, and the metal is added to the quantity formerly obtained.

8. To learn the weight of the platinum we must subtract that of the peroxide of rhodium from the common weight of the platinum, peroxide of rhodium, and peroxide of iridium. The weight of iridium obtained must be increased 12 per cent. to convert it into peroxide, and this augmented weight must also be deducted from the sum total. The remainder, after these two subtractions have been made, is the weight of the platinum.

9. We have still the alcoholic solution of No. 4. to examine. We put it into a flask furnished with a ground stopper, and pass a current of sulphuretted hydrogen through it till it is saturated. The flask is then closed, and left for twelve hours in a warm place, by which time a precipitate will have subsided. It is now filtered, and the alcohol evaporated off. During this concentration an additional precipitate falls, which is added to the former.

This precipitate consists of sulphuret of iridium, sulphuret of rhodium, sulphuret of palladium, and sulphuret of copper, while the filtered liquid contains iron, a little rhodium and iridium, and a trace of manganese. During the evaporation of the alcohol, a greasy and disagreeable smelling sulphuret is deposited, which cannot be washed out. After the solution has been entirely washed away, this substance can be removed by pouring a little ammonia into the vessel. The solution of it is put into a platinum crucible and evaporated to dryness, after which the other moist sulphurets are also put into the same crucible and roasted as long as sulphurous acid is produced. When the roasting is ended, muriatic acid is poured over the mass, subsulphates of copper and palladium dissolve, forming a green or yellowish-green solution, while the oxides of iridium and rhodium, with a small quantity of platinum, remain undissolved.

10. The muriatic acid solution is mixed with chloride of potassium and nitric acid, and evaporated to dryness. A dark

coloured saline mass is obtained, which contains chloride of potassium, potassium-chloride of copper, and potassium-chloride of palladium. The first two of these salts being soluble in alcohol of the specific gravity of 0·833, are extracted by that spirit. The palladium salt then alone remains; it is collected on a filter and washed with alcohol. It contains 28·84 per cent. of palladium.

The spirituous solution of the copper salt contains a trace of palladium, too small to be of any consequence in the analysis. The solution is evaporated to get rid of the alcohol, and the copper precipitated by caustic potash. It is in the state of black oxide, every 5 grains of which are equivalent to 4 grains of metallic copper.

11. The roasted sulphurets (No. 9.) which could not be dissolved in muriatic acid are fused with bisulphate of potash, the process being repeated as long as the salt becomes coloured. By this means the rhodium is dissolved out. The residual matter thus deprived of rhodium is treated with aqua regia, which dissolves a little platinum, and leaves peroxide of iridium.

12. The concentrated solution from which the sulphurets were precipitated, contains only iron in the state of protochloride, a small quantity of iridium and rhodium, and a trace of manganese. It is mixed with a sufficient quantity of nitric acid, and boiled till the iron is fully peroxidized. The peroxide of iron is then precipitated by caustic ammonia, and the precipitate is washed, ignited, and weighed. The peroxide of iron is reduced by hydrogen gas, and the metal is dissolved in muriatic acid, which, towards the end, must be warmed. There remains undissolved a small quantity of black powder. This black powder is ignited in an open vessel, by which it acquires the same degree of oxidizement as the peroxide of iron. It is then weighed, and its weight is deducted from that of the peroxide of iron. Every 5 grains of this peroxide are equivalent to 3·5 grains of metallic iron. The black powder is a mixture of iridium and rhodium, in a state not yet well understood.

13. The solution which was precipitated by caustic ammonia, still contains iridium and rhodium. It is mixed with carbonate of soda in sufficient quantity to decompose the ammoniacal salts, and then evaporated to dryness. The residue, after gentle ignition, is dissolved in water. The metallic oxides remain undissolved. The quantity of manganese con-

tained in the metallic oxides, is scarcely greater than to enable the operator to detect it. It may be extracted from the washed oxides by muriatic acid. But when 30 grains only of the ore are analyzed, the manganese is too minute to be capable of being weighed.

The preceding mode of analyzing the ore of platinum, is the one put in practice by Berzelius, in his elaborate paper on the metals in native platinum, inserted in the Memoirs of the Stockholm Academy for 1828. It is exceedingly intricate, and too complicated to give exact results. But it is the only mode hitherto devised by analytical chemists. Before it was published, we were not in possession of any method of separating these singular metals from each other with any pretensions to accuracy. The method suggested by Berzelius, therefore, though imperfect, is still of considerable value as a first step, which, no doubt, will be gradually improved upon and simplified, till it reaches the requisite degree of precision.

Sect. 11. *Arsenic.*

Arsenic occurs occasionally in the mineral kingdom in the state of metal, and is then known by the name of *native arsenic*. It is found, however, much more frequently combined with other metals constituting arseniets, or united to sulphur, forming a sulphur acid or a sulphide of arsenic. We shall therefore defer the account of the mode of separating arsenic from other bodies till we come to treat of the sulphur salts. In this section it will be sufficient to give the characters of the metal, and the mode of detecting it or its acids, when they occur in the mineral kingdom.

Arsenic is a white metal, very brilliant while quite fresh, and not unlike iron, but speedily tarnishing and becoming black on the surface. It is soft and very brittle, and rather light. When heated, it sublimes before it melts. If it be heated almost to redness in the open air, it takes fire, and burns with a very pale white flame, giving out a white smoke having a strong smell of garlic. It combines with two proportions of oxygen, forming two acids, the arsenious and arsenic. It is by converting arsenic into arsenic acid, that its quantity in any compound can be most accurately determined. This, in general, is easily done, by dissolving the ore in nitric acid, or nitro-muriatic acids. It is requisite to be acquainted with the effect of re-agents upon this acid, that we may know it when it occurs.

(1.) An arseniate when mixed with carbonate of soda, and exposed to the action of the blowpipe on charcoal, gives out the well-known odour of garlic, which characterizes the vapour of metallic arsenic. When mixed with charcoal powder and a little boracic acid, and heated in a glass tube closed at one end, they deposit on the cold part of the tube, a metallic mirror of arsenic, easily distinguished by the characteristic odour producible by heat.

(2.) When an arseniet is in solution, sulphuretted hydrogen gas immediately strikes a yellow colour, and if the solution be acidulated with muriatic acid, a bright yellow precipitate falls. This precipitate is soluble in sulphohydrate of ammonia; while the precipitate from cadmium, which resembles the arsenical precipitate very closely, is insoluble in that liquid.

(3.) Sulphohydrate of ammonia occasions no precipitate in a solution containing a neutral arseniate; but if muriatic acid be added, sulphuretted hydrogen is disengaged, and a bright yellow precipitate falls.

(4.) Nitrate of silver throws down a brown precipitate, easily soluble in nitric acid or in ammonia.

(5.) Chloride of barium, chloride of calcium, and lime water, occasion white precipitates, very readily soluble in sal ammoniac, provided the liquid does not contain free ammonia.

(6.) Nitrate of lead throws down a white precipitate, which, when heated on charcoal before the blowpipe, gives out a white smoke, characterized by the well-known garlic odour of arsenic.

The action of re-agents upon salts containing arsenious acid, closely resembles their action on arseniates. They may be distinguished from arseniates by the *yellow* precipitate which they let fall when mixed with nitrate of silver. The precipitate by nitrate of silver from an arseniate, is brown.

Sect. 12. *Antimony.*

Antimony occurs occasionally in the metallic state, and is then distinguished by the name of native antimony. But it is much more frequently met with combined with sulphur. It will be better on that account to reserve an account of the method of separating antimony from other metals, till we come to treat of the sulphur salts. Here it may be proper to point out the characters of antimony, by which it may be recognised when it occurs.

Antimony has a silver, or rather zinc white colour, a good deal of lustre, and a plated texture. It is brittle, so that it can be easily reduced to powder in a mortar. When heated to redness, it melts and gives out copious white fumes of oxide of antimony, which are deposited in shining crystals. Nitric acid oxidizes antimony with rapidity, but does not dissolve it. The best solvent is aqua regia; the solution is brown, contains always an excess of acid, and is very corrosive.

Antimony unites with three different proportions of oxygen, and forms oxide of antimony, antimonious acid, and antimonic acid.

The oxide of antimony is white, but when heated in a retort, it melts into a yellow mass and may be easily sublimed, when it forms brilliant needle-form crystals. It dissolves in muriatic acid, and the solution becomes milky when diluted with water, but a considerable excess of acid re-dissolves the precipitate. This acid solution of oxide of antimony produces the following phenomena with re-agents.

(1.) Potash produces a white precipitate, insoluble in an excess of the potash.

(2.) Ammonia acts in the same manner, and so do carbonate of potash, bicarbonate of potash, and carbonate of ammonia.

(3.) Phosphate of soda throws down a white precipitate, and so does oxalic acid. These precipitates are occasioned by the water in which the re-agents are dissolved.

(4.) Prussiate of potash throws down a white precipitate, which does not dissolve in muriatic acid.

(5.) Sulphuretted hydrogen produces a beautiful orange-red precipitate. Sulphohydrate of ammonia throws down the same precipitate, but it is easily re-dissolved by adding an excess of the sulphohydrate.

(6.) A plate of zinc throws down antimony in the metallic state, and in the form of a black powder.

Salts containing oxide of antimony, if mixed with carbonate of soda, and heated on charcoal by the interior flame of the blowpipe, are reduced. The bead of antimony produced remains long in the melted state, and gives off a thick white smoke. When the smoke ceases, the globule of antimony becomes covered with a net-work of crystals of oxide of antimony.

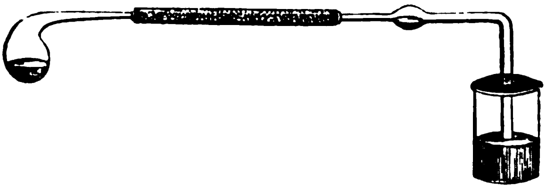
The phenomena with antimonious and antimonic salts, are so nearly the same, that it is unnecessary to enter into details.

CHAP. II.

METHOD OF ANALYZING SELENIETS.

SELENIUM has been found in the mineral kingdom, united to zinc, lead, copper, silver, and palladium. Of these seleniets, the most abundant is seleniet of lead, which has been found in considerable quantity in the Hartz mines. We are indebted to M. H. Rose for the first analysis of these seleniets. He proceeded in the following way:—

A small globular cavity was blown in the centre of a glass tube. To one extremity of this globe, a small glass tube, 4 inches long, was attached by the blowpipe, and to the other extremity, a wide glass tube, about 12 inches long, and bent at a right angle in the middle. These tubes, with the glass cavity, were weighed, the seleniet to be analyzed was then put into the glass globe, and its weight determined. The narrow tube was then attached to an apparatus for preparing chlorine, which was dried by passing it through an intermediate tube containing chloride of calcium. The extremity of the wide tube was plunged into the bottom of a vessel filled with water. The tubes being filled with chlorine gas, the bulb is heated gently by a spirit of wine lamp. Chloride of selenium is formed and volatilized. The protochloride is first formed. It flows in the form of an orange-coloured liquid along the tube into the water. Selenium is deposited, but again dissolved by the chlorine which passes into it. Afterwards nothing is formed but perchloride of selenium, which condenses in the tube, and would shut it up altogether unless it were very wide. This chloride must frequently be driven by a lamp along the tube, till it passes into the water. The chlorine should pass over very slowly, for if the bubbles of gas rise too rapidly through the water, some of the chloride of selenium



might be carried off by it before it had time to be decomposed by the water. After the passage of the chlorine has continued five or six hours, all the metals in the bulb are converted into chlorides. The process is at an end when no more chloride of selenium is sublimed. The bulb is then allowed to cool with the requisite precautions to prevent its cracking, when the chloride of lead, which had been in fusion, congeals. The portion of the tube containing chloride of selenium, is now to be cut off, and this chloride is carefully washed into the water containing the rest of it. After washing and drying the tube, it is weighed with the glass bulb containing the metallic chloride. We must take care not to apply too much heat to the bulb, otherwise some of the chloride of lead might be volatilized.

Muriatic acid is added to the water containing the chloride of selenium, and then a sufficient quantity of sulphite of ammonia to precipitate the selenium. For this purpose, the whole must be digested for a considerable time, and even boiled, to ensure the deposition of the whole selenium. The selenium is now to be collected on a weighed filter, washed, dried, and weighed.

If the mineral analyzed be seleniet of lead, what remains in the bulb is merely chloride of lead, composed of

Chlorine, . . .	4·5
Lead, . . .	13
	17·5

Or, every 17·5 grains of it contain 13 of lead, or 0·743 of the weight is lead.

Should silver be present as well as lead, we separate the two metals by boiling the chlorides in water. The chloride of lead dissolves, while that of silver remains.

Should iron be present, it is sublimed along with the chloride of selenium, and easily separated by means of ammonia, which throws it down in the state of peroxide.

Should cobalt occur along with the lead, it will remain in the bulb in the state of chloride, mixed with chloride of lead. Water will dissolve the two chlorides completely. Mix sulphuric acid with the solution, and evaporate to dryness to get rid of the muriatic acid and the excess of sulphuric acid. This residue being digested in water, the sulphate of cobalt will dissolve, while the sulphate of lead remains in the state of a white powder. Let it be washed, ignited, and weighed.

Multiply the weight by 0·684, the product is the weight of the metallic lead.

The cobalt may then be precipitated by caustic potash. The precipitate washed, dried, and ignited, is protoxide, each 4·25 grains of which are equivalent to 3·25 grains of metallic cobalt. So that if we multiply the weight of the oxide by 0·765, the product will be the quantity of metallic cobalt.

Caustic potash does not throw down cobalt completely, but the small residue falls when sulphohydrate of ammonia is added to the solution. This precipitate when dried, is sulphuret of cobalt. If we multiply its weight by 0·619, the product is the quantity of cobalt which it contains.

Should copper exist in the mineral along with lead, it is separated precisely in the same way as cobalt, by throwing it down, after abstracting the sulphate of lead, by caustic potash. When copper, lead, and silver, occur together, the chlorides of lead and copper are dissolved by boiling water, while the chloride of silver remains behind. Then the chlorides of lead and copper are converted into sulphates, and the sulphate of copper being dissolved, the metal is thrown down in the state of oxide by caustic potash.

When seleniet of mercury is mixed with seleniet of lead, the method of analysis is a little different. The chloride of mercury (corrosive sublimate) sublimes along with the chloride of selenium, and both are dissolved in the water, but the oxide of mercury cannot be completely precipitated by an alkali. But sulphohydrate of ammonia throws it down completely. Add to the aqueous liquid containing the two volatile chlorides ammonia, and then sulphohydrate of ammonia. Collect the sulphuret of mercury on a weighed filter, wash it and weigh it. If the weight be multiplied by 0·862, the product gives the weight of the mercury contained in it. Having thus separated the mercury, add muriatic acid till the liquid becomes acid, and drive off the sulphuretted hydrogen. After oxidizing by aqua regia the sulphuret of selenium deposited, and adding it to the liquid, let the selenium be thrown down by sulphite of ammonia in the way already described.*

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* Ann. de Chim. et de Phys. xxix. 113.

CHAP III.

ANALYSIS OF ANTIMONIETS.

Only two minerals are at present known which are composed of antimony united to another metal, and both in the metallic state. These are *antimoniet of nickel* and *antimoniet of silver*.

Antimoniet of nickel may be dissolved in nitromuriatic acid, and the antimony thrown down by sulphuretted hydrogen, after having added a quantity of tartaric acid to prevent the precipitation of any of the nickel. The sulphuret of antimony is collected on a filter, washed, and dried, and reduced by hydrogen gas. The nickel may be thrown down by caustic potash, washed, dried, ignited, and weighed. The weight multiplied by 0·765 gives the quantity of metallic nickel in the oxide.*

When antimoniet of silver is digested in nitric acid the silver is gradually dissolved, while the antimony remains behind in the state of an oxide. This oxide may be dissolved in muriatic acid, precipitated by dilution with water, and the remainder by an alkali. The precipitated oxide is reduced by hydrogen, and its weight estimated. The silver solution is to be thrown down by common salt, and the resulting chloride collected, washed, dried, fused, and weighed. Should any iron exist in the mineral it will be found in the nitric acid solution after the silver has been thrown down, and may be precipitated by potash, or ammonia, washed, dried, ignited, and weighed.

CHAP. IV.

ANALYSIS OF ARSENIETS.

Arsenic, in the metallic state, exists in the mineral kingdom in combination with no fewer than seven metals, constituting seven different mineral species. These are

Sesquiarseniet of iron,

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* See Stromeyer, Poggendorff's Annalen, xxxi. 134.

Arseniet of manganese,
Arseniet of nickel,
Arseniet of cobalt,
Arseniet of copper,
Arseniet of silver,
Arseniet of antimony.

Arseniet of iron may be digested in aqua regia as long as any thing is taken up. The undissolved residue is collected on a filter, washed, dried, and weighed. Being exposed to a red heat, the sulphur mixed with this residue burns, and its quantity is determined by weighing the residue, and subtracting the amount of its weight from that of the original quantity. What remains now is part of the gangue with which the mineral was contaminated. Its amount is to be subtracted from that of the mineral subjected to analysis.

The solution contains sulphuric acid which is thrown down by chloride of barium, taking care that such an excess of acid exists in the liquid as will prevent the precipitation of any arseniate of barytes.

A current of sulphuretted hydrogen gas is now passed through the liquid till it is saturated, and smells strongly of that gas. It is put in a warm place, and left till all this smell is dissipated. The sulphuret of arsenic thrown down is collected on a filter, washed, dried, and weighed. It is a compound of 4·25 arsenic and 5 sulphur. Therefore, if we multiply the weight of sulphuret obtained by 0·459, the product will be the amount of the arsenic in the mineral. Or after weighing the sulphuret of arsenic we may digest it in aqua regia, determine the amount of sulphur that remains undissolved, throw down the sulphuric acid by chloride of barium, and determine the amount of the sulphur which it contains. The quantity of sulphur in the sulphuret being thus known, if we subtract it from the weight of the sulphuret of arsenic the remainder will be the weight of the arsenic in the mineral.

The iron in the solution has by the action of the sulphuretted hydrogen been brought into the state of protoxide. By digestion with nitric acid, or by a current of chlorine gas, it is to be brought to the state of peroxide, and then thrown down by ammonia, washed, dried, ignited, and weighed.

Should the solution besides iron contain cobalt and nickel, as is sometimes the case, the iron must be thrown down by benzoate of ammonia, and the oxides of nickel and cobalt, by caustic potash. The nickel and cobalt must be separated from each other by processes to be afterwards described.

Arseniet of copper may be dissolved in aqua regia. The solution must be rendered alkaline by an excess of ammonia, and then digested in a close vessel with a considerable excess of sulphohydrate of ammonia. The copper is precipitated in the state of sulphuret. One half the weight of this sulphuret usually denotes the amount of the copper. But as this is not always the case the best way is to digest the sulphuret in nitric acid till the copper is dissolved, and then to throw it down by caustic potash or soda. It is obtained in the state of black oxide, every 5 grains of which are equivalent to 4 grains of metallic copper.

The solution containing the arsenic is diluted with water, and then mixed with as much muriatic acid as is sufficient to render it acid. Sulphuretted hydrogen is disengaged, and sulphuretted arsenic is precipitated. It must be collected on a weighed filter, washed, dried in a gentle heat, and weighed. Put as much of it as can be separated from the filter into a small glass flask, then weigh the filter with what remains on it to determine how much of the sulphuret of arsenic has been submitted to experiment. Pour aqua regia over the sulphuret in the flask and allow it to digest. The arsenic is converted into arsenic acid, and the sulphur partly acidified, and partly precipitated in the state of pure sulphur. Filter the solution to separate the unacidified sulphur, and precipitate the sulphuric acid by means of chloride of barium. Calculate the quantity of sulphur in the sulphate of barytes thrown down, and add it to the weight of the sulphur collected on the filter. The amount of this subtracted from that of the sulphuret of arsenic experimented upon gives the weight of arsenic contained in that arseniet. The only error likely to be committed is collecting the sulphur upon the filter before all the arsenic is dissolved. This must be carefully guarded against.

Should the arseniet of copper contain iron, as is said to be the case, that metal will be precipitated along with the copper in the state of sulphuret. We must digest the precipitated sulphurets in aqua regia till both the metals are completely dissolved. The solution must then be neutralized, and the iron thrown down by benzoate of ammonia, and afterwards the copper by caustic potash. From these precipitates the weight of the iron and copper is to be determined in the way already explained.

Arsenical silver, according to the analysis of Klaproth, contains silver, iron, arsenic, and antimony. It may be digested in nitric acid, which will dissolve the silver and arsenic, and most of the iron. Common salt will throw down the silver in the state of chloride. The iron and arsenic may be separated by the methods already pointed out.

The residue insoluble in nitric acid may be taken up by digestion in muriatic acid, except a little chloride of silver, which is to be washed, dried, fused, and weighed. Let the solution be precipitated by caustic potash, and the precipitate after being washed re-dissolved in muriatic acid. If we dilute the solution with water the antimony will precipitate. What remains in solution is peroxide of iron, which may be precipitated by caustic ammonia.

The method of separating *arsenic* and *antimony* has not been brought to the same state of perfection, as the separation of arsenic from the other metals treated of in this chapter. If the alloy consists of arsenic and antimony alone, the former metal may be sublimed from the latter by the simple application of heat. The alloy is put into a glass ball blown in the middle of a tube. A current of dry hydrogen gas is passed through it till all the common air is expelled. Then heat is applied to the ball and continued as long as arsenic sublimes. The arsenic must be driven along the tube and expelled by a small spirit lamp. After the process is finished the metallic antimony is weighed. The difference between its weight and that of the original alloy gives the amount of the arsenic driven off.

When the antimony and arsenic are in solution, or when they are combined with other bodies, this process cannot be applied. Mix the solution with tartaric acid to prevent the antimony from being precipitated when water is added. Dilute with water, and pass a current of sulphuretted hydrogen gas through the liquid till it is saturated, and apply heat to ensure the complete precipitation of the sulphurets. What precipitates first is sulphuret of antimony, and after a considerable interval the bright yellow precipitate of sulphuret of arsenic appears. Mix the precipitates by agitation, and collect them on a weighed filter. Let it be dried in a very gentle heat till it ceases to lose weight. After determining the weight of the whole, shake about one half into a flask. Warm the filter with the remainder, and weigh it; by this proceeding the exact quantity experimented on is known.

The portion shaken into the flask is very cautiously oxidized by aqua regia, beginning first by adding fuming nitric acid in small quantities at a time, and finally muriatic acid. Mix the solution thus produced with tartaric acid, and dilute it with water. Should any sulphur fall down it should be collected, dried, and weighed. The sulphuric acid in the solution is precipitated by chloride of barium, and the weight of sulphur in it determined. The knowledge of the weight of the sulphur gives us that of the arsenic and antimony together.

Another portion of the precipitated sulphurets is heated in an atmosphere of hydrogen gas, just as sulphuret of antimony is heated to determine how much antimony it contains. The sulphur from the antimony first sublimes, and then the sulphuret of arsenic. At last nothing remains but metallic antimony. Knowing by these two processes the weight of sulphur and of antimony in the mixed sulphuret, it is easy to deduce that of the arsenic.

When arsenic and antimony are together alloyed with other metals, these metals will remain in solution after the arsenic has been thrown down by sulphuretted hydrogen, provided they be metals not precipitated by sulphuretted hydrogen, as is the case with iron, manganese, nickel, and cobalt. After separating the arsenic and antimony, we must throw down these metals by sulphohydrate of ammonia, and analyze the sulphurets thus obtained by the methods hereafter to be explained.

CHAP. V.

ANALYSIS OF TELLURETS.

TELLURIUM is found in the mineral kingdom alloyed with lead, bismuth, and silver, under the forms of bitelluret of lead, bitelluret of silver, and telluret of bismuth. It occurs also in the state of native tellurium, and there are two ores of gold formerly found in Transylvania, and still existing in cabinets, which contain tellurium. These are white tellurium ore, and graphic ore of tellurium.

Tellurium is a brittle foliated metal, having the colour of silver, easily fusible, and capable of being sublimed at a heat below redness. When heated before the blowpipe it gives a blue tinge to the flame. It forms an oxide when heated in the open air, which has a white colour, and 5 grains of it are equivalent to 4 grains of the metal. Tellurium dissolves readily in nitric acid or aqua regia, and the solution is colourless. The oxide of tellurium is much more easily soluble in aqua regia than in nitric acid. This solution, brought as nearly as possible to a neutral state, exhibits the following phenomena with reagents:—

(1.) Potash throws down an abundant white precipitate, soluble in an excess of the precipitant. Ammonia, and carbonate and bicarbonate of potash, and carbonate of ammonia, act precisely in the same way. An excess of carbonate of potash strikes a green colour, which disappears on boiling the liquid, and does not again show itself.

(2.) Phosphate of soda throws down a white precipitate.

(3.) Oxalic acid throws down no precipitate.

(4.) Prussiate of potash occasions no precipitate.

(5.) Sulphuretted hydrogen throws down a brown precipitate, very similar to the precipitate thrown down by the same reagent from a solution of protoxide of tin. Sulphohydrate of ammonia throws down a similar precipitate.

(6.) A plate of zinc throws down tellurium in the metallic state, under the form of a bulky black matter.

The insoluble compounds of tellurium are generally soluble in muriatic acid.

Bitelluret of lead was found by Klaproth to contain lead, tellurium, gold, silver, copper, and sulphur.

Reduced to a fine powder it may be digested in aqua regia, and the solution separated while boiling hot from the residue, consisting partly of sulphur, and partly of sulphate of lead. Let the residue be weighed and the sulphur driven off. The residue is sulphate of lead, composed of 5 sulphuric acid and 14 oxide of lead. Hence every 19 grains of it are equivalent to 2 grains of sulphur, and 13 grains of lead in the metallic state.*

The solution thus freed from sulphur, on cooling deposits numerous crystals of chloride of lead. The liquid must be concentrated, and set aside to obtain as many of these crystals as possible. When washed and dried they are composed of

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* The silver, of which only a very minute quantity exists in the ore, will also be found in the residue in the state of chloride. It may be separated from the sulphate of lead by digesting the mixture in caustic ammonia.

4·5 chlorine, and 13 lead. Hence every 17½ grains of them contain 13 grains of lead.

The liquid thus freed from lead may be diluted with a little water, and then mixed with alcohol as long as a white precipitate continues to fall. After allowing the mixture to remain for some time in a warm place, collect this precipitate on a filter, and after washing it in alcohol, dissolve it in muriatic acid, and throw it down by caustic soda, taking care not to add the alkali in excess. When washed and dried it constitutes oxide of tellurium, every 5 grains of which are equivalent to 4 grains of metallic tellurium.

Distil off the alcohol, and dilute the concentrated solution with a little water, then add nitrated suboxide of mercury as long as a brown precipitate continues to fall. Collect this precipitate and fuse it with saltpetre; the gold will be obtained in the metallic state, melted into a globule.

The copper still remains in solution, but it may be thrown down by caustic potash. Even should a slight excess of the mercurial salt have been added it will not be injurious, because it will be driven off when we ignite the oxide of copper before weighing it.

Telluret of bismuth may be dissolved in nitric acid or aqua regia, and the solution is to be supersaturated with ammonia. After this sulphohydrate of ammonia is added in excess, and the whole set aside for some time in a stoppered phial. Sulphuret of bismuth precipitates, and may be analyzed by the methods afterwards to be pointed out; or we may consider every 11 grains of this sulphuret to be equivalent to 9 grains of bismuth.

The solution containing the tellurium is precipitated by muriatic acid, warming the liquid till the odour of sulphuretted hydrogen is dissipated. Collect the sulphuret of tellurium on a filter, wash it and dry it, and dissolve it in aqua regia. Raise this liquid (which must always contain an excess of muriatic acid) to the boiling point, and then add sulphite of ammonia gradually till the whole tellurium be precipitated in the state of a black powder. In this state it is metallic tellurium, which must be washed, dried in a gentle heat, and weighed.

Bitelluret of silver contains nothing but tellurium, silver, and a trace of iron. It dissolves readily in nitric acid, and the solution is hastened by the application of heat.

Throw down the silver from this solution by means of muriatic acid; the residual liquid may be put into a warm place, and treated with successive portions of muriatic acid till all the nitric acid which it contained is decomposed. It may then be diluted with water, and after being heated it may be mixed with muriatic acid and sulphite of ammonia. The tellurium is thrown down in the metallic state under the form of a black powder. The process must be repeated till all the tellurium is thrown down.

The liquid remaining still contains iron. A current of chlorine may be passed through it to peroxidize this iron, and the peroxide may be thrown down by caustic ammonia.

The other ores containing tellurium may be analyzed by the methods now pointed out.

CHAP. VI.

ANALYSIS OF IODIDES.

THE only combination of iodine and a metal, hitherto met with in the mineral kingdom, is *iodide of silver*.

Iodine is a substance having a blackish colour, and something of the metallic lustre. It is volatile, and characterized by the fine violet colour which it assumes when converted into vapour. It dissolves slightly in water, though the quantity is sufficient to strike a beautiful blue colour when mixed with a jelly of starch in water. It is much more soluble in alcohol than in water, and the solution has a pretty deep brown colour. It dissolves in caustic potash or soda ley, and by the solution is converted into two acids; namely, hydriodic acid, which forms with the soda a soluble salt, and iodic acid, the combination of which with soda is much less soluble, so that it usually falls in the state of a white powder.

When nitrate of silver is dropt into a hydriodate a white matter falls, having considerable resemblance to chloride of silver. This precipitate, like chloride and bromide of silver, is insoluble in dilute nitric acid; caustic ammonia has but little action on it, whereas it readily dissolves chloride and bromide of silver. These two characters are sufficient to enable us to distinguish the iodide of silver from other bodies, and consequently to detect the presence of iodine in liquids.

When iodide of silver is digested in nitric acid it is not attacked unless the acid be very strong. When digested in muriatic acid it is partly decomposed, and the colour and smell of iodine become sensible when heat is applied. When the muriatic acid is subjected to distillation, the iodine passes into the receiver, and is deposited in crystals.

CHAP. VII.

ANALYSIS OF CHLORIDES.

THE only chlorides hitherto observed in the mineral kingdom are those of silver and mercury.

The analysis of *chloride of silver* is sufficiently simple. A quantity of the chloride is put into a globular cavity, blown in a glass tube, to which is afterwards attached an apparatus for disengaging hydrogen gas and drying it, by allowing it to pass through a glass tube containing fused chloride of calcium. When the apparatus is filled with hydrogen gas, the heat of a lamp is applied to the glass containing the chloride, and continued till the chlorine is disengaged under the form of muriatic acid gas, and the reduced silver remains behind. By weighing this silver, and deducting the weight from that of the original chloride, we determine the weight of the chlorine disengaged.

The analysis may be conducted in another way. We may mix together in a porcelain crucible 5 parts of carbonate of potash and 4 parts of carbonate of soda, amounting together to twice the weight of the chloride of silver to be analyzed. This quantity, reduced to powder, is intimately mixed with the carbonates. By applying the heat of a spirit lamp with a circular wick, the silver is reduced with the evolution of carbonic acid gas. We dissolve out the alkalies, and saturate them with nitric acid; we then throw down the chlorine which they contain by nitrate of silver. The chloride washed, dried, and fused, gives us the weight of the chlorine. This chloride, if the assay was pure, ought to weigh just as much as the quantity experimented on.

Should *chloride of mercury* occur in the mineral kingdom, as it is said to do, it is easily analyzed by digesting it with a solution of caustic potash or soda. The filtered solution contains the chlorine. We have only to saturate it with nitric acid, and throw the chlorine down by nitrate of silver.

The mercury might be estimated from the weight of the oxide. The only chloride likely to occur is calomel, from which potash separates suboxide of mercury, composed of 25 mercury and 1 oxygen. But it is more accurate to estimate the mercury by putting another portion of the chloride, previously reduced to powder, into a flask, and pouring over it first a quantity of muriatic acid, and afterwards of protochloride of tin. This mixture is heated to the boiling point, and then set aside to cool, after being well corked up. The mercury is thrown down in the metallic state, first as a black powder, but which runs into globules when heated with muriatic acid. It is to be carefully dried and weighed.

CHAP. VIII.

ANALYSIS OF OXIDES.

THE number of minerals existing composed almost entirely of one or more metallic oxides united together, is very considerable, and the processes requisite differ so much, according to the nature of the metallic oxide present, that we must treat of each metal separately.

Sect. 1. *Oxides of Iron.*

Iron combines with two different proportions of oxygen, and forms two oxides; the protoxide is black, or rather very deep blue, and is a compound of 3·5 iron and 1 oxygen, so that its atomic weight is 4·5. It nowhere occurs pure in the mineral kingdom, but it is found in combination with the peroxide of iron, constituting the well known ore called *magnetic iron ore.* The peroxide of iron is red, and is composed of 3·5 iron and 1·5 oxygen, so that its atomic weight is 5. It occurs in the mineral kingdom in a pure state, and likewise in combination with water, constituting various species, formerly confounded under the name of *hematite.*

Magnetic iron ore, which is a compound of protoxide and peroxide of iron, requires, to render it soluble in muriatic acid, to be previously fused with thrice its weight of anhydrous carbonate of soda. If we digest the fused mass in water till every thing soluble is taken up, the iron ore will remain in a state fit for solution in muriatic acid. To the solution add a little nitric acid, and digest for some time, in order to peroxidize the iron. Concentrate the solution nearly, but not quite, to dryness, to drive off as much of the excess of acid as possible. Then dilute with water, neutralize with ammonia, and precipitate the peroxide of iron by benzoate of ammonia. The precipitate being collected, washed, dried, and ignited, gives the weight of peroxide of iron from the portion of ore analyzed. If the ore be pure nothing will remain in solution after the iron is thrown down.

Suppose that the weight of magnetic iron ore (after ignition) experimented upon is 29 grains, and that we obtain when we precipitate it by benzoate of ammonia 30 grains of peroxide. It is clear from the increase of weight that the iron during the digestion with nitric acid had combined with an additional dose of oxygen. Thirty grains of peroxide of iron are composed of

Iron, . . .	21
Oxygen, . . .	9
	30

Now, 21 iron is equivalent to 6 atoms, the atomic weight of iron being 3·5; and 9 being equivalent to 9 atoms of oxygen, it is obvious that in the peroxide of iron every atom of the metal is united to $1\frac{1}{2}$ atoms oxygen. But in the ore the metal was combined with only 8 atoms oxygen, as the original weight was only 29. It is obvious that in the ore 4 atoms of iron were combined with $1\frac{1}{2}$ atoms of oxygen, and two with 1 atom; or which is the same thing, the ore is a compound of 2 atoms peroxide of iron and 1 atom of protoxide, for protoxide of iron is a compound of 1 atom iron and 1 atom oxygen.

Fuchs has shown that carbonate of lime has the property of precipitating the peroxide of iron from its solution, but not the protoxide. Hence it may be employed to separate the two oxides from each other. Liebig has found that carbonate of magnesia answers better than carbonate of lime, because it forms a double salt with protoxide of iron, and thus prevents it from falling down when it absorbs oxygen.*

Specular iron ore is wholly composed of peroxide of iron. It requires, like the preceding mineral, to be fused with carbonate of soda, to render it soluble in muriatic acid. But when we precipitate the iron, wash it, dry it, and expose it to

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* Ann. de Chim. et de Phys. xlviii. 290.

a red heat, no increase of weight takes place. Frequently this ore of iron is mixed with variable quantities of earthy matter. The analysis of such impure specimens is to be conducted precisely in the way described in the early part of this work, when the method of analyzing stony bodies was detailed.

The analysis of *manganesian iron ore* and *Franklinite* are conducted precisely on the same principles. The ore is rendered soluble in muriatic acid by fusing it with carbonate of soda. The water in the mineral is determined, and the silica separated by the rules already laid down. The iron (which is in the state of peroxide) is thrown down by benzoate of ammonia, and the manganese by chloride of lime saturated with chlorine, or at least containing no excess of lime. Six grains of this precipitate, which is red, after ignition is equivavalent to 4½ grains of protoxide of manganese.

After the separation of the iron and manganese nothing remains but the zinc, which is thrown down from the solution raised to the boiling temperature by the addition of carbonate of soda.

The *hydrous peroxide of iron*, or *hematites*, as they were formerly called by mineralogists, are analyzed in the same way, taking care in the first place, to determine the quantity of water, by the methods already explained.

Sect. 2. *Oxides of Manganese.*

Manganese never occurs in the mineral kingdom except in the state of oxide. The protoxide is only met with when the mineral consists of a salt; the sesquioxide and the binoxide occur both in a separate state, and variously united with each other, and with water. Some of these ores of manganese contain also barytes, in a state of chemical combination with the deutoxide of manganese, which appears to act the part of an acid. Nearly the same method of analysis is to be applied to them all.

100 grains, or (better) 200 grains of the ore broken into small fragments, are put into a small green glass or porcelain retort, to the beak of which is luted a glass tube, the internal cavity of which is about half an inch in diameter, and the length of the tube is about 12 inches. This tube is filled with fragments of fused chloride of calcium, kept in their place by a little amianthus or cotton inserted into the two extremities of the tube. The retort, with its contents, and likewise this glass tube, must be previously weighed. A strong red heat

is now applied to the retort, and it is kept in this state of ignition for about an hour. The retort, with its contents, including the tube filled with chloride of calcium, are now weighed. The diminution of weight indicates the oxygen gas which has been driven off from the manganese ore. The tube with the chloride of calcium being now weighed, the increase of weight indicates the water expelled from the ore.

Another portion of the ore is to be digested in muriatic acid till complete solution takes place. The solution being evaporated to dryness, and re-dissolved in water acidulated with muriatic acid, leaves the silica, which is collected and estimated in the usual manner. The solution thus freed from silica, is tested for iron and for barytes. Should iron be found, it must be peroxidized and thrown down by benzoate of ammonia. Should barytes be present, (which is a pretty common occurrence,) it may be thrown down by sulphate of soda or sulphate of ammonia, or even by sulphuric acid. The sulphate of barytes is to be washed, dried, ignited, and weighed. From it we easily deduce the quantity of barytes contained in the ore under examination.

The manganese may be precipitated by caustic ammonia, washed, dried, and ignited. It is in the state of red oxide, every 4·833 grains of which are equivalent to 5 grains of sesquioxide, and 4·5 grains of protoxide.

On comparing the weight of the manganese extracted with that of the ore examined, making allowance for the water, silica, and barytes, obtained, it is easy to see in what state of oxidation the manganese existed. For example, if the oxygen evolved when added to the red oxide obtained, will just convert the whole into sesquioxide, it is obvious, that in the ore the manganese was in the state of sesquioxide. If the red oxide and oxygen together, convert the manganese into deutoxide, then deutoxide is the state of oxidation of the manganese in the ore. Most frequently the manganese is not wholly in the state of sesquioxide nor of deutoxide, but intermediate between protoxide and sesquioxide, or between sesquioxide and deutoxide. The quantity of red oxide obtained and of oxygen evolved, is always sufficient to enable us to determine the exact state of the oxidizement of the manganese, remembering that the atomic weights of these bodies are as follows:—

Manganese, . . .	3·5
Protoxide, . . .	4·5

Sesquioxide, . . .	5
Red oxide, . . .	4·833
Deutoxide, . . .	5·5

When oxide of manganese and oxide of zinc occur together, as they do in red zinc, we dissolve the mixture in muriatic acid. The solution may be divided into two equal portions. From the one we precipitate the oxide of manganese by means of chloride of lime, and from the other the oxides of zinc and manganese together, by heat and carbonate of soda.* The precipitate being washed, dried, and strongly ignited, is a mixture of oxide of zinc and red oxide of manganese. The knowledge of the quantity of manganese precipitated from one half of the liquid by means of chloride of lime, will enable us to deduce the weight of zinc in the second precipitate. This being deducted from the original weight of the ore, (supposing nothing else present) gives the weight of the oxide of manganese. And as we know how much manganese exists in the ore, we can easily infer the state of its oxidizement.

Sect. 3. *Oxides of Lead.*

The protoxide of lead and also the sesquioxide, have been met with in the mineral kingdom. Should these minerals, or at least, the first of them, contain carbonic acid, the quantity may be determined by putting 100 or 200 grains of the ore into a small porcelain retort, to which a tube with chloride of calcium is luted. A red heat will drive off the carbonic acid, and the diminution of weight sustained by the retort and tube, gives the weight of carbonic acid driven off. The increase in the weight of the tube with chloride of calcium gives the quantity of water in the ore.†

Another portion of the ore may be reduced to a fine powder, and digested with potash or soda ley. The oxide of lead will be dissolved. What remains is impurity, consisting usu-

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* When oxides of iron, and manganese, and magnesia, occur together, they may be separated by the following method first suggested by Stromeyer: Let the iron be peroxidized. Throw it down by means of bicarbonate of potash. Render the residual liquid acid, dilute it, and pass a current of chlorine through it, then add bicarbonate of potash. The manganese falls in the state of binoxide. Care must be taken to add the bicarbonate slowly as long as a precipitate falls. The magnesia may now be precipitated by phosphate of soda and caustic ammonia. See Poggendorff's Annalen, xi. 170.

† When the red oxide of lead is treated in this way, the loss of weight is owing to the evolution of oxygen gas, not of carbonic acid gas.

ally of oxide of iron, silica, lime, and perhaps alumina. This residue is to be analyzed by the rules already laid down in the first division of this treatise. The alkaline solution is neutralized by nitric acid, and the oxide of lead thrown down by sulphate of ammonia. The sulphate of lead, washed, dried, and ignited, is to be weighed. If we multiply the weight by 0·737, the product will indicate the weight of protoxide of lead which it contains. Knowing the weight of protoxide of lead, it is easy to deduce that of sesquioxide, for every 14 grains of protoxide are equivalent to 14½ grains of sesquioxide of lead.

The sulphate of ammonia does not throw down the whole of the lead: a little escapes and still remains in the liquid. If we evaporate the solution to dryness and ignite the residue, and then dissolve it in water, a portion of this lead will be separated in the state of sulphate, but not the whole. The best way therefore, is to throw down this residue by means of sulphuretted hydrogen gas. The precipitate when washed, dried, and ignited, is sulphuret of lead, every 15 grains of which is equivalent to 14 grains of protoxide, or 14·5 grains of sesquioxide of lead.

Sect. 4. *Oxide of Tin.*

The only oxide of tin found native is the peroxide, constituting an exceedingly hard heavy ore, having the diamond lustre, and a brown or black colour. It is quite insoluble in acids, even when reduced to a very fine powder. Nor does it become soluble though fused with carbonate of soda. But if we mix it with five times its weight of caustic potash or soda, and ignite the mixture in a silver crucible furnished with a close cover, for half an hour, we obtain a mass which has usually a green colour, and which may be dissolved in muriatic acid. If the tinstone was pure, the solution is generally complete.

Through the muriatic solution rendered as neutral as possible by concentration and subsequent dilution with water, a current of sulphuretted hydrogen is passed as long as any precipitate falls. The yellow-coloured precipitate is collected on a filter, washed, and digested in aqua regia till it is completely dissolved. The oxide of tin is now thrown down by caustic ammonia, washed, heated to redness, and weighed. Ammonia does not throw down the whole of the oxide of tin. But if we add succinate of ammonia, and leave the mixture for some time at rest, the whole peroxide of tin remaining in the liquid is precipitated. It may be ignited and weighed, and the weight added to that of the peroxide previously obtained.

The liquid from which the peroxide of tin has been precipitated by sulphuretted hydrogen, is now to be examined. Let a little nitric acid be added to it, and let the whole be digested for some time to peroxidize the iron which it always contains. Let the liquid be now neutralized and precipitated by benzoate of ammonia. Collect the precipitate, wash it, ignite it, and weigh it. Let it then be digested in muriatic acid; if it dissolve completely, it is pure peroxide of iron. If it leave an insoluble residue, which is often the case, subtract the weight of this residue from that of the whole ignited precipitate; the remainder is the weight of peroxide of iron. The insoluble residue is usually peroxide of tin. This is easily determined by mixing it with some carbonate of soda and borax, and fusing it before the blowpipe on charcoal. If it be oxide of tin, that metal will be reduced and a globule of tin obtained.

The liquid freed from iron and tin may still contain oxide of manganese. Add to it a quantity of sulphohydrate of ammonia, and set it aside in a phial furnished with a ground stopper. If manganese be present, a reddish or yellowish precipitate gradually falls. Collect this precipitate, wash it, and dissolve it in muriatic acid. Raise the solution to the boiling temperature, and throw down the oxide of manganese by carbonate of soda. The precipitate collected, washed, dried, and strongly ignited, is red oxide of manganese, every 4·833 grains of which are equivalent to 4·5 grains of protoxide, and 5 grains of sesquioxide.

Sect. 5. *Oxide of Bismuth.*

Bismuth is found much more abundantly in the metallic state than in any other; yet the oxide of bismuth has been met with in the mineral kingdom, sometimes isolated, or nearly so, and sometimes united to carbonic acid.

Oxide of bismuth must be dissolved in nitric acid. After rendering the solution as neutral as we can by concentration, we add a quantity of acetic acid, and then dilute with water. A current of sulphuretted hydrogen gas is then passed through, till the whole bismuth is precipitated in the state of sulphuret. The sulphuret is dissolved in nitric acid, and the oxide of bismuth thrown down by carbonate of ammonia. The precipitate washed, dried, and ignited, is pure oxide of bismuth.

The liquid from which the bismuth has been precipitated by sulphuretted hydrogen, is to be digested with some nitric acid, after having driven off the excess of sulphuretted hydrogen. It is then to be neutralized and thrown down by benzoate of ammonia. The precipitate after ignition gives the quantity of peroxide of iron contained in the ore.

These are the only substances said to exist in oxide of bismuth. Should it leave an earthy residue it may be analyzed by the rules already laid down.

Sect. 6. *Oxides of Copper.*

Both the oxides of copper occur native. The *red* crystallized, and in a state of great purity; the *black* usually mixed with oxide of iron. The analysis of both is exceedingly easy. The red oxide may be digested in muriatic acid, and to the solution nitric acid may be added till it has assumed the usual green colour which characterizes the solution of black oxide of copper in muriatic acid. We may then test the solution for iron, or any other impurity which may be suspected, and if nothing be found we neutralize the solution and throw down the oxide of copper with caustic potash. When this oxide is weighed after ignition, every 5 grains of it are equivalent to 4½ grains of red oxide of copper. Or the red oxide is equivalent to nine-tenths of the black oxide obtained.

The analysis of the black oxide is to be conducted in the same way. Only the iron must be precipitated by benzoate of ammonia. And should alumina, silica, or lime, be present, as may occasionally be the case, they are to be separated and analyzed in the usual way.

Sect. 7. *Oxides of Arsenic.*

Both arsenious and arsenic acid occur in the mineral kingdom, sometimes in a separate state, but more frequently united with bases. Our business here is only with these bodies when in a separate state.

Arsenious acid may be dissolved in aqua regia, and precipitated in the state of sulphuret by a current of sulphuretted hydrogen gas. The precipitate is to be washed upon a filter, and dried in a gentle heat. This sulphuret is analogous to arsenious acid, every 7¾ grains of it being equivalent to 6¼ grains of arsenious acid. But it is apt to contain an excess of sulphur, in consequence of the decomposition of some of the sulphuretted hydrogen. On that account it is better to determine its composition by analysis. Put a portion of it into a flask, and digest it cautiously with aqua regia till the sulphur collects into lumps, separate the sulphur, wash it, dry it, and weigh it. The liquid contains a portion of the sulphur converted into sulphuric acid. Throw it down by chloride of barium, and determine its weight. From this the weight of the sulphur which it contains is easily deduced. Subtract the weight of the sulphur from that of the sulphuret analyzed, the remainder gives the weight of the arsenic. And every 4·75 grains of metallic arsenic are equivalent to 6¼ grains of arsenious acid.

Arsenic acid may be precipitated in the same way by sulphuretted hydrogen gas. But the process is a good deal more tedious. Every 9·75 grains of the precipitated sulphuret are equivalent to 7¼ grains of arsenic acid. But it is better to determine the weight of sulphur contained in this sulphuret, from which the weight of the arsenic is deduced as before. And every 4·75 grains of metallic arsenic are equivalent to 7¼ grains of arsenic acid.

Berthier has proposed another way of determining the quantity of arsenic acid when in solution, which may be frequently practised with advantage, and therefore deserves to be described here:—A quantity of iron (as pure as possible) is dissolved in nitric acid, and the solution is mixed with the liquid containing the arsenic acid. The process succeeds very well though the solution contains nitric acid, muriatic acid, or sulphuric acid. It may contain also fixed alkalies, or indeed any base which does not form an insoluble salt with arsenic acid, sulphuric acid, or muriatic acid, and which is not precipitable by ammonia, either by itself or in combination with any of the acids present in the liquid.

To the mixture ammonia is added in excess: the peroxide of iron falls down in combination with the arsenic acid. It is better that a considerable excess of iron should be present, so as to form a subsalt, for the neutral arseniated peroxide of iron is very gelatinous and difficult to wash. The precipitate is to be washed on a filter, dried, and very cautiously heated to ignition. If it were very rapidly ignited, and ammonia be present in it, (as is often the case, the precipitate being an ammonia-subsesquiarseniate of iron,) the ammonia would act upon the arsenic acid, and convert it into arsenious acid, which would be driven off by the heat. The precipitate, after strong ignition, is to be weighed. Knowing the weight of iron employed, we have the quantity of peroxide of iron present. This being deducted from the weight of the precipitate, the remainder is the amount of arsenic acid.

The only objection to this method of Berthier is the impossibility of obtaining iron perfectly pure. We cannot err very much if we allow half a per cent. of impurity, and reckon only 99·5 grains for every 100 grains of iron that we employ. According to this mode of estimating, 100 grains of iron yield 142·143 grains of peroxide. Knowing the weight of peroxide, it is easy to deduce that of the arsenic acid.

When arsenious, or arsenic, acid is in a solution with bodies not precipitable by sulphuretted hydrogen, we can easily throw down these acids by means of a current of that gas. We begin by rendering the solution slightly acid, and then the current of gas is continued till the liquid is saturated. We then expose it to a gentle heat till the smell of sulphuretted hydrogen vanishes. The precipitated sulphuret is collected on the filter, and the quantity of arsenic which it contains estimated in the way already explained. In this way these acids may be separated from *potash*, *soda*, *lithia*, *barytes*, *strontian*, *lime*, *magnesia*, *alumina*, and *the other earths*, *manganese*, *iron*, *zinc*, *cobalt*, *nickel*, *uranium*, *titanium*, and *chromium*.

When the bases with which these acids are combined are precipitated by sulphuretted hydrogen gas, we must employ sulphohydrate of ammonia to separate them. We must render the solution ammoniacal, and then add an excess of sulphohydrate of ammonia. The whole is put into a well closed flask, and digested for some time in a gentle heat. The bases are thrown down in the state of sulphurets, while the arsenic is held in solution. We filter to separate the precipitate, and to the filtered liquid add an excess of muriatic acid, and digest till the smell of sulphuretted hydrogen is dissipated. The sulphuret of arsenic precipitates, and is collected and analyzed in the way already explained.

In this way arsenious and arsenic acid may be separated from *cadmium*, *lead*, *bismuth*, *copper*, *mercury*, and *silver*. The same method may also be followed, if we think proper, to separate these acids from oxides of manganese, iron, zinc, cobalt, &c. For all these oxides are converted into sulphurets, and precipitated by sulphohydrate of ammonia. Nor is there any reason why it may not be employed to separate the same acids from alkalies and earthy bodies.

We cannot separate arsenic acid from metallic oxides by precipitating these oxides by means of caustic potash or soda, because a portion of the arsenic acid always falls down in combination with the oxide, and no excess of alkali, even assisted by long continued digestion, is capable of preventing this. The method therefore of analyzing arseniates of copper practised by Klaproth and Chenevix, could not be exact.

Sect. 8. *Oxide of Antimony.*

The protoxide of antimony is found in the mineral kingdom, though it is rather a scarce mineral. It may be easily recognised by the characters already given in a former part of this treatise, especially by the action of the blowpipe. When we wish to analyze it, the best method of proceeding is to dissolve it in muriatic acid, and throw it down by a current of sulphuretted hydrogen. The solution after saturation is left in a warm place till the smell of sulphuretted hydrogen vanishes. For the whole sulphuret of antimony does not fall as long as there is any sulphuretted hydrogen in the liquid. We then collect the sulphuret of antimony on a weighed filter, wash it well, and dry it in a gentle heat. After the sulphuret is dry, we must take a small quantity of it and digest it in concentrated muriatic acid. If it dissolve completely with the evolution of sulphuretted hydrogen gas, then the sulphuret is a compound of 3 sulphur and 8 antimony, so that every 11 grains of it are equivalent to 8 grains of antimony, or 9½ grains of protoxide of antimony. But if it leaves a portion of sulphur undissolved, we must infer that it is a mixture of various sulphurets, and must subject it to analysis, in order to determine its composition.

For this purpose we may put a quantity of the sulphuret into a glass spherule blown in the middle of a tube. To one extremity is attached an apparatus for generating hydrogen gas, and a tube filled with dry chloride of calcium, through which it must pass. As soon as the apparatus is filled with hydrogen gas, heat is applied to the sulphuret in the spherule. The sulphur is converted into sulphuretted hydrogen gas, and gradually dissipated, while the antimony is reduced. We weigh the antimony, and subtracting the weight from the quantity of sulphuret subjected to analysis, we have the weight of the sulphur, and thus know the composition of the sulphuret of antimony.

Or we put a determined portion of our sulphuret of antimony into a flask, and pour upon it very cautiously fuming nitric acid by a small quantity at a time. When a sufficient quantity of nitric acid has been added, we pour into the flask concentrated muriatic acid, and digest till the whole is dissolved. To this solution add tartaric acid to prevent the precipitation of the antimony when it is diluted, then throw down the sulphuric acid by chloride of barium. From the weight of the sulphate of barytes obtained, we deduce that of the sulphuric acid, which gives us that of the sulphur. The weight of the sulphur subtracted from that of the sulphuret employed gives us that of the antimony; and thus the composition of the sulphuret is known.

Sect. 9. *Oxide of Chromium.*

I am not certain that the oxide of chromium has hitherto been met with in the mineral kingdom in an isolated state, though that such a mineral species may be met with hereafter is not unlikely. But this oxide occurs as an essential constituent of *chromeiron ore*, a mineral of great importance, because it is from it that all the chromate of potash, so much employed in calico printing is procured. Its essential constituents are green oxide of chromium, peroxide of iron, and alumina.

To analyze it, the best way is to reduce it to powder, and to mix it with thrice its weight of caustic potash and saltpetre and fuse the mixture in a silver crucible. By this fusion the oxide of chromium is converted into chromic acid. Digest the fused mass in water till every thing soluble is taken up. The solution has a yellow colour, and is a combination of chromic acid with a great excess of potash. Saturate the alkali with acetic acid, and throw down the chromic acid by acetate of lead. The precipitate, when washed, dried, and ignited, is composed of 14 parts of lead, and 6·5 of chromic acid. Hence every 20·5 grains of the ignited precipitate contain 6·5 grains of chromic acid equivalent to 5 grains of green oxide.

Before throwing down the chromic acid it is better to add a slight excess of carbonate of ammonia, which throws down the alumina. When washed, dried, and ignited, it is to be weighed, and then dissolved in muriatic acid to separate a little silica, which is usually present.

The portion of the matter which does not dissolve in water consists chiefly of peroxide of iron. It is to be dissolved in muriatic acid, and after being neutralized the peroxide of iron is thrown down by benzoate of ammonia. Being washed, dried, and ignited, it consists of nearly pure peroxide of iron. When re-dissolved in muriatic acid it sometimes leaves a little silica.

The liquid thus freed from iron may be tested by carbonate of ammonia to see whether it contains any other substance. I have always found that when it is diluted with water it lets fall a small quantity of white matter, seemingly a salt, but existing in such minute quantity that its nature could not be determined.

Instead of throwing down the chromic acid by means of acetate of lead, we may reduce it again to the state of green oxide. The method of proceeding is this:—We cautiously add muriatic acid to the potash solution of chromic acid till there is an excess of acid, and boil the liquid in a flask till the chromic acid is reduced to green oxide. We then add ammonia, which throws down the oxide. We collect it on a filter, wash it, dry it, expose it to a red heat, and determine its weight.

Sect. 10. *Oxide of Uranium.*

The only mineral containing oxide of uranium in an uncombined state is pitchblende, which is rather a mixture than a chemical compound. For not merely the proportions, but even the constituents vary in different specimens, as has been explained, when describing the ore in the first part of this work.

Uranium in the metallic state has only been obtained as a brown powder destitute of the metallic lustre. It forms two oxides. The protoxide is of a dingy grey colour, and the peroxide, or uranic acid, has probably a yellow colour, at least all the compounds which it forms are yellow. The protoxide after ignition is hardly soluble in muriatic acid, but it dissolves easily in nitric acid, and in concentrated sulphuric acid, when assisted by heat. The sulphated protoxide of uranium exhibits the following characters to reagents:—

(1.) Potash throws down a bulky brown precipitate, not soluble in an excess of the precipitant.

(2.) Ammonia throws down a dark brown precipitate, also insoluble in an excess of ammonia. The upper surface of this precipitate, after a considerable interval, becomes yellow, being converted into peroxide.

(3.) Carbonate of potash throws down a dingy green precipitate, soluble in a great excess of the carbonate. Bicarbonate of potash and carbonate of ammonia act in the same manner, only the precipitate is more readily dissolved than when carbonate of potash is the precipitant.

(4.) Phosphate of soda, when the solution does not contain too much acid, throws down a dirty greenish-white precipitate.

(5.) Oxalic acid throws down a dirty greenish-yellow precipitate, even when the solution contains a considerable excess of acid.

(6.) Prussiate of potash throws down a reddish-brown precipitate.

(7.) Sulphuretted hydrogen occasions no precipitate, but sulphohydrate of ammonia throws down a black precipitate, provided the solution does not contain too much free acid. The precipitate is insoluble in an excess of sulphohydrate of ammonia.

When the peroxide of uranium is exposed to a red heat it is converted into protoxide, and assumes a dark green colour. When peroxide of uranium is thrown down by potash or soda the precipitate contains a quantity of the alkali, and assumes an orange-yellow colour when heated to redness.

The solution of peroxide of uranium in nitric acid has a greenish-yellow colour. The action of reagents upon this salt is as follows:—

(1.) Potash throws down a yellow precipitate insoluble in an excess of the precipitant. Ammonia acts in the same way.

(2.) Carbonate of potash throws down a yellow precipitate, soluble in an excess of the carbonate. Bicarbonate of potash and carbonate of ammonia act in the same way. When these solutions, with excess of alkaline carbonates, are kept, a yellow precipitate falls.

(3.) Phosphate of soda throws down a white precipitate with a tint of yellow, provided the solution does not contain too large an excess of acid.

(4.) Prussiate of potash throws down a reddish-brown precipitate, very characteristic of uranium.

(5.) Sulphuretted hydrogen occasions no precipitate; sulphohydrate of ammonia throws down a brown precipitate, provided there be no considerable excess of acid.

(6.) When heated with biphosphate of soda before the blowpipe the globule assumes in the outer flame a yellowish colour, inclining to green. On cooling the colour changes entirely to green. When the bead is melted by the interior flame the colour is green; when fused with borax the colours are nearly the same.

CHAP. IX.

ANALYSIS OF SULPHURETS AND SULPHUR SALTS.

Sulphur occurs in the mineral kingdom combined with iron, manganese, nickel, cobalt, molybdenum, lead, tin, zinc, bismuth, copper, mercury, and silver, and with some of these metals in more than one proportion. It constitutes also one of the constituents of the sulphur salts of iron, of lead, of copper, and of silver. We must point out the methods of analysis to be followed with all these numerous compounds.

Sect. 1. *Sulphurets of Iron.*

There are three combinations of iron and sulphur which are found in the mineral kingdom, namely, *magnetic pyrites*, *bisulphuret of iron*, or *common pyrites*, and *radiated pyrites*, but the method of analyzing them is the same for all.

The mineral to be subjected to analysis must be reduced to powder and put into a glass flask; into the mouth of this flask a funnel is put, and strong fuming nitric acid is added by little at a time, waiting always till the action of the first portion is at an end before an additional portion is added. It is best to place the flask upon hot sand to promote the action. When this process is rightly followed the whole sulphur is converted into sulphuric acid, while at the same time the iron is peroxidized. We then dilute the whole with water, and, if necessary, add a little muriatic acid to dissolve the peroxide of iron completely. The peroxide of iron is then precipitated by ammonia, washed, dried, ignited, and weighed. Every 5 grains of it are equivalent to 3·5 grains of iron.

The liquid thus freed from iron is neutralized by muriatic acid, and the sulphuric acid which it contains is thrown down by chloride of barium. We collect the sulphate of barytes on a filter, and wash it carefully with boiling water. The washing is a tedious process. I am in the habit of acidulating the water with a little nitric acid, which I consider as facilitating the washing. From the weight of the ignited sulphate of barytes it is easy to determine that of the sulphur by the methods already explained.

It is not very often that the sulphurets of iron are analyzed by means of fuming nitric acid. Dilute nitric acid is much more frequently used. When we digest sulphuret of iron in dilute nitric acid, the iron is peroxidized and dissolved long before the sulphur is all acidified. When the sulphur has concreted into lumps, and assumed its natural greenish-yellow colour, we collect it on a weighed filter, wash it, and dry it in a gentle heat. We then collect as much of it as possible into a porcelain crucible, and burn it all away. A small residue of oxide of iron usually remains, amounting only to a fraction of a grain. We determine its weight, and then dissolve it in muriatic acid. In general a minute quantity of silica is left; which we determine and subtract from the weight of the oxide. The muriatic solution must be tested by chloride of barium, to ascertain whether any sulphuric acid be present. If there is, we determine its amount, subtract it from the oxide, and add the sulphur which it contains to the weight of the sulphur previously found, less the weight of the residual oxide.

The liquid thus freed from sulphur is neutralized, and the peroxide of iron thrown down by ammonia. After washing, drying, and ignition, the amount of iron is determined as before. We then throw down the sulphuric acid by chloride of barium, and estimate the sulphur as before.

Magnetic pyrites is soluble in muriatic acid, and during the solution sulphuretted hydrogen escapes. If the pyrites be pure no sulphur is precipitated, and no sulphuric acid is ever found in the solution. This shows clearly that magnetic pyrites is a compound of 1 atom of iron and 1 atom of sulphur.

Common pyrites is insoluble in muriatic acid; but if we expose it to a red heat half the sulphur is driven off, and the residue, reduced to the state of magnetic pyrites, is soluble in muriatic acid without a residue.

The analysis of radiated pyrites is to be conducted precisely in the same way as that of common pyrites. No difference between the constitution of the two species has been discovered.

Native magnetic pyrites is combined usually with a variable quantity of common pyrites: hence, when digested in muriatic acid it is never completely soluble; and if the iron dissolve completely, a little sulphur will be left behind, showing that the atoms of sulphur somewhat exceed those of iron.

Sect. 2. *Sulphuret of Manganese.*

Sulphuret of manganese may be analyzed exactly in the same way as sulphuret of iron. The manganese is usually obtained in the state of red oxide, every 4·833 grains of which are equivalent to 3·5 grains of metallic manganese.

Arfvedson employed the following method to analyze this mineral:—He roasted the sulphuret, previously reduced to powder, till it ceased to undergo any alteration in weight. This process is tedious. What remained was pure red oxide of manganese,* every 4·833 grains of which are equivalent to 3·5 grains of metallic manganese. Knowing the weight of the specimen subjected to analysis, and of the manganese which it contained, it was easy to deduce that of the sulphur.†

Sect. 3. *Sulphuret of Nickel.*

The sulphuret of nickel may be analyzed in the same way as the preceding sulphurets; or we may digest it in aqua regia till every thing is dissolved but a little sulphur, which is to be separated and estimated in the way already described when treating of the sulphurets of iron. The solution is to be precipitated by chloride of barium, and from the weight of the sulphate of barytes that of the acidified sulphur determined. The oxide of nickel is now to be precipitated by caustic potash or soda, and its weight estimated after ignition. Every 4·25 grains of it are equivalent to 3·25 grains of metallic nickel.

Sect. 4. *Sulphuret of Cobalt.*

The only specimens of sulphuret of cobalt hitherto examined by chemists contained, besides sulphur and cobalt, some copper and some iron. Such a sulphuret may be analyzed by the following method:—Digest it in dilute nitric acid till every thing is dissolved except a little sulphur. Towards the end of the digestion the solution is facilitated by adding a little muriatic acid. Separate the sulphur, and treat it in the way already explained.

Through the solution pass a current of sulphuretted hydrogen till every thing precipitable by that reagent is thrown

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* It contained merely a trace of iron.

† Kong. Vet. Acad. Handl., 1822, p. 435.

down. By this process we separate the copper in the state of sulphuret. This sulphuret is dissolved in a boiling heat in nitric acid, except a little sulphur, which is separated by the filter. The nitric acid solution is then mixed with an excess of caustic potash or soda, and the black oxide of copper separated. After ignition every 5 grains of it are equivalent to 4 grains of metallic copper.

The red cobalt solution thus freed from copper is to be neutralized, and the peroxide of iron which it contains is to be thrown down by benzoate of ammonia. The benzoate being ignited leaves peroxide of iron, every 5 grains of which are equivalent to 3·5 grains of metallic iron. Finally, the oxide of cobalt must be thrown down by caustic potash or soda. This oxide after ignition is composed of 3·25 cobalt and 1 oxygen, so that every 4·25 grains are equivalent to 3·25 grains of metallic cobalt.

Sect. 5. *Sulphuret of Molybdenum.*

The only combination of molybdenum and sulphur hitherto met with in the mineral kingdom is *molybdena*, or *disulphide of molybdenum.*

We cannot determine the quantity of sulphur in this mineral by roasting, because the molybdenum makes its escape during the process as well as the sulphur. The best way is to put the quantity to be subjected to analysis, reduced to as thin leaves as possible, into a retort, and to pour over it moderately strong nitric acid. This acid is to be distilled nearly to dryness, and a new portion of acid being poured on, we continue the process till the sulphuret has lost its appearance and is quite decomposed. We then (after driving off most of the acid) digest the residue in a sufficient quantity of caustic ammonia, to dissolve the whole. From this solution, muriatic acid throws down the molybdenum in the state of molybdic acid. Every 9 grains of this when washed, dried, and ignited, are equivalent to 6 grains of metallic molybdenum. From the liquid thus freed from molybdenum, we throw down the sulphuric acid by means of chloride of barium. The sulphate of barytes being weighed after ignition, it is easy from it to deduce the quantity of sulphur existing in the specimen subjected to analysis.

Should sulphuret of molybdenum contain fragments of quartz, as is sometimes the case, they remain undissolved when the matter in the retort is taken up by ammonia.

Sect. 6. *Sulphuret of Lead.*

The easiest method of determining the constituents of sulphuret of lead, is to reduce a quantity of it to powder, to put it into a flask, and digest it with fuming nitric acid added very cautiously, by a little at a time. By this treatment, the sulphuret is converted into sulphate of lead. Every 19 grains of ignited sulphate is equivalent to 15 grains of sulphuret of lead. Suppose in any process we obtain 38 grains of sulphate of lead, we say, 19 : 15 : : 38 : 30 = sulphuret of lead. If the quantity of sulphuret of lead be exactly equivalent to the 30 grains thus obtained by calculation, that is to say, if we employed just 30 grains of sulphuret of lead in our experiment, it follows that the galena examined was pure, and a compound of 1 atom sulphur and 1 atom lead. But if the quantity was either greater or less than 30, and if we be sure that we lost nothing during the process,* it is clear that the sulphuret contained something else than pure lead and sulphur.

When we wish to determine the quantity of sulphur combined with the lead exactly, we put a quantity of the galena in powder into a glass globule, to each side of which a glass tube is cemented. To one of these tubes is attached an apparatus for generating hydrogen, with a glass tube filled with fragments of chloride of calcium, through which the hydrogen passes. When the apparatus is filled with hydrogen gas, we apply the heat of a lamp to the galena, and continue the heat and the evolution of hydrogen gas till the whole sulphur is disengaged in the state of sulphuretted hydrogen gas. We then allow the apparatus to cool, and weighing the lead, we have by subtracting the weight from that of the original sulphuret, the quantity of sulphur with which the lead was combined.

Sect. 7. *Sulphuret of Tin.*

The sulphuret of tin is a rare ore, and hitherto has, so far as I know, been analyzed by Klaproth only. He found in it, besides sulphur and tin, copper and iron. His mode of analysis was this:

He digested the ore in aqua regia till the sulphur remained, being recognised by its yellow colour. The sulphur was separated, washed, dried, and weighed. It was then burnt

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* sulphate of lead should be ignited in a covered crucible.

off. The residue was undecomposed ore, which was treated as before with aqua regia, and the sulphur burnt off. These processes were repeated till the ore was completely decomposed.

The liquid was mixed with chloride of barium, and the sulphate of barytes being washed, dried, and ignited, its weight gave the means of determining the quantity of sulphur that had been acidified. This added to the sulphur burnt off, gave the whole weight of sulphur contained in the portion of ore subjected to analysis.

The liquid thus freed from sulphuric acid, and afterwards from barytes, was concentrated and mixed with a great excess of caustic ammonia, which retained the copper in solution but threw down the tin and iron. The ammoniacal solution was saturated with sulphuric acid, and the copper being precipitated by an iron plate, was washed, dried, and weighed.

The mixed precipitate of oxides of tin and iron, was digested in a solution of caustic potash, which dissolved in a boiling heat the oxide of tin, but left the oxide of iron. The solution being filtered and saturated with muriatic acid, a plate of zinc threw down the tin, which was washed, dried, and weighed.

The iron was drenched in oil and heated to bring it to the state of black oxide. It was found all to be attracted by the magnet. From its weight, that of the iron contained in the ore was calculated.*

This method though ingenious, and though considerably better than the method at first followed by Klaproth, is not susceptible of any great degree of accuracy.

Sect. 8. *Sulphurets of Bismuth.*

There are two minerals containing sulphur and bismuth which have been met with in the mineral kingdom. The first, *bismuth glance*, or *sulphuret of bismuth*, and the second, *needle ore of bismuth*, a very complicated ore, which, besides bismuth and sulphur, contains also lead, copper, nickel, tellurium, and gold.

Sulphuret of bismuth is rather a scarce ore, and so far as I know, has been hitherto analyzed only by M. H. Rose. The analysis is very simple. The pounded ore is digested in a flask with concentrated nitric acid, till every thing is dissolved. Carbonate of ammonia throws down the oxide of bismuth. It

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* Beitrage, v. 228.

is washed, dried, ignited, and weighed. Every 10 grains of it are equivalent to 9 grains of metallic bismuth. The sulphuric acid is precipitated from the liquid (after it has been rendered neutral by muriatic acid) by means of chloride of barium. From the sulphate of barytes, the quantity of sulphur is determined in the way already explained.

Needle ore of bismuth was analyzed by John, as long ago as 1808. He dissolved it in nitric acid, and concentrated the solution to get rid of the excess of acid. Being now diluted with water, the oxide of bismuth was precipitated. It was washed, dried, and ignited, and from its weight, that of the metallic bismuth contained in the ore was deduced.

Sulphate of soda being poured into the blue liquid remaining, the lead was precipitated in the state of sulphate. When this sulphate is washed, dried, and ignited, if we multiply its weight by 0·684, the product will give the weight of metallic lead which it contains.

The residual liquid was precipitated by an excess of caustic potash. The precipitate was again re-dissolved in sulphuric acid, and the copper thrown down by a bar of iron.

The ferruginous solution from which the copper had been thrown down, was mixed with an excess of carbonate of ammonia, and the precipitate was washed repeatedly with fresh doses of ammonia. A blue coloured solution was obtained, which was concentrated, neutralized with sulphuric acid, and a plate of iron was put into it. Some black flocks were precipitated which possessed the characters of copper. The liquid was now precipitated by carbonate of potash. The precipitate being digested in ammonia, left a little oxide of iron. The portion dissolved was considered to be oxide of nickel, because it dissolved in ammonia with a blue colour, gave a green precipitate with prussiate of soda, and a yellow with infusion of nut galls.

What remained undissolved by the nitric acid, after being dried and weighed, was heated, sulphur burnt off, and its weight was determined. The residue was treated with nitro-muriatic acid, which dissolved it, with the exception of some quartz grains. The solution being concentrated to get rid of the excess of acid, and then diluted with water, yielded a precipitate of oxide of bismuth. The liquid separated from this precipitate had a yellow colour, and nitrate of mercury threw down from it a small quantity of gold.*

* Gehlen's Journal (second series), v. 230.

This mode of analysis was scarcely capable of giving correct results; but it will be better to delay giving any account of the mode of analyzing these complicated ores till we come to treat of the sulphur salts, because one general process may be given which will apply to them all, and thus considerably shorten the details.

Sect. 9. *Sulphuret of Copper.*

The only simple combination of copper and sulphur found in the mineral kingdom, is *glance copper*, or *disulphuret of copper.* Besides copper and sulphur it contains a little iron, probably in the state of bisulphuret.

The portion of this disulphuret intended to be analyzed is digested with pretty strong nitric acid, or aqua regia on the sand bath till the whole is dissolved, or till nothing remains but sulphur concreted in lumps. This sulphur is separated, washed, dried, and burnt off after being weighed, and any residue is to be digested anew in nitric acid, or aqua regia, till the whole be dissolved. The sulphuric acid is thrown down from the liquid by chloride of barium, and the amount of the sulphur which it contains determined as already explained.

From the liquid (previously deprived of any barytes that may have been added in excess) we throw down the peroxide of iron by benzoate of ammonia, taking care to neutralize it exactly before adding the benzoate.

The copper now only remains which may be thrown down in the state of black oxide by caustic potash or soda.

Sec. 10. *Sulphuret of Zinc.*

There are two ores of zinc which contain sulphur. These are *blende* or *sulphuret of zinc*, very seldom free from iron, and *Voltzine* or *oxysulphuret of zinc*, containing sulphuret of zinc, oxide of zinc, and oxide of iron.

The mode of analyzing blende is precisely the same as that of disulphuret of copper, only that the oxide of zinc must be thrown down by carbonate of soda at a boiling temperature.

Nor is it necessary to point out any particular rules for the analysis of Voltzine, which may obviously be conducted precisely in the same way.

The animal matter which this mineral contains is soluble in weak muriatic acid. We must therefore begin the analysis by digesting the ore in weak muriatic acid. From this solution the animal matter is thrown down in the state of a white powder by diluting it with water. When this matter is heated it melts. If we increase the heat it swells up and leaves a charry matter, which when burnt leaves oxide of zinc. Probably this oxide was thrown down in combination with the animal matter.

Sec. 11. *Sulphuret of Mercury.*

The only combination of sulphur and mercury met with in the mineral kingdom is *cinnabar*, which is a simple sulphuret.

It must be digested in a flask upon the sand bath, with pretty strong aqua regia, for nitric acid is not capable of decomposing it. If the digestion be continued long enough the whole sulphur is acidified. The sulphuric acid is thrown down by chloride of barium, and the quantity of sulphur determined in the way already explained.

We now pass a current of sulphuretted hydrogen gas through the solution, till the whole mercury is precipitated in the state of sulphuret. This sulphuret is collected and washed on a weighed filter, and then dried in a gentle heat. Put this sulphuret into a flask, and pour over it a little muriatic acid. Then pass over it a current of chlorine till the mercury is changed into chloride, and the sulphur disengaged. Filter off the chloride of mercury, after all the free chlorine has been dissipated, and mix the liquid with a solution of protochloride of tin. The mercury is thrown down in the metallic state. It is to be washed, dried, and weighed.

Sec. 12. *Sulphurets of Silver.*

There are three ores composed of silver and sulphur. *Silver glance* or *common sulphuret* contains when pure nothing but silver and sulphur. But *flexible sulphuret* and *Sternbergite* contain also metallic iron.

Sulphuret of silver is to be digested in pure nitric acid till the sulphur appears in clots, and of its usual colour. We then filter off the liquid, throw down the sulphuric acid formed by means of nitrate of barytes, and estimate the sulphur as already explained.

The liquid thus freed from sulphuric acid is mixed with muriatic acid, or sal ammoniac. The silver falls down in the state of chloride. It is to be collected, washed, dried, fused, and weighed. Every 18·25 grains of it are equivalent to 13·75 grains of metallic silver.

If the sulphuret analyzed contained iron, it will remain in solution after the separation of the sulphur and silver. If we are sure that nothing is present but peroxide of iron, we may throw it down by caustic ammonia. Should any thing else be suspected we precipitate the iron by benzoate of ammonia, and then test the residual liquid to determine whether any other substance be present.

Sec. 13. *The Sulphur Salts.*

The mode of analyzing all the combinations of sulphur and the metals has been explained in the preceding sections, excepting the compounds which it forms with arsenic and antimony. Now these combinations constitute sulphur acids, which have the property of combining with other metallic sulphurets as bases, and thus of forming what are called *sulphur salts.* The analysis of these sulphur salts is attended with peculiar difficulties, which were first effectually overcome by M. H. Rose; though Bonsdorff, Arfvedson, and above all Berzelius had previously pointed out what may be called the theory of the processes.

The sulphur salts hitherto met with in the mineral kingdom, and whose analysis will occupy our attention in this section, are the following:—

I. Sulphur salts of iron.
   1. *Arsenical pyrites;* composed of sulphur, arsenic, and iron.
   2. *Berthierite;* composed of the same constituents, with traces of zinc and some iron pyrites.

II. Sulphur salts of nickel.
   1. *Nickel glance;* composed of sulphur, arsenic, and nickel, with a little iron and trace of cobalt.
   2. *Sulpho-antimonite of nickel;* composed of sulphur, antimony, and nickel.

III. Sulphur salts of cobalt.
   1. *Cobalt glance;* composed of sulphur, arsenic, and cobalt, with a little iron.

IV. Sulphur salts of lead.
   1. *Zinkenite;* composed of sulphur, antimony, and lead, with a little copper.
   2. *Plagionite;* composed of sulphur, antimony, and lead.
   3. *Jamesonite;* composed of sulphur, antimony, and lead, with some iron and copper.
   4. *Feather ore of lead;* composed of sulphur, antimony and lead, with some iron and zinc.

5. *Nagyag tellurium ore;* composed of sulphur, antimony, lead, tellurium, gold, and copper.

V. Sulphur salts of copper.

1. *Variegated copper ore;* composed of sulphur, iron, and copper.
2. *Copper pyrites;* composed of sulphur, iron, and copper.
3. *Bournonite;* composed of sulphur, antimony, lead, copper, and iron.
4. *Grey copper ore;* composed of sulphur, antimony, arsenic, copper, silver, iron, and zinc.
5. *Tennantite;* composed of sulphur, arsenic, copper, and iron.

VI. Sulphur salts of silver.

1. *Cupreous sulphuret;* composed of sulphur, copper, and silver.
2. *Brittle silver glance;* composed of sulphur, antimony, silver, with a little copper.
3. *Dark red silver ore;* composed of sulphur, antimony, and silver.
4. *Miargirite;* composed of sulphur, antimony, and silver, with some copper and iron.
5. *Light red silver ore;* composed of sulphur, arsenic, and silver, with a little antimony.
6. *Polybasite;* composed of sulphur, antimony, arsenic, silver, and copper, with a trace of iron.

From the preceding list it appears that the number of sulphur salts which have been met with in the mineral kingdom, amount to 21 species. The acid in all of these species except two is either sulphide of arsenic, or sulphide of antimony. The bases are sulphurets of iron, nickel, cobalt, lead, copper, or silver. The two exceptions are variegated copper ore and copper pyrites, in which the constituents are sulphur, iron, and copper. In them the sulphur is combined with two bases. But it is probable that the sulphuret of iron acts in them the part of an acid, and thus brings these two species under the class of sulphur salts. But the mode of analyzing these two species has been already given in the eighth section of this chapter, while treating of the mode of analyzing disulphuret of copper. We have only at present to treat of the mode of analyzing the other 19 species, all of which contain sulphide of antimony, or sulphide of arsenic, united to one or more sulphurets which act the part of a base.

Nickel glance may be digested in dilute nitric acid till every thing be dissolved, except a portion of sulphur, which is separated, washed, dried, and weighed. The liquid which passes through the filter contains a quantity of sulphur converted into sulphuric acid. This acid is thrown down by chloride of barium, and the sulphur calculated from the sulphate of barytes in the way already explained.

The liquid thus freed from sulphuric acid must next be freed from any barytes which it may contain by means of sulphuric acid, and a current of sulphuretted hydrogen gas is passed through it till all the arsenic is thrown down. The sulphuret of arsenic thus obtained may be dissolved in ammonia, in order to get rid of a quantity of loose sulphur with which it is always mixed. If we deduce the weight of the sulphur thus separated from that of the original weight of the precipitate, the remainder will be the true weight of the sulphuret of arsenic. Every 7·75 grains of this sulphuret are equivalent to 4·75 grains of metallic arsenic. But as the quantity of sulphur combined with arsenic is apt to vary, the best method of proceeding is to weigh out a portion of the sulphuret of arsenic obtained, and to digest it in aqua regia till the arsenic is acidified. Separate the sulphur remaining and weigh it. Throw down the sulphuric acid formed by means of chloride of barium, taking care that so much free acid exists in it as will prevent the arsenic acid from being thrown down, and determine the sulphur in the sulphate of barytes obtained in the way already explained. Subtract the weight of sulphur thus determined from that of the sulphuret examined, the remainder will be the weight of the arsenic which it contains.

From the liquid thus freed from arsenic drive off the sulphuretted hydrogen, and digest it with some nitric acid to peroxidize the iron. Neutralize and throw down the peroxide of iron by benzoate of ammonia. Finally throw down the oxide of nickel by carbonate of soda, wash, dry, and ignite. Every 4¼ grains of it are equivalent to 3·25 grains of metallic nickel.

A similar process will answer for analyzing the *sulpho-antimonite of nickel*, and for *cobalt glance*.

Zinkenite may be analyzed most accurately in the following way:—A quantity of the ore in powder is put into a glass bulb, connected with an apparatus by which dry chlorine gas can be passed over it, and the resulting compound conveyed by means of a glass tube into a covered vessel filled with water. Heat being applied to the bulb the sulphur and the antimony pass over into the receiver in the state of chlorides. The liquid in the receiver must consist of a weak solution of tartaric and muriatic acids. If we persist in passing chlorine into the receiver, the whole sulphur is at last acidified. Its quantity is determined by throwing down the sulphuric acid by means of chloride of barium, and estimating the sulphur from the quantity of sulphate of barytes obtained. The antimony is then thrown down by a current of sulphuretted hydrogen gas, and the sulphuret of antimony is analyzed, and the quantity of antimony determined in the way already explained.

What remains in the glass bulb is a mixture of chlorides of lead and copper. It may be dissolved in boiling water, and the oxide of lead precipitated by means of sulphate of soda. The sulphate of lead, after its ignition, contains $\frac{13}{19}$ths, or 0·684 of its weight of metallic lead. The black oxide of copper which alone remains may be thrown down by caustic potash or soda, and its weight determined: $\frac{4}{5}$ths of that weight represent the quantity of metallic copper.

The method of analyzing *plagionite*, *Jamesonite*, and *feather ore* of lead is precisely the same.

Nagyag tellurium ore, or the *blätторerz*

Cupreous sulphuret of iron may be digested in nitric acid till every thing is dissolved, except a few flocks of sulphur, which are to be separated and weighed.

The silver is to be thrown down from the solution by means of common salt, and the sulphuric acid by means of chloride of barium. Nothing now remains in solution but the peroxide of iron and the black oxide of copper. If we neutralize the solution and heat it, the peroxide of iron precipitates, and may be collected and weighed. Caustic potash or soda will throw down the oxide of copper.

Brittle silver glance is to be treated with chlorine in the same way as zinkenite, and the sulphur and antimony estimated in the way already explained. What remains in the glass bulb, is chloride of silver and chloride of copper. Water dissolves off the latter and leaves the former. The oxide of copper is thrown down by caustic of potash, and its weight determined.

We may either estimate the quantity of silver from the chloride in the way already explained, or we may reduce it to metallic silver, by passing a current of dry hydrogen gas over it in a glass tube or bulb, while we apply heat. The chlorine passes off in the state of muriatic acid, and metallic silver remains.

The method of analyzing *dark red silver ore*, *miargarite*, *light red silver ore*, and *polybasite*, is precisely the same, so that no additional remarks are necessary.

CHAP. X.

ANALYSIS OF MINERAL SALTS.

THE salts which occur in the mineral kingdom are very numerous, indeed, by far the greater number of minerals constituting real chemical compounds, may be considered as salts more or less complex in their nature. But the term salt here is limited to simple salts, or combinations of a single acid with a single base; we shall include also a few double salts, consisting either of one base united to different acids, or of one acid combined at once with two different bases.

The salts (omitting the salts of ammonia, potash, and soda) hitherto observed in the mineral kingdom, constitute twelve different sets, namely,

1. Hydrates,
2. Carbonates,
3. Sulphates,
4. Phosphates,
5. Arseniates,
6. Borates,
7. Vanadiates,
8. Chromates,
9. Molybdates,
10. Tungstates,
11. Columbates,
12. Titaniates.

The mode of analyzing each of these different sets will be explained in the following sections:—

Sect. 1. *Analysis of Hydrates.*

The only simple hydrates hitherto met with in the mineral kingdom, are the following:—

1. Hydrate of magnesia,
2. Hydrate of alumina, or Gibbsite,
3. Bihydrate of alumina,
4. Dihydrate of alumina, or diaspore,
5. Dihydrous peroxide of iron,
6. Hydrous peroxide of iron.

The mode of analyzing them is exceedingly simple. We first determine whether they contain water by heating a portion over a spirit lamp in a glass tube shut at one end. The water is driven off, and condenses on the cold part of the tube. We examine it by tasting it, and by applying test paper to know whether it contains any acid or alkali, or whether it be quite pure. After this preliminary experiment, we put a small quantity of the mineral, generally 100 grains, if we can dispose of so much, into a small green glass, or porcelain retort, to the extremity of which is luted a glass tube, filled with fragments of fused chloride of calcium. The weight of the retort is accurately determined, and also that of the glass tube filled with chloride of calcium. We now expose the retort to a heat gradually raised to redness, and keep it at that temperature till the whole water is driven out of the retort, or at least into the beak. The apparatus is then allowed to cool, and the tube, with chloride of calcium, being weighed again, the increase of weight indicates the water which it has absorbed. Should any water (as often happens) remain in the beak of the retort, we weigh the retort accurately and note down the weight. We now raise its temperature as high as that of boiling water, and pushing a glass tube open at both ends, as far into the retort as it will go, we suck out the air with our mouth, thus causing a current of air to pass through the hot *beak*: the water is speedily carried off, and the beak becomes dry. We then weigh again; the difference between the two weights gives the quantity of water drawn out. The loss of weight sustained by the mineral, compared with the water thus obtained, enables us to know whether any thing else besides water has been driven off. The only other volatile matter likely to be driven off, is carbonic acid, the presence of which would be shown by the effervescence which would take place when a portion of the mineral is digested in an acid.

What remains in the retort after the water has been driven off, is either magnesia, alumina, or peroxide of iron. It is to be examined, and its nature ascertained by the rules formerly laid down, when treating of the analysis of stony bodies.

Sect. 2. *Analysis of Carbonates.*

The carbonates at present known to exist in the mineral kingdom, amount to about 18: namely,

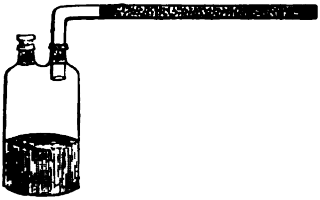
1. Carbonate of barytes,
2. Carbonate of strontian,
3. Carbonate of lime,
4. Subsesqui-carbon. of lime,
5. Baryto-carbonate of lime,
6. Carbonate of magnesia,
7. Hydro-carbonate of magnesia,
8. Carbonate of iron,
9. Junkerite,
10. Carbonate of manganese,
11. Carbonate of zinc,
12. Carbonate of lead,
13. Sulphato-carbonate of lead,
14. Cupreo-sulphato-carbonate of lead,
15. Carbonate of bismuth,
16. Carbonate of copper,
17. Hydro-carbonate of copper,
18. Carbonate of silver.

From all of these carbonates, except the five first, the carbonic acid is driven off by a red heat. We have only to put a given weight of them into a bottle glass retort, as described in the last section, and lute to its beak a tube filled with fragments of chloride of calcium. We then expose the retort to a red heat, sufficiently strong and long continued, to drive off the whole carbonic acid. We then allow the apparatus to cool, and weigh the retort with its contents, and also the glass tube with the chloride of calcium. The loss of weight indicates the carbonic acid given off, while the increase of weight of the tube with the chloride of calcium, gives the water of the mineral, if it contains any.

It is needless to observe, that before we proceed to determine the quantity of carbonic acid and water in a mineral, we must, by previous experiments, ascertain that carbonic acid is present, and also what the nature of the other constituent may be.

The nature of the base remaining in the retort, is determined by the rules already laid down.

Were we to attempt the analysis of carbonates of barytes, strontian, or lime, by the above method, we would fail. From barytes and strontian, we cannot drive off carbonic acid by heat, and a white heat is requisite before lime can be freed from that acid. We must therefore determine the quantity of carbonic acid in these bodies by dissolving them in an acid, and the best acid for the purpose is nitric acid moderately concentrated. The method which I employ is the following:—A small glass flask is procured with two mouths. To the one is fitted a glass stopper, pretty conical, and ground air-tight. To the other is luted a glass tube, bent at right angles, and filled with fragments of chloride of calcium. A quantity of nitric acid sufficient to dissolve the quantity of mineral to be experimented on is put into the flask, and the whole is then accurately counterpoised in a pair of scales, sufficiently delicate to turn when so loaded, with the tenth part of a grain. The mineral in small lumps (not in powder) is then weighed out, (I usually employ 100 grains,) and thrown as speedily as possible into the flask, which must be held obliquely to prevent any of the acid from being driven out of the flask by the effervescence which ensues. The stopper is then replaced as speedily as possible. As the carbonate dissolves, the carbonic acid gas makes its escape through the tube filled with fragments of chloride of calcium. I allow the whole to remain for twenty-four hours after the solution is completed, by which time all the carbonic acid has made its escape out of the flask, which will be found filled with common air, as at first. The whole is now weighed, as at first. The loss of weight gives the quantity of carbonic acid driven off. What remains in the flask, is the base of the carbonate dissolved in nitric acid. If we concentrate the solution sufficiently, we obtain crystals, if the base was barytes or strontian; but the solution does not crystallize when lime constitutes the base. The shape of the crystals is an octahedron, whether the base be barytes or strontian. If we put one of these crystals into the wick of a candle, the flame assumes a yellow colour if the base be barytes, but a beautiful red, if the base be strontian. If the



base be a mixture of lime and barytes, or strontian, we evaporate the nitric acid solution to dryness, and digest the dry residue in absolute alcohol. The nitrate of lime will dissolve, and will be obtained by evaporating the alcohol to dryness, but the nitrate of barytes or strontian will remain undissolved.

If the base be a mixture of barytes and strontian, we evaporate the nitric acid solution as before, to dryness, re-dissolve the dry residue in water, and throw down the barytes and strontian by carbonate of soda. The precipitate after being well washed, is dissolved in muriatic acid, and the solution evaporated to dryness. The residual salt being digested in absolute alcohol, the chloride of strontium dissolves, but the chloride of barium remains undissolved. Having thus separated the two bases, we convert them into carbonates or sulphates. These, after ignition, give us the quantities of barytes and strontian respectively. Every 12·25 grains of carbonate, and every 14·5 grains of sulphate of barytes, contain 9·5 grains of barytes. Every 9·25 of carbonate, and every 11·5 of sulphate of strontian, contain 6·5 grains of strontian.

When the base consists of a mixture of lime, magnesia, and oxide of iron, as sometimes happens, these three substances are to be separated from each other by the rules laid down when treating of the analysis of stony bodies.

Sect. 3. *Analysis of Sulphates.*

The sulphates in the mineral kingdom are still more numerous than the carbonates, amounting to no fewer than twenty-four species: namely,

1. Sulphate of barytes,
2. Calcareo-sulph. of barytes,
3. Sulphate of strontian,
4. Baryto-sulphate of strontian,
5. Calcareo-sulphate of strontian,
6. Hydrous sulphate of lime,
7. Anhydrous ditto.
8. Siliceous ditto.
9. Sulphate of magnesia,
10. Sulphate of alumina,
11. Ammonia-alum,
12. Soda-alum,
13. Potash-alum,
14. Alum stone,
15. Aluminite,
16. Sulphated perox. of iron,
17. Alumina-sulphate of iron,
18. Disulphate of cobalt,
19. Sulphate of zinc,
20. Sulphate of lead,
21. Sulphate of copper,
22. Tetrasulphate of copper,
23. Sulphated protoxide of uranium,
24. Sulphated peroxide of uranium.

Of these salts, there are twelve which are soluble in water;

namely, sulphate of magnesia, sulphate of alumina, ammonia alum, soda alum, potash alum, sulphated peroxide of iron, alumina-sulphate of iron, disulphate of cobalt, sulphate of zinc, sulphate of copper, and the two sulphates of uranium. To analyze these twelve, we dissolve them in water, and throw down the sulphuric acid by chloride of barium. The sulphate of barytes being washed, dried, and ignited, gives the quantity of sulphuric acid.

The bases require various precipitants, according to their nature. Magnesia is thrown down at a boiling temperature by carbonate of soda. Alumina is thrown down by carbonate of ammonia, and its purity is determined by its solubility in a ley of caustic potash or soda. The alumina from alum may be thrown down in the same way, but very long digestion is necessary before the sulphuric acid can be completely separated from it. Perhaps the following is an easier way of analyzing alum.

1. Determine the quantity of water by exposure to a moderate heat.

2. Take another equal portion of the alum, dissolve it in water, and throw down the sulphuric acid by chloride of barium; thus determining the quantity of acid which it contains.

3. Weigh out a third quantity of the same alum, expose it to a strong heat in a platinum crucible, and note the loss of weight. If the alum was ammonia alum, nothing will remain but the alumina. Now, as the weight of the water, acid, and alumina are known, we can easily determine the amount of the ammonia driven off, for the acid was saturated by the alumina and ammonia. Let the weight of alumina be a, we say $2{\cdot}25 : 5 :: a : \frac{5a}{2{\cdot}25}$ = weight of sulphuric acid combined with the alumina. Let the rest of the sulphuric acid weigh b, then we have $5 : 2{\cdot}125 :: b : \frac{2{\cdot}125b}{5}$ = weight of ammonia united to the sulphuric acid b.

If the alum be soda or potash alum, after exposure to a strong red heat, the alumina will be deprived of the acid with which it was combined, but the sulphate of soda or sulphate of potash will remain undecomposed, (unless the heat to which the salt has been exposed be too high). Digest the residue for a couple of days on the sand bath in distilled water, and separate the water from the alumina. The alumina being washed, dried, and ignited, its weight is ascertained. The aqueous solution being evaporated to dryness, will leave the sulphate of potash or of soda, the weight of which is to be determined, and it is easy to distinguish the potash from the soda by the solubility, the shape of the crystals, or the addition of some tartaric acid to the solution. If the salt be potash, bitartrate of potash immediately falls, but if it be soda, no precipitate appears.

From the *alumina-sulphate of iron*, the bases may be thrown down by carbonate of ammonia, taking care, in the first place, to peroxidize the iron. The alumina is separated from the iron, by boiling in caustic potash or soda ley.

The oxide of cobalt may be thrown down by caustic potash or soda; the oxide of zinc by carbonate of soda, at a boiling temperature; the oxide of copper by caustic potash or soda. To precipitate the protoxide of uranium, we must, in the first place, peroxidize it, and then it is thrown down by caustic ammonia. We must wash it not with water, but with a solution of sal ammoniac, otherwise it will pass through the filter. We then dry and ignite it, and weigh it. It is by this process converted into protoxide of uranium. When the oxide in the salt was peroxide, we easily obtain its weight by calculation, every 27 grains of protoxide being equivalent to 28 grains of peroxide.

The remaining 12 sulphates are insoluble in water, or nearly so; we must therefore proceed with their analysis in a different manner.

All the sulphates of lime are easily decomposed by reducing them to a fine powder, and boiling them for some hours with a solution of carbonate of soda. We then filter off the solution, saturate the alkali with muriatic acid, and throw down the sulphuric acid by means of chloride of barium.

The lime remains in the state of carbonate. It may be dissolved in muriatic acid, and tested for iron and magnesia. If it be found pure we may estimate the lime from the carbonate, every 6·25 grains of carbonate being equivalent to 3·5 grains of lime. If silica be present it will remain undissolved, when the carbonate of lime is taken up by muriatic acid.

The sulphates of barytes and strontian are not so easily decomposed as sulphate of lime. We must reduce them to a fine powder, mix them intimately with thrice their weight of anhydrous carbonate of soda, and fuse the mixture in a platinum crucible, and keep it in fusion for at least a couple of hours. We then dissolve out the alkali by digesting the fused mass in water. The alkali is saturated with muriatic acid, and the sulphuric acid, with which it has combined by double decomposition is thrown down by chloride of barium, and its quantity determined by the methods already more than once explained.

The undissolved matter, consisting of carbonate of barytes, or strontian, is digested in muriatic acid till a complete solution is obtained. Should any thing remain undissolved, it is a proof that the decomposition has not been complete. We must fuse it again with carbonate of soda, and proceed as before directed till we have obtained a complete separation of the acid and base, and a complete solution of the base in muriatic acid. We then test the muriatic solution to determine whether it consists of barytes or strontian, or whether it contains any lime. If it consists of pure barytes we throw it down by means of sulphate of soda. The precipitate after being washed, dried, and ignited, is pure sulphate of barytes, every 14·5 grains of which are equivalent to 9·5 grains of barytes.

When strontian constitutes the base we proceed in the same way, every 11·5 grains of its sulphate is equivalent to 6·5 grains of strontian.

Should the base be a mixture of barytes and strontian, we evaporate the muriatic solution to dryness, and digest the salt obtained in absolute alcohol. The chloride of strontium is dissolved, but the chloride of barium remains untouched. Having thus separated the two chlorides, we throw down their respective bases by sulphate of soda, and estimate the quantity of each as before explained.

If the base be a mixture of lime and barytes or strontian, we dissolve it in nitric acid instead of muriatic, evaporate the solution to dryness, and digest the residual salt in absolute alcohol. The nitrate of lime will be dissolved, but the nitrate of barytes, or of strontian, will remain. The salts being thus separated, the quantity of each of the bases is determined as before explained.

Aluminite, which is a tris-sulphate of alumina, may be dissolved by digestion in muriatic acid. From the solution the alumina may be thrown down by carbonate of ammonia, and the sulphuric acid by chloride of barium.

Alumstone is precisely similar in its composition to potash alum, excepting that each of the atoms of alumina is combined with only the third part of an atom of sulphuric acid instead of a whole atom. This renders it insoluble in water. We must therefore dissolve it by digestion in muriatic acid. The alumina may be precipitated by carbonate of ammonia, and the sulphuric acid by chloride of barium. By depriving another portion dissolved in muriatic acid of its alumina, evaporating to dryness and ignition, we obtain the sulphate of potash, from which the quantity of potash is easily estimated. Finally the water is known either by the loss or by exposing the mineral to a heat scarcely amounting to ignition.

Sulphate of lead may be decomposed by fusion with carbonate of soda. The oxide of lead remaining after washing off the alkali may be dissolved in nitric acid, and after the solution has been tested to ascertain its purity, the oxide of lead may be thrown down by sulphate of soda. Every 19 grains of ignited sulphate of lead being equivalent to 14 grains of oxide of lead. The quantity of sulphuric acid is determined in the way already explained.

The *tetrasulphate of copper* may be dissolved in muriatic acid, and the copper thrown down by caustic potash or soda, and the sulphuric acid by chloride of barium.

Sect. 4. *Analysis of Phosphates.*

The phosphates already known to exist in the mineral kingdom amount to 18 species; namely,

1. Subsesquiphosphate of lime.
2. Wavellite, or phosphate of alumina.
3. Lazulite, or diphosphate of alumina and magnesia.
4. Blue spar, or diphosphate of alumina and magnesia.
5. Phosphate of yttria.
6. Mullicite, or diphosphate of iron.
7. Subsesquiphosphate of iron.
8. Vivianite, or phosphate of iron.
9. Cacoxenite, or diphosphated peroxide of iron, combined with silicate of alumina and water.
10. Native Prussian blue.
11. Manganese-phosphate of iron.
12. Huraulite, or phosphate of manganese and iron.
13. Chloro-phosphate of lead.
14. Diphosphate of copper.

15. Pelokonite.
16. Sub-bisesquiphosphate of copper.
17. Uranite.
18. Chalcolite.

Not one of these salts is soluble in water, so that they all require certain processes to enable us to subject them to analysis. The analysis of the phosphates is attended with much greater difficulties than the analysis of any other class of bodies in the mineral kingdom. It will be requisite on that account to enter somewhat into detail, in order to smooth the difficulties as much as possible.

Phosphoric acid in the solid glacial state in which it is usually exhibited is a compound of real phosphoric acid and water, most commonly one atom acid and one atom water, though Rose obtained it with only the third part of an atom of water united to an atom of real acid. If we heat it in vessels of glass or porcelain it attacks them powerfully, and becomes in consequence less volatile, and only partially soluble in water.

All the phosphates are insoluble in water except the alkaline. But they dissolve easily in an excess of nitric, or muriatic acid, and even frequently in phosphoric acid. After ignition the greater number of them are insoluble in all acids, except the concentrated sulphuric, in which they dissolve at a boiling heat. But of course those phosphates whose bases form with sulphuric acid an insoluble compound, barytes, strontian, and oxide of lead, for example, cannot be dissolved by this process.

The neutral alkaline phosphates afford precipitates with all the earthy and metalline salts. These precipitates are phosphates consisting of phosphoric acid, combined with the precipitating base. They are soluble in acids, and again precipitated by alkalies. If we add a considerable excess of alkali they are often decomposed, at least partially, and the base appears with its characteristic properties. Precipitated phosphate of lime and some other phosphates, dissolve readily in a solution of sal ammoniac. But if we add caustic ammonia almost the whole of the phosphate is again precipitated. The precipitated phosphate of lead, formed by adding acetate or nitrate of lead to an alkaline phosphate, is insoluble in acetic, but soluble in nitric acid.

Nitrate of silver throws down a yellow precipitate from neutral solutions of a phosphate. This is the most characteristic of all the precipitates of phosphates, and is therefore usually employed to detect the presence of phosphoric acid in neutral solutions. If the phosphate has been recently ignited, the precipitate by nitrate of silver is not yellow but white. Arsenic acid indeed gives also a yellow precipitate with nitrate of silver, but the presence of arsenic acid in any compound is easily detected by means of the blowpipe.

Phosphate of barytes, of strontian, of lime, and of magnesia, are detected by their dissolving in muriatic acid, and being again precipitated by ammonia. But we must satisfy ourselves in the first place that the acid present in the compound is not arsenic, boracic, or fluoric. The two first are easily detected by the blowpipe, and the last by its corroding glass when the salt is drenched in sulphuric acid, and heated in a platinum crucible. The most difficult thing is to detect phosphoric acid when in combination with alumina. For phosphate of alumina and pure alumina have very nearly the same properties. In a subsequent part of this section the methods which have been devised for solving this difficult problem will be stated.

Thenard and Vauquelin have given us the following method of detecting phosphoric acid in a phosphate:—A small portion of potassium is put into the bottom of a small glass tube shut at one end, and the phosphate for examination is put upon the metal. This phosphate must be perfectly dry, but need not exceed a small fraction of a grain in weight. Heat the tube slowly to ignition. The potassium reduces the phosphoric acid and converts it into phosphuret of potassium. Pour a little mercury into the glass tube to remove any excess of potassium, and in about a minute pour it out again. Then blow cautiously through a fine tube upon the matter contained in the glass tube in order to moisten it. A strong and characteristic smell of phosphuretted hydrogen is immediately perceived.

According to Fuchs, if a solid phosphate be moistened with sulphuric acid, and held by a platinum forceps in the inner flame of the blowpipe it communicates a green colour to the outer flame.* This green colour continues only for a short time, and it does not always appear. It must be recollected too that borates produce a similar colour, indeed with them it is much finer and much deeper.

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* Schweigger's Jour. xxiv. 130.

Berzelius has given a method of detecting phosphoric acid by means of the blowpipe. A portion of the mineral for examination is fused with boracic acid on charcoal, and when the intumescence is ended a piece of fine harpischord wire is thrust into the bead in such a manner that the two ends of the wire project out of the bead. The whole is then strongly heated in the inner flame. The resulting bead when cold is taken from the charcoal, and wrapped up in a piece of paper, and then crushed in two by a slight blow of a hammer. We find a round grain of phosphuret of iron, which possesses a metallic appearance, is magnetic and brittle, so that it breaks in pieces when struck with a hammer. A small proportion of phosphoric acid cannot be detected by this method. The assay must contain no sulphuric acid, arsenic acid, nor any metallic oxide which is reduced by iron, otherwise globules would be obtained which could not be distinguished from phosphuret of iron.

We have no very modern analysis of phosphate of lime, but the analysis by Klaproth approaches pretty nearly to accuracy. He reduced the mineral to a fine powder, and dissolved it in muriatic acid. The muriatic acid solution was rendered as neutral as possible without precipitating the phosphate of lime, and then oxalate of ammonia was dropt into the liquid till all the lime was thrown down. The oxalate of lime was collected on a filter, washed, dried, and ignited. It was then in the state of carbonate of lime, every 6·25 grains of which are equivalent to 3·5 grains of lime. The liquid thus deprived of the lime was evaporated to dryness, and heated to drive off the ammoniacal salts. It was then weighed. Being dissolved in water, a quantity of undecomposed phosphate of lime remained, amounting to about $\frac{1}{14}$th of the original quantity subjected to analysis. This being deducted the remainder was considered as phosphoric acid.

In this analysis the obvious defect was the exposing the phosphoric acid to a red heat, because at that temperature a portion of it is volatilized. It would have been better to have saturated the acid with ammonia, which would have thrown down the undecomposed phosphate of lime. The liquid is now to be evaporated to dryness, and the dry salt intimately mixed with a quantity of oxide of lead more than sufficient to saturate the acid. Heat is then applied; the ammonia is displaced by the oxide of lead. After it has been disengaged we raise the heat to ignition, and then weigh the matter obtained. If from this weight we subtract that of the oxide of lead employed, the remainder is the weight of the phosphoric acid.

Wavellite is a salt composed of water, phosphoric acid, and alumina. Now, phosphate of alumina resembles alumina so closely in many of its characters that the phosphoric acid is apt to be overlooked altogether, and accordingly wavellite was long considered as a hydrate of alumina. Phosphate of alumina dissolves in nitric and muriatic acids; it dissolves also in caustic potash or soda ley, and it is precipitated from these solutions precisely as alumina is.

The method of separating alumina from phosphoric acid was first suggested by Professor Fuchs, and is as follows:—The weighed compound is dissolved in a solution of caustic potash, and to this liquid a solution of silicate of potash (or liquor of flints, as it was formerly called,) is added. This addition converts the whole into a thick slimy mass, which is diluted with water, and made to boil. An abundant precipitate falls, which is potash-silicate of alumina. This precipitate is separated, washed, and dissolved in muriatic acid. Being evaporated to dryness, the silica is separated in the usual way, and the alumina is thrown down from the muriatic acid solution, either by carbonate of ammonia or sal ammoniac.

The solution, filtered from the precipitated potash-silicate, contains the phosphoric acid combined with potash. It may be neutralized, and mixed with a neutral solution of chloride of calcium. Phosphate of lime precipitates, composed of 1 atom phosphoric acid and 1½ atom lime: so that every 9·75 grains of it are equivalent to 4·5 grains of phosphoric acid.

The method employed by Berzelius was merely a modification of the preceding. He mixed 2 parts of wavellite with 1½ parts of silica in fine powder, and 6 parts of carbonate of soda. The mixture was ignited for half an hour. It was then digested in water, till every thing soluble was taken up. The liquid portion contained the phosphoric acid united to soda, together with a little silicate of soda. On adding carbonate of ammonia, and digesting, the silica precipitated. The alkaline liquid was now reduced by concentration to half its bulk, in order to get rid of the excess of ammonia. It was then neutralized by muriatic acid, and left till the carbonic acid was dissipated. It was then supersaturated with caustic ammonia, which occasioned the precipitation of a little silica. The liquid was now mixed with chloride of calcium, added as long as any precipitate fell. This precipitate, after being well washed, was ignited and weighed. It was a mixture of subsesquiphosphate and fluate of lime. It was dissolved in muriatic acid, and sulphuric acid being added, the whole was evaporated to get rid of the fluoric acid. It was allowed to cool, and digested in alcohol. The whole was dissolved except the sulphate of lime, which was ignited and weighed. It contained, of course, the lime united in the mineral both with the phosphoric and fluoric acids. From the weight of sulphate it is easy to deduce that of the lime; for every 8·5 grains of anhydrous gypsum are equivalent to 3·5 grains of lime.

The alcoholic liquid contained the phosphoric acid mixed with sulphuric acid. The alcohol was evaporated off, water was added, and a sufficient quantity of muriatic acid, to prevent the precipitation of phosphate of barytes. Chloride of barium was then added to throw down the sulphuric acid. The liquid thus freed from sulphuric acid was filtered and mixed with a great excess of caustic ammonia, in order to precipitate the phosphate in the state of what has been called *intermediate subphosphate of barytes*. It is composed of 1 atom barytes, and 0·8 atom phosphoric acid: hence every 13·1 grains of it contain 3·6 grains of phosphoric acid. Subtracting the quantity of phosphoric acid from that of the original weight of the two acids, the remainder gives the weight of fluoric acid.

The soda-silicate of alumina was dissolved in muriatic acid, and evaporated to dryness to get rid of the silica. The alumina was then separated in the usual manner, and a small quantity of oxides of iron and manganese were obtained by digesting the precipitate in caustic potash.

The water was determined in the usual manner by exposing a given weight of wavellite to ignition in a small retort, to the beak of which a tube filled with fragments of chloride of calcium was luted.*

Lazulite and *blue spar*, which contain magnesia, silica, oxide of iron, and lime, besides phosphoric acid and alumina, require for their analysis a preliminary process. A portion of the mineral, reduced to a fine powder, is digested in a platinum crucible, with a sufficient quantity of caustic potash ley. The heat is continued till the watery portion evaporates, and the

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* Ann. de Chim. et de Phys. xii. 16.

dry mass is at last raised to ignition. The matter thus treated is digested in water till every thing soluble is taken up, and the insoluble portion collected on a filter. The silica, lime, magnesia, oxide of iron, and a small portion of alumina remain undissolved, while the alkaline solution contains the phosphoric acid and the alumina. It is mixed with silicated potash ley in sufficient quantity, and boiled. The potash-silicate of alumina precipitates, and is to be treated as already explained. The phosphoric acid is to be thrown down by chloride of calcium, and its quantity estimated in the way already explained.

If we boil the precipitate collected on the filter with a solution of sal ammoniac, the magnesia will be dissolved, while the silica, the alumina, oxide of iron, and lime, if any be present, will remain. These substances are to be separated from each other in the way already explained, when treating of the analysis of stony bodies.

Phosphate of yttria was analyzed by Berzelius in the following manner:—

A portion of the mineral in fine powder was mixed with three times its weight of carbonate of soda, and the mixture heated till the mass fused, and all evolution of carbonic acid was at an end. The fused mass was digested in water till every thing soluble was taken up. The undissolved portion was collected on a filter.

The liquid which contained the phosphoric acid being saturated with acetic acid, evaporated to dryness, and the residual salt dissolved in water, a trace of silica remained behind too small to be weighed. The phosphoric acid was precipitated by acetate of lead. The precipitate is a subsesquiphosphate of lead, every 25·5 grains of which are equivalent to 4·5 grains of phosphoric acid. For greater security the phosphate of lead should be converted into sulphate of lead, composed of 14 grains oxide of lead and 5 grains of sulphuric acid. This gives the weight of the oxide of lead, from which that of the phosphoric acid in the phosphate is easily deduced. The phosphoric acid being examined in the usual way, was found to contain a small quantity of fluoric acid mixed with it.

The portion undissolved by the water being digested in muriatic acid, left a small residue consisting partly of silica and partly of undecomposed mineral. The muriatic solution was dropt into a solution of carbonate of ammonia, by which the matter at first precipitated was again re-dissolved. The liquid was evaporated to dryness, the sal ammoniac driven off, and the residual matter dissolved in muriatic acid, and the solution evaporated to dryness. Being again digested in water a dark brown substance remained undissolved. It was ignited and then digested in muriatic acid; about $\frac{2}{3}$ths of it dissolved. The dissolved portion was subphosphate of iron, with a trace of subsesquiphosphate of lime. The undissolved portion possessed the characters of zirconia, but it was not particularly examined. The subphosphate of iron and the zirconia being subtracted from the weight of the undissolved matter originally remaining when the mineral heated with carbonate of soda was digested in water, left the quantity of yttria contained in the portion subjected to analysis. This matter was examined and found to possess the characters of yttria.*

The different species of *phosphated iron*, namely, Mullicite, subsesquiphosphate, Vivianite, cacoxenite, and native Prussian blue, may be analyzed in the following manner:—

By exposure to heat the water is driven off, and its weight estimated.

The anhydrous residue being digested in muriatic acid, every thing dissolves except some grains of siliceous matter, which may be accidentally present.

Let the muriatic solution be mixed with sulphohydrate of ammonia: the iron is thrown down in the state of sulphuret, and may be separated by the filter after the liquid has been deprived of its excess of sulphohydrate of ammonia by boiling it with a mixture of some muriatic acid.

The sulphuret of iron is to be dissolved in aqua regia, and the peroxide of iron thrown down by an alkaline carbonate. After edulcoration and ignition every 5 grains of it are equivalent to 4·5 grains of protoxide of iron.

The liquid freed from iron contains the phosphoric acid, which may be thrown down (after neutralizing the liquid) by chloride of barium. Let the phosphate of barytes be washed, dried, ignited, and weighed. Let it then be dissolved in muriatic acid. Should any sulphate of barytes be present (which might happen through some impurity in the reagents) it will remain undissolved, and its weight must be deducted from that of the phosphate of barytes originally obtained.

Add sulphuric acid to the muriatic acid solution. The barytes will be thrown down in the state of sulphate. Let

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* Kõng. Vet. Acad. Handl., 1824, p. 336.

this sulphate be collected, dried, ignited and weighed. From the weight we easily deduce that of the barytes which it contains; and subtracting this weight from that of the phosphate of barytes originally obtained, the remainder gives the weight of the phosphoric acid in the mineral.

The phosphate of barytes thrown down is usually a subsesquiphosphate, composed of 1 atom of phosphoric acid and 1½ atom barytes. But the phosphoric acid forms so many compounds with each base, that it would not be safe to calculate from such a salt without actual analysis; and the conversion of the phosphate into the sulphate of barytes affords the easiest analysis that we can apply.

The analysis of *manganeso-phosphate of iron* and of *Huraulite* can occasion no difficulty after the remarks already made. The oxides of iron and manganese are easily separated, by peroxidizing the iron, and throwing it down by benzoate of ammonia; or we may prevent the oxide of manganese from falling by adding sal ammoniac to the solution, and then throwing down the iron by ammonia; or we may peroxidize the manganese by chlorine, and then throw it down by bicarbonate of potash.

Chloro-phosphate of lead consists essentially of chloride of lead and subsesquiphosphate of lead, but it contains occasionally oxide of iron, and from Kersten's analysis we learn that in the brown varieties lime constitutes an occasional constituent, and that it likewise contains fluoric acid. To analyze it the simplest method is to dissolve it in nitric acid, and to throw down the chlorine from the solution by means of nitrate of silver. The chloride of silver is washed, dried, fused, and weighed. Every 18·25 grains of it are equivalent to 4·5 grains of chlorine.

The liquid thus freed from chlorine must be freed from any excess of silver accidentally added, by a few drops of muriatic acid. A current of sulphuretted hydrogen being then passed through it, the lead is precipitated in the state of sulphuret, every 15 grains of which are equivalent to 14 grains of oxide of lead. The addition of sulphuric acid and alcohol will throw down the lime in the state of sulphate, every 8½ grains of which after ignition are equal to 3½ grains of lime.

Having thus separated the lime and the lead, we add chloride of barium to the remaining liquid, taking care that it contains a sufficient excess of acid to prevent the precipitation of the phosphate of barytes. After the sulphate of barytes has precipitated and been separated, we neutralize the solution by ammonia, taking care not to add any excess, to avoid throwing down the oxide of iron, if any should be present. The phosphate of barytes precipitates; and from it the quantity of phosphoric acid may be determined, in the way already explained. Finally, the peroxide of iron is thrown down by ammonia, washed, dried, and ignited. We must take care of two things in the last part of this analysis: 1st, that the oxide of iron do not fall with the phosphate of barytes; and 2d, that the iron be not in the state of phosphate when thrown down, which might very easily be the case if the requisite precautions be not taken.*

Diphosphate of copper dissolves readily in nitric acid. From the solution sulphuretted hydrogen throws down the copper. From this sulphuret the quantity of oxide of copper is determined, in the way already explained. The phosphoric acid may now be thrown down by means of chloride of barium or nitrate of lead, and the quantity of phosphoric acid determined from the precipitate, in the way already explained.

The analysis of pelokonite and subbisesquiphosphate of copper may be conducted upon the same principles; only to separate the oxides of iron and manganese we must employ sulphohydrate of ammonia, after having thrown down the copper by a current of sulphuretted hydrogen.

Uranite contains a great number of constituents, though it consists chiefly of phosphated peroxide of uranium and subsesquiphosphate of lime. The other constituents, not reckoning the water, are barytes, magnesia, manganese, and a trace of fluoric acid. It may be analyzed in the following manner:—

After determining the water, by igniting the mineral, it is dissolved in nitric acid, and the solution mixed with alcohol. To this mixture sulphuric acid, previously diluted with alcohol, is added, as long as sulphate of lime continues to precipitate. The gypsum thus obtained is washed with alcohol, dried, ignited, and weighed. It is to be dissolved in muriatic acid by the assistance of heat; a little sulphate of barytes remains undissolved. This is to be washed, dried, ignited, and weighed. Being subtracted from the weight of the original precipitate, the remainder gives the amount of the gypsum. The weight of the gypsum and sulphate of barytes being

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* The only sure way of proceeding is to throw down the iron by means of sulphohydrate of ammonia.

known, it is easy to deduce from them the quantity of lime and barytes contained in the mineral.

The alcoholic solution is now to be evaporated to dryness, and the residue being intimately mixed with carbonate of soda, is exposed to a strong red heat, in order to obtain by double decomposition the phosphoric acid united to the soda, and the peroxide of uranium also united to soda. Water dissolves the former of these compounds, but leaves the latter undissolved.

The uraniate of soda thus remaining is to be dissolved in muriatic acid, from which the peroxide of uranium is thrown down by caustic ammonia. The precipitate being washed with a solution of sal ammoniac, is dried, ignited, and weighed. It is now pure protoxide of uranium, every 27 grains of which represent 28 grains of peroxide.

When the ammoniacal solution is neutralized by muriatic acid a scanty white precipitate usually appears. This, according to Berzelius, is a mixture of phosphated peroxide of uranium, and phosphated peroxide of tin.

The liquid now contains nothing but the phosphoric acid united to an alkali. Let it be acidulated and boiled till the carbonic acid is completely driven off, and then let a mixture of chloride of calcium and ammonia be added. The subsesquiphosphate of lime is precipitated, from which the quantity of phosphoric acid is determined, in the way already explained.

The analysis of *chalcolite* may be conducted in nearly the same way, excepting that from the solution containing the oxides of copper and uranium we must throw down the copper by sulphuretted hydrogen; and as no lime or barytes is present, we have no occasion to throw these bodies down by means of sulphuric acid and alcohol. We at once fuse a mixture of chalcolite and carbonate of soda; the solution contains the phosphoric acid, which is to be obtained as already explained. The undissolved matter contains the oxides of copper and uranium; it is to be dissolved in muriatic acid. The copper is to be thrown down by sulphuretted hydrogen, and the oxide of uranium by caustic ammonia.

Sect. 5. *Analysis of Arseniates.*

The arseniates known at present to exist in the mineral kingdom amount to 15 species; namely,

1. Sesquihydrous arseniate of lime,
2. Bisesquihydrous arseniate of lime,
3. Diarseniate of iron,

4. Subsesquiarseniate of iron,
5. Arseniate of iron,
6. Diarseniate of nickel,
7. Diarseniate of cobalt,
8. Arseniate of lead,
9. Hydrous subbisesquiarseniate of copper,
10. Diarseniate of copper,
11. Prismatic oliven ore,
12. Acicular oliven ore,
13. Copper mica,
14. Octahedral arseniate of copper,
15. Copper schaum.

All these arseniates are insoluble in water; but the presence of arsenic acid, or at least of arsenic, in a mineral is easily discovered by heating a fragment of it on charcoal before the blowpipe. White fumes of arsenious acid are driven off, which possess the well known alliaceous smell which characterizes arsenic. If a mineral destitute of the metallic lustre gives out arsenical fumes before the blowpipe, we may conclude that it contains arsenic acid.

The arseniates are all insoluble in water, except those which have an alkali for their base. But the insoluble arseniates dissolve readily in muriatic acid, except when the base happens to form an insoluble salt with muriatic acid, in which case they dissolve in nitric acid. If through the acid solution of an arseniate, rendered as neutral as possible without causing the salt to fall, we pass a current of sulphuretted hydrogen gas, the well known yellow sulphuret of arsenic falls, which sufficiently characterizes the presence of arsenious or arsenic acid. It is true that cadmium strikes also a yellow colour when treated with sulphuretted hydrogen, but the nature of the mineral under examination is always sufficient to prevent our confounding together cadmium and arsenic.

The *arseniates of lime* present no peculiar difficulty in their analysis.

By exposing the mineral to incipient ignition we drive off the water, and determine its quantity. The anhydrous portion is then dissolved in nitric acid, and the solution, if the mineral be pure, takes place without any effervescence.

The arsenic acid may be thrown down by a current of sulphuretted hydrogen, and the quantity of arsenic acid deduced from that of the sulphuret in the way formerly explained; or we may precipitate the arsenic acid by means of nitrate of lead. The precipitate, after edulcoration and exposure to a red heat, is anhydrous arseniate of lead, every 21·25 grains of which are equivalent to 7·25 grains of arsenic acid; or after having thrown down the lime, magnesia and oxide of cobalt, which are usually present, we may add the requisite quantity of a salt of iron, and determine the weight of arsenic acid by Berthier's process, formerly explained.

After throwing down the whole arsenic acid by means of sulphuretted hydrogen, nothing remains in solution but the base of the salt. This base is lime, generally mixed with a little oxide of cobalt, and in the picropharmacolite of Stromeyer with some magnesia.

To the solution freed from sulphuretted hydrogen add a sufficient quantity of sulphuric acid to saturate the bases, and evaporate to dryness to get rid of the nitric acid. After exposure to a red heat, let the saline mass be weighed. Let it be digested in a little water till the sulphate of magnesia and the sulphate of cobalt are dissolved. The white matter remaining is sulphate of lime; let it be ignited and weighed. By repeated crystallizations and solutions the portion of sulphate of lime which had been at first dissolved may be obtained; or we may add to the solution of sulphate of magnesia and sulphate of cobalt, previously diluted with water, a sufficient quantity of oxalate of ammonia to throw down the residual lime.

The cobalt may be thrown down by sulphohydrate of ammonia. The sulphuret of cobalt obtained is to be dissolved in nitric acid, and the oxide of cobalt thrown down by caustic potash, washed, dried, ignited, and weighed. From the weight of oxide of cobalt it is easy to deduce that of sulphate of cobalt contained in the mixed sulphates; for every 4·25 grains of oxide of cobalt are equivalent to 9·25 grains of anhydrous sulphate. Knowing the weights of the sulphate of lime and of the sulphate of cobalt, we have only to add them together and deduct their sum from that of the sulphates originally obtained. The remainder is obviously the weight of the sulphate of magnesia; and anhydrous sulphate of magnesia contains the third part of its weight of magnesia.

The different *arseniates of iron* may be dissolved in muriatic acid, and the solution mixed with an excess of sulphohydrate of ammonia. The sulphuret of iron and of copper, if any be present, will be precipitated, while the arsenic will remain in solution.

Let the precipitate be digested in muriatic acid; the iron will be dissolved, but copper will remain. Let the residual black matter be roasted in an open vessel; it is now oxide of copper. Let the solution be digested with nitric acid, and the peroxide of iron thrown down by ammonia. After washing, drying, and ignition, it is peroxide of iron, every 5 grains of which are equivalent to 4·5 grains of protoxide of iron.

To the liquid in which the arsenic is held in solution by means of the sulphohydrate of ammonia, muriatic acid is to be added. Sulphuretted hydrogen is disengaged, and the sulphuret of arsenic is precipitated. Let it be washed and digested in aqua regia till the arsenic is acidified and dissolved. Let the undissolved sulphur be dried and weighed, and the sulphuric acid formed during the digestion in aqua regia be thrown down by chloride of barium, and the sulphur contained in it determined. Thus the weight of the sulphur becomes known. Subtracting this weight from that of the sulphuretted arsenic, the remainder gives the quantity of arsenic. From this quantity the amount of arsenic acid is easily deduced, for 4·75 grains arsenic are equivalent to 7·25 grains of arsenic acid.

If to the liquid thus freed from the bases and from arsenic acid we add a quantity of ammonia and of chloride of calcium, the phosphoric acid (if any be present) will be thrown down in the state of subsesquiphosphate of lime, every 9·75 grains of which are equivalent to 4·5 grains of phosphoric acid.

The *diarseniate of nickel*, when mixed with potash and ignited in a silver crucible, undergoes decomposition. The acid unites to the potash, while the oxide of nickel remains. Water removes the potash and arsenic acid. Let the oxide of nickel be ignited and weighed. To see whether it contain any oxide of cobalt let it be dissolved in muriatic acid, thrown down by carbonate of soda, and converted into oxalate by digestion in oxalic acid. Let the oxalate be dissolved in ammonia, and exposed for some days in a glass jar simply covered with paper. As the ammonia makes its escape the oxalate of nickel precipitates, but the oxalate of cobalt remains in solution. Let the liquid be decanted off, and the oxide of cobalt thrown down by caustic potash. Its weight after ignition being subtracted from that of the original base, will leave the weight of the oxide of nickel.

The arsenic acid united with the potash may be determined by the processes already sufficiently explained.

The *diarseniate of cobalt* may be analyzed precisely in the same way.

The *arseniate of lead* contains chlorine and phosphoric acid, and likewise a trace of fluoric acid. It may be dissolved in nitric acid, and the chlorine thrown down by nitrate of silver.

To the solution thus freed from chlorine, and from which all excess of silver has been removed by means of muriatic acid, sulphohydrate of ammonia may be added after the nitric acid has been neutralized by ammonia. The lead is thrown down in the state of sulphuret. Wash this sulphuret and digest it in nitric acid till it is converted into sulphate. Let this sulphate be ignited and weighed; every 19 grains of it are equivalent to 14 grains of oxide of lead.

Add muriatic acid to the solution containing sulphohydrate of ammonia; the arsenic will be thrown down in the state of a sulphuret. This sulphuret is to be washed and treated as already explained, in order to deduce from it the quantity of arsenic acid in the mineral. The residual liquid still contains the phosphoric acid. If we mix it with ammonia and chloride of calcium we obtain a precipitate of subsesquiphosphate of lime, from which the quantity of phosphoric acid is deduced, in the way already explained.

The seven species of *arseniated copper ores*, though differing in the proportions of their constituents, yet as the nature of the constituents is the same in all, namely water, oxide of copper, arsenic acid and phosphoric acid occasionally, may be all analyzed by a similar process.

Let the mineral be dissolved in nitric acid, after having heated it to drive off the water. Add an excess of ammonia, and then a sufficient quantity of sulphohydrate of ammonia to keep the arsenic in solution. The copper precipitates in the state of sulphuret. Let it be dissolved by digestion in nitric acid, and let the oxide of copper be precipitated by caustic potash, washed, dried, ignited, and weighed.

Add muriatic acid to the sulphohydrated solution; the sulphuret of arsenic precipitates. It is to be washed and treated as already explained, in order to deduce from it the weight of the arsenic acid in the mineral.

Nothing now remains but the phosphoric acid, which is thrown down in the state of subsesquiphosphate of lime by ammonia and chloride of calcium.

If we determine the water, and ascertain that the mineral contains only arsenic acid and oxide of copper, we have only to dissolve a given weight of the specimen in nitric acid, and throw down the oxide of copper by means of caustic potash or soda. This precipitate, being washed, dried, and ignited, gives the weight of oxide of copper, which being deduced from that of the anhydrous mineral analyzed, leaves the weight of arsenic acid with which it was combined.

Sect. 6. *Analysis of Borates.*

The minerals containing boracic acid hitherto met with in the mineral kingdom, are six; namely,

1. Borax, or biborate of soda,
2. Datholite, or borosilicate of lime,
3. Botryolite,
4. Biborate of magnesia,
5. Hydroboracite,
6. Tourmalin,

The presence of boracic acid in a mineral, is detected by pulverizing a small quantity of it, and after adding a few drops of sulphuric acid to the powder, pouring over it some alcohol, and setting the spirit on fire. If boracic acid be present the alcohol will burn with a green flame.*

Dr. Turner has given us the following method of detecting boracic acid in a mineral by the blowpipe: Mix the assay with a flux, composed of 1 part of fluor spar, and 4½ parts of bisulphate of potash. This mixture moistened with a little water, is attached to the extremity of a platinum wire, and exposed to the inner flame of a candle before the blowpipe. Shortly after fusion there appears a green colour around the flame, which soon disappears however, and is not again seen.

Boracic acid, when pure, forms a transparent brittle glass, which fuses at a red heat, and is not volatile. After fusion in a platinum crucible, it dissolves with difficulty in water. If it be dissolved in hot water, the solution deposits scales of hydrated boracic acid, which have a pearly lustre, and feel greasy. It dissolves very sparingly in water, and when we evaporate it, even in a low heat, a considerable portion of the acid is volatilized along with the water. This acid gives a reddish-brown colour to turmeric paper, as the alkalies do, but it reddens litmus paper. It is soluble in alcohol, and the alcoholic solution burns with a fine green-coloured flame.

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* The chlorides communicate also a green colour to the flame of alcohol when moistened with sulphuric acid, but in this case the flame is bluish-green, with boracic acid it is emerald-green.

This is the most characteristic property of boracic acid. A good deal of the boracic acid is volatilized along with the alcohol, if we attempt to evaporate it.

The borates, with the exception of those that have an alkali for their base, are very slightly soluble in water. Hence, chlorides of barium, strontium, and calcium, throw down white precipitates when mixed with a solution of a borate, provided it be not too dilute. But these precipitates dissolve in a large quantity of water, and still more readily in a solution of sal ammoniac.

Nitrate of lead throws down a white precipitate, nitrate of mercury a brown, and nitrate of silver throws down a white precipitate from concentrated solutions, but a brown precipitate from dilute solutions. These precipitates are very imperfectly soluble in water, but they dissolve readily in ammonia and in nitric acid.

When a soluble borate is boiled with sulphuric acid, it undergoes decomposition, and pearly scales of hydrated boracic acid are deposited.

The only accurate method of separating boracic acid from those minerals, of which it forms an essential constituent, is the following, which was first suggested by Arfvedson in 1822:* A weighed quantity of the borate, previously freed from water (if any be present) and in the state of a fine powder, is mixed with four times its weight of finely pulverized fluor spar, and this mixture being put into a platinum crucible, is made up into a thick pap with sulphuric acid. The whole is then heated and finally ignited, till all the excess of sulphuric acid is driven off. The fluoric acid as it is disengaged, combines with the boracic, and flies off in the state of fluoboric acid. Nothing at last remains but sulphate of lime from the fluor spar, and the base of the borate converted into a sulphate.

Suppose we were to analyze borax by this method; after the process is finished, nothing remains but sulphate of soda and sulphate of lime. If we digest the residue in water, the sulphate of soda will be dissolved, together with a little sulphate of lime. The addition of carbonate of ammonia, with some oxalate of ammonia, will throw down the lime. We then filter, evaporate to dryness, and ignite the residual salt to get rid of the sulphate of ammonia. Nothing remains but

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* Köng. Vet. Acad. Handl., 1822, p. 93.

anhydrous sulphate of soda, every 9 grains of which are equivalent to 4 grains of soda. Subtracting this soda from the original weight of the anhydrous borax submitted to analysis, the remainder gives the quantity of boracic acid which the salt contained.

Datholite, which contains silica, lime, boracic acid, and water, with a trace of iron and manganese, was analyzed by Klaproth in the following way:—

The proportion of water was determined by igniting a portion of the mineral.

A quantity of datholite reduced to a fine powder, was digested in dilute nitric acid, till the whole assumed the form of a jelly. After dilution with water and digestion, till the whole mineral was decomposed, the liquid was evaporated to dryness in a gentle heat. The dry mass being digested in water acidulated with nitric acid, left the silica, which was washed, dried, ignited, and weighed.

The nitric acid solution was mixed with sulphuric acid, and evaporated to dryness in a gentle heat. The residual matter was digested in alcohol; the spirits were drawn off into a retort and distilled; the boracic acid remained behind, and its quantity was estimated after ignition. What the alcohol left undissolved was sulphate of lime, which was also ignited and weighed. From its weight, that of the lime in the mineral was estimated.

In another experiment, he raised the nitric acid solution to the boiling temperature, and then added carbonate of soda in quantity sufficient to throw down the lime. From the quantity of carbonate of lime obtained, the lime was easily deduced. The solution still contained the boracic acid. It was saturated with sulphuric acid, evaporated to dryness, and the boracic acid extracted by alcohol, as before.*

From the properties of boracic acid, stated at the beginning of this section, it is obvious, that during Klaproth's analysis, a considerable portion of the boracic acid must have been volatilized and escaped detection. The mineral might be analyzed by two processes:—1. The quantity of silica and lime in the mineral must be accurately determined, by dissolving the datholite in nitric acid, evaporating the solution to dryness, separating the silica in the usual manner, and then throwing down the lime by oxalate of ammonia, and determining the quantity. The silica and lime deducted from the original

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* Gehlen's Jour. vi. 109.

weight of the anhydrous mineral, leave the quantity of boracic acid which the mineral contained. 2. For the abstraction of the silica and boracic acid, we add a quantity of pure fluor spar, equal to 2·375 times the weight of the silica, and 1·583 times the weight of the boracic acid, to a given portion of the anhydrous mineral. This mixture we drench with sulphuric acid, and heat. Every thing is driven off except sulphate of lime. The sulphate of lime from the fluor spar, amounts to 1·789 times the original weight of the fluor spar. This quantity subtracted from the total sulphate of lime left, gives the sulphate of lime from the lime of the datholite analyzed. And from this sulphate the weight of the lime is easily deduced. If we add this lime to that of the silica, and subtract the amount from that of the anhydrous datholite analyzed, the remainder must be the amount of the boracic acid.

The analysis of *boracite* and *hydroboracite*, must be conducted on the same principles. What remains after the expulsion of the boracic acid, is a mixture of sulphates of lime and magnesia. The method of analyzing such a mixture, and determining the quantity of magnesia, has been already explained.

To give the reader an idea of the way employed by analysts, to estimate the quantity of boracic acid in the tourmalin, the easiest method will be to state Leplay's analysis of one of these minerals.

Five parts of tourmalin in fine powder, were mixed with 15 parts of carbonate of lead, and 10 parts of nitrate of lead, and fused for a quarter of an hour in a covered platinum crucible. The glass was, when cold, dissolved in nitric acid, and the solution evaporated to dryness by a very gentle heat, to prevent the escape of boracic acid. The dry mass being digested in water acidulated with nitric acid, the silica was left. It was washed, and its quantity estimated in the usual manner.

A current of sulphuretted hydrogen gas was passed through the liquid to throw down the lead. The liquid was filtered and concentrated, till it was reduced almost to the state of a paste. It was then diluted with water, and a sufficient quantity of carbonate of ammonia added to throw down the alumina and peroxide of iron, without acting upon the lime and magnesia which the liquid contained. The alumina and oxide of iron thus obtained, were separated in the usual manner, and the quantity of each determined.

Oxalate of ammonia dropt into the liquid thus freed from alumina and oxide of iron, threw down the lime in the state of oxalate.

The liquid, which now contained potash, boracic acid, magnesia, nitric acid, and ammonia, was evaporated to dryness at a low heat, in a porcelain basin. The dry residue was put into a flat platinum vessel, and kept at a heat of incipient ignition, till the nitrate of magnesia was deprived of its acid. Care must be taken not to raise the heat too high, otherwise the boracic acid would be volatilized. The matter being now digested in boiling water, left the magnesia.

A few drops of nitric acid were added to the aqueous liquor, and it was gently evaporated to dryness, and the residual salt carefully weighed. Alcohol was then poured over it and set on fire. It burned with a green flame. New portions of alcohol were poured on and burned off in the same way, till the flame ceased to have a green tinge. This happened after 15 doses of alcohol had been employed. The residual salt was now weighed. This weight subtracted from the original weight of the salt, gave the weight of the boracic acid that had been volatilized with the burning alcohol.

The alkali only remained. The salt was dissolved in water, and sulphuric acid added to drive off the nitric acid. The whole was evaporated to dryness, and by the addition of a little carbonate of ammonia, all excess of sulphuric acid was got rid of. The salt was now dissolved in water, and the sulphuric acid thrown down by chloride of barium, and its quantity determined. It was found that the salt was a compound of

Sulphuric acid, .	105, or 5
Alkali, . .	113, or 5·38

From which he concluded that the alkali was potash.[*] It is obvious, however, that some soda must have been present. A mixture of 2 atoms potash and 1 atom soda, would make the alkali united to 5 sulphuric acid amount to 5·33, which is very nearly the quantity found by Leplay. Hence the alkali found by him, instead of being 2·32 per cent. potash, ought to have been

Potash, ...	1·79
Soda, ...	0·53
	2·32

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[*] Ann. de Chim. et de Phys. xlii. 272.

Sect. 7. *Analysis of Vanadiates.*

The only vanadiate known at present to exist in the mineral kingdom, is the *vanadiate of lead.* Besides vanadic acid and oxide of lead, it contains also chlorine, together with a trace of silica and oxide of iron.

By dissolving it in nitric acid and adding nitrate of silver, we throw down the chlorine, and determine its amount. A little muriatic acid will remove any excess of silver that may have been added.

We now mix the vanadiate deprived of its chlorine, and in the state of fine powder, with bisulphate of potash, and fuse the mixture in a platinum crucible. If we digest the fused mass in water the vanadic acid and excess of bisulphate of potash will be dissolved, and sulphate of lead will remain behind, every 19 grains of which are equivalent to 14 grains of oxide of lead.

The vanadic acid solution is now mixed with muriatic acid, and a little sugar, and boiled till it assumes a blue colour, a proof that it is converted into oxide of vanadium. Ammonia will throw down oxide. But the digestion with muriatic acid and sugar must be long continued before the whole vanadic acid is deoxidized. Every 10·5 grains of oxide of vanadium are equivalent to 11·5 grains of vanadic acid.

Sect. 8. *Analysis of Chromates.*

The only chromates hitherto met with in the mineral kingdom are the *chromate of lead* and *melanochroite,* which is a subsesquichromate of lead.

The colouring powers of chromic acid are so great that it is easily recognised when it enters as a constituent of a solid body. If we mix a little of the substance suspected to contain it with borax, and fuse it before the blowpipe on charcoal, the bead assumes a beautiful emerald green colour. This colour of course will be modified when metallic oxides capable of communicating colours to borax are present. If we heat a chromate with muriatic acid, chlorine is disengaged, and the acid assumes a dark green colour.

When a chromate is in solution in water, nitrate of lead throws down a fine yellow precipitate, and nitrated suboxide of mercury a deep red precipitate.

The analysis of chromate of lead is very simple. Reduce it to a fine powder, and digest it for some time in muriatic acid. If we pour alcohol into the mixture we dissolve off the chromic acid, and leave chloride of lead. Every 17½ grains of which after fusion are equivalent to 14 grains of oxide of lead. If we digest the alcoholic solution, and then add caustic ammonia, the chromic acid is separated in the state of green oxide, every 5 grains of which after ignition are equivalent to 6½ grains of chromic acid.

Sect. 9. *Analysis of Molybdates.*

The only molybdates hitherto met with in the mineral kingdom are *molybdate of lead* and *trismolybdate of lead.*

When molybdic acid or oxide is fused before the blowpipe on a platinum wire with biphosphate of soda, the bead in the inner flame assumes a beautiful green colour, which is permanent; in the outer flame the colour is weaker, and almost disappears when the bead is cold. When borax is substituted for biphosphate of soda, the bead in the inner flame is brownish red. When fused with carbonate of soda on charcoal, the molybdenum is reduced and appears under the form of a grey metal.

Molybdic acid is easily dissolved by alkaline solutions, or their carbonates, forming with these bases very soluble salts; but its compounds with earths and metallic oxides are generally insoluble. Hence most of the earthy and metallic salts occasion precipitates when dropt into the alkaline molybdates: these precipitates even appear in the bimolybdates, provided the solutions be not too dilute.

Nitrate of lead throws down a *white* precipitate; nitrated suboxide of mercury a *yellow* precipitate; solutions of peroxide of iron a *yellow* precipitate; nitrate of silver a *white* precipitate. The precipitates formed by chloride of barium, or chloride of calcium in the bimolybdates are not dissolved by the addition of water, but they dissolve readily in nitric or muriatic acid.

When nitric or muriatic acid is dropt into a molybdate the molybdic acid is thrown down, but it is re-dissolved by an excess of the precipitating acid, and even by water if added in sufficient quantity. Oxalic acid, tartaric acid, acetic acid, and even sulphuric acid, occasion no precipitate when dropt into solutions of alkaline molybdates. They even dissolve the precipitate thrown down by muriatic acid.

Molybdic acid before ignition is easily soluble in acids, but exposure to a red heat renders it insoluble in these bodies. However, bitartrate of potash dissolves it in a boiling heat even after ignition.

Prussiate of potash when dropt into acid solutions of molybdic acid, or into alkaline molybdates mixed with muriatic acid, throws down a reddish brown precipitate, which is redissolved by the addition of ammonia, and the solution becomes light coloured.

Sulphuretted hydrogen gas gives the solutions of molybdic acid a green colour, and throws down a brown precipitate. But sulphohydrate of ammonia produces no precipitate. Yet if we add muriatic acid, a brown precipitate of sulphuret of molybdenum falls.

A piece of zinc put into a molybdate, or solution of molybdic acid, reduces the acid to protoxide of molybdenum. Hence the liquid assumes a dark blackish brown colour. Tin produces the same change.

Molybdate of lead may be dissolved in dilute muriatic acid by means of heat. On cooling the chloride of lead separates in crystals, which may be separated, fused, and weighed. Every 17·5 grains of this chloride are equivalent to 14 grains of oxide of lead.

Evaporate the residual liquid to dryness, and digest the dry mass (which is blue) in nitric acid. It will be converted into a yellowish powder, which is molybdic acid. This acid is to be cautiously dried, ignited, and weighed.

The method of analysis just given is exceedingly easy, but it does not give an accurate result, as we cannot by means of muriatic acid effect a complete separation of the molybdic acid and oxide of lead. If we wish for accurate results we must dissolve the molybdate of lead in muriatic acid, and after separating as much chloride of lead as we conveniently can, we must add sulphohydrate of ammonia in excess to the liquid, and digest for some time in a flask, the mouth of which is stopped by a cork. The rest of the lead will precipitate in the state of sulphuret. Let it be separated by the filter, washed, ignited, and weighed. Every 15 grains of it are equivalent to 14 grains of oxide of lead.

Add muriatic acid to the liquid thus deprived of lead, and set it aside in a warm place till the sulphuretted hydrogen has made its escape. A brown precipitate falls, consisting of sulphuret of molybdenum. Determine the weight of this precipitate, and then digest it in aqua regia till the molybdenum is dissolved, and only sulphur remains. Estimate the weight of this sulphur in the way already explained. Then throw down the sulphuric acid in the liquid by chloride of barium, and determine the weight of the sulphur in it by the method formerly stated. The weight of the sulphur being thus known, and subtracted from the original weight of the sulphuret, leaves the weight of molybdenum which it contained. Every 6 grains of molybdenum are equivalent to 9 grains of molybdic acid.

Sect. 10. *Analysis of Tungstates.*

The only tungstates hitherto observed in the mineral kingdom are the three following; namely,

1. Tungstate of lime.
2. Wolfram, or tungstate of iron and manganese.
3. Tungstate of lead.

Tungstic acid has a yellowish colour, and when heated it assumes a lemon yellow tint. It is fixed, and does not sensibly dissolve in water, or in acids.

With the alkalies it forms salts which are soluble in water. The alkalies and their carbonates dissolve this acid, even after it has been ignited, but the solution is much more difficultly accomplished than that of molybdic acid by the same bodies.

When muriatic acid, nitric acid, or sulphuric acid, is dropt into these solutions, white precipitates fall, composed of tungstic acid, and the precipitating acid. They are not soluble in an excess of the acids employed to throw them down. Phosphoric acid throws down a precipitate which is soluble in an excess of phosphoric acid. Oxalic acid occasions no precipitate. The same remark applies to tartaric and citric acids; but acetic acid throws down a precipitate not soluble in an excess of the acid.

Almost all the compounds of tungstic acid, with the earths and metallic oxides, are insoluble in water. Hence most of the earthy and metallic salts occasion precipitates when dropt into an alkaline tungstate. Chloride of barium, chloride of calcium, nitrate of lead, and nitrate of silver, throw down white precipitates, not soluble in an excess of water.

Sulphuretted hydrogen, or even sulphohydrate of ammonia, occasions no change in the alkaline tungstates. But if we add a little dilute muriatic acid, a light brown precipitate of sulphuret of tungsten is thrown down.

When tungstic acid is fused with biphosphate of soda in the inner flame before the blowpipe, the globule assumes a fine *blue* colour. In the outer flame this colour disappears. If the tungstic acid contain iron, the globule in the inner flame assumes a blood-red colour. When tungstic acid is fused with borax in the inner flame, the colour is yellow or reddish yellow. When fused with carbonate of soda on charcoal, tungstic acid is reduced to the metallic state.

Tungstate of lime, in the state of a fine powder, may be digested in thrice its weight of concentrated nitric acid till almost all the acid is evaporated away. We then add an additional dose of acid, and continue the digestion till the whole is reduced a second time almost to dryness. By this continued digestion the lime will be separated from the tungstic acid, and combined with the nitric acid. If we digest the matter in alcohol, the nitrate of lime will be dissolved, and caustic ammonia will dissolve the tungstic acid. If any thing remain, it will be silica or the stony matter (usually quartz) on which the crystals of tungstate of lime had been deposited.

If we mix the alcoholic solution with sulphate of ammonia, the lime will be thrown down in the state of sulphate. Let it be dried, ignited, and weighed. Every 8·5 grains of it are equivalent to 3·5 grains of lime.

The ammoniacal solution of tungstic acid is evaporated to dryness and ignited. It is now pure tungstic acid.

When tungstic acid is combined, as in *wolfram*, with oxides whose chlorides are soluble in water, it may, according to Wöhler, be analyzed in the following manner:*—Reduce the wolfram to powder, and fuse it with twice its weight of anhydrous chloride of calcium in a platinum crucible. Boil the melted mass in water; the chlorides of iron and manganese are dissolved, but the tungstate of lime remains undissolved. The iron and manganese are separated and determined in the way formerly explained, and the tungstate of lime may be analyzed in the way just described.

I tried this process of Wöhler unsuccessfully. The wolfram remained undecomposed after being kept a considerable time in fusion with chloride of calcium. But the usual mode of analyzing this mineral is fully as easy as this process of Wöhler, even supposing it successful. It is as follows:—

Reduce the wolfram to powder, mix it with twice its weight of carbonate of soda, and fuse the mixture in a platinum crucible. Digest the fused mass in water till every thing soluble be taken up. The oxides of iron and manganese remain undissolved. Dissolve them in muriatic acid, and

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* Poggendorff's Annalen, ii. 345.

separate the iron (after peroxidizement) by benzoate of ammonia, and then throw down the oxide of manganese by carbonate of soda. The alkaline solution contains the tungstic acid, which may be thrown down by muriatic acid, and dissolved in ammonia. The solution being evaporated to dryness, and the residue ignited, leaves pure tungstic acid.

Tungstate of lead may be dissolved in nitric acid, and the solution being rendered as neutral as possible, is to be digested with an excess of sulphohydrate of ammonia. The lead is precipitated in the state of sulphuret. Let it be separated, and estimated in the way already more than once explained.

Add dilute nitric acid to the filtered liquid, and set it aside till all smell of sulphuretted hydrogen is dissipated. The tungsten precipitates in the state of a sulphuret. Let it be separated and washed with water containing some muriatic acid, as pure water dissolves it. Let it be dried and roasted in a gentle heat. It is by this process converted into tungstic acid, which requires only to be weighed.

Sect. 11. *Analysis of Columbates.*

The only columbates at present known in the mineral kingdom are the following five:—

Yttrotantalite, of which there are three species, namely,

1. Dicolumbate of yttria.
2. Triscolumbate of yttria.
3. Tetracolumbate of yttria.—and
4. Fergusonite, or pentacolumbate of yttria.
5. Columbite, or columbate of iron and manganese.

Before the blowpipe columbic acid fuses into a transparent glass with biphosphate of soda, which distinguishes it from silica. With borax also it fuses into a transparent glass, which becomes milk-white on cooling, or at least when gently heated after cooling. This also distinguishes it from silica. With carbonate of soda it unites with effervescence, and when this is done on charcoal, the columbium is not reduced to the metallic state.

Pure columbic acid is a white tasteless powder, which does not redden litmus paper, and after ignition it is insoluble both in acids and alkalies. But it becomes soluble if we fuse it with caustic potash, or soda, or with their carbonates. It dissolves also when fused with bisulphate of potash. If the fused mass be digested in water, the hydrated columbic acid remains undissolved.

This hydrate is insoluble in water, and very little soluble in acids. Sulphuric acid in a concentrated state indeed dissolves a little of it, but it is again precipitated when we dilute the acid with water. Fluoric acid however dissolves it readily. When boiled with binoxalate of potash it is dissolved in considerable quantity. From this solution prussiate of potash throws down a yellow, and tincture of nut galls an orange precipitate.

Hydrated columbic acid dissolves in caustic potash. From this solution the columbic acid is thrown down by muriatic acid, and doubtless by other acids, and is not re-dissolved by an excess of the acid.

When we fuse columbic acid with fixed alkaline carbonates the fused mass does not dissolve in water. But if we wash out the excess of alkali by cold water an alkaline columbate remains, which may be dissolved in boiling water. From this solution the columbic acid is precipitated by simple exposure to the air in consequence of the carbonic acid which is absorbed.

Sulphuretted hydrogen gas produces no change upon columbic acid. If sulphohydrate of ammonia be introduced into the solution of columbic acid in binoxalate of potash, the columbic acid is thrown down by the ammonia, while sulphuretted hydrogen gas is driven off.

The different species of *yttrotantalites* were analyzed by Berzelius in the following manner:—

The mineral being reduced to a fine powder was mixed with six times its weight of bisulphate of potash, also in fine powder, and fused in a large platinum crucible till the whole of the mineral was dissolved in the salt. The melted mass being allowed to cool, it was boiled repeatedly with a large quantity of water, till all the soluble matter was extracted. The columbic acid remained undissolved, while the bases contained in the mineral were dissolved in the excess of sulphuric acid of the bisulphate. To ensure the complete solution of all the bases, the undissolved portion may be boiled for some hours with muriatic acid, and the acid afterwards added to the original solution.

The liquid thus obtained was neutralized by ammonia, and a current of sulphuretted hydrogen gas passed through it. A slight dark brown precipitate fell. After washing, drying, and roasting, this precipitate consists of tungstic acid.

The liquid thus freed from tungstic acid was boiled to drive off the sulphuretted hydrogen, and mixed with some nitric acid in excess to peroxidize the iron which it contained. It was then thrown down by caustic ammonia. The precipitate was white coloured; it was collected on a filter, washed, and dried.

Oxalate of ammonia threw down the lime from the filtered liquid.

The white precipitate was dissolved in nitric acid, and precipitated by oxalate of ammonia. The precipitate was collected on a filter, and washed first with pure water, and afterwards with caustic ammonia. It was now ignited and weighed. Being dissolved in muriatic acid, it left a small quantity of columbic acid. The solution being neutralized and mixed with acetic acid, a little sulphohydrate of ammonia was added till the acid was saturated. The liquid being heated, and put in a warm place, a little dark powder fell, which after ignition proved to be oxide of uranium. The rest of the white precipitate was yttria.

To the liquid thus freed from yttria by oxalate of ammonia, a little caustic ammonia being added, a yellow matter fell. It was re-dissolved in muriatic acid, and thrown down by carbonate of ammonia in considerable excess. It was now pure peroxide of iron.

The analysis of *Fergusonite* is conducted upon nearly the same principles as that of yttrotantalite, but as it contains also oxide of cerium, zirconia, and oxide of tin, some additional steps are necessary.

The columbic acid left, after dissolving the bisulphate of potash off with water, was washed in a solution of sulphohydrate of ammonia, which dissolved a little tin. The solution being evaporated to dryness, and roasted, left grey oxide of tin, easily recognised, because when treated before the blowpipe with carbonate of soda it is reduced to metallic tin.

The liquid from which the columbic acid was separated, was precipitated by caustic ammonia. The precipitate was white, but became tile red after ignition, showing that it contained oxide of cerium. Being dissolved in muriatic acid, chlorine was given out, and when crystals of sulphate of potash were put into the solution, potash-sulphate of cerium precipitated. When dissolved in boiling water, and mixed with caustic potash, the pure oxide of cerium precipitated. It was washed, dried, ignited, and weighed. And the quantity of protoxide of cerium is estimated from the peroxide thus obtained in the way already explained.

The muriatic acid solution, obtained by boiling the impure columbic acid in that acid, was precipitated by caustic ammonia; a brown precipitate fell, which dissolved in boiling muriatic acid, except a trace of columbic acid. The solution being neutralized with ammonia, and mixed, at a boiling temperature, with sulphate of potash, a precipitate fell, which was zirconia. Benzoate of ammonia now threw down a little peroxide of iron.

The liquid from which the oxide of cerium had been precipitated by sulphate of potash, being treated with caustic potash, a precipitate fell, which was ignited. Being dissolved in muriatic acid, it left a little zirconia. The solution in muriatic acid being neutralized by ammonia, and mixed with sulphate of potash, a little more zirconia was thrown down. The liquid thus freed from zirconia was saturated with tartaric acid, and mixed with sulphohydrate of ammonia. The iron was thrown down. This precipitate being dissolved in nitric acid, and the iron thrown down by ammonia, gave the amount of that metal in the state of peroxide.

The residual liquid was evaporated to dryness, and the residue ignited. It was now dissolved in dilute muriatic acid, and precipitated by caustic ammonia. The precipitate, while still moist, was digested in carbonate of ammonia, which dissolved the oxide of uranium. What remained possessed the characters of yttria.*

No remarks are necessary on the mode of analyzing columbite; the process is precisely the same as that for yttrotantalite, only the number of constituents being fewer, the steps are less numerous.

Sect. 12. *Analysis of Titaniates.*

The only titaniates known at present to exist in the mineral kingdom are the nine following:—

1. Titaniate of iron, or menachanite,
2. Iserine,
3. Subsesquititaniate of iron,
4. Crichtonite,
5. Nigrin, or quintotitaniate of iron,

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* *See Hartwall's analysis*, Kong. Vet. Acad. Handl., 1828, p. 167.

6. Titaniferous iron ore, consisting of three subspecies, namely,
  (1.) Dititaniate of iron,
  (2.) Tetratitaniate of iron,
  (3.) Pentetitaniate of iron.
7. Pyrochlore,
8. Æschynite, or titaniates of zirconia, cerium, lime, and iron,
9. Sphene.

When titanic acid is fused before the blowpipe with biphosphate of soda in the inner flame, the bead assumes a violet colour, which appears much more conspicuous when the glass cools. The addition of a little tin causes the blue colour to appear sooner. In the outer flame the blue colour disappears. If the titanic acid contains iron the colour becomes in the inner flame blood-red. With borax titanic acid fuses in the outer flame into a colourless glass, which when again heated becomes milk-white. In the inner flame the glass becomes yellow, and by continuing the blast it assumes a blue colour, which becomes much deeper by increasing the quantity of titanic acid. With carbonate of soda on charcoal, titanic acid fuses into a yellow glass with effervescence, which on cooling becomes grey and opaque.*

Pure titanic acid, when precipitated from muriatic acid by boiling, and afterwards ignited, is a white tasteless powder. If it be precipitated by an alkali and then ignited, the colour is light brown, and it is concreted into lumps which have a strong lustre. When its colour is reddish it contains a little iron. When titanic acid is heated it becomes lemon-yellow, but the white colour returns as the acid cools.

Ignited titanic acid is insoluble in all acids. If it be fused with pure alkalies or their carbonates, it combines with them, while the carbonic acid makes its escape. The fused mass has a crystalline texture. Water dissolves the excess of base, and leaves the alkaline titaniate undissolved; it dissolves in muriatic acid by the assistance of a gentle heat. If we dilute the solution and boil it, the greatest part of the titanic acid is precipitated in the state of a white heavy powder. When this precipitate is collected on a filter, the liquid passes through clear as long as it continues acid; but when the water becomes

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* Titanic acid is easily distinguished by the blowpipe from manganese and cobalt. Manganese gives a violet colour with biphosphate of soda in *the* outer flame, titanic acid in the inner, while cobalt gives a blue colour *both* in the outer and inner flame.

pure it passes milk-white, and this continues till the whole precipitate makes its way through the filter. This can be prevented by acidulating the water employed for washing the precipitate with muriatic acid.

When titanic acid has been thrown down from its solution by an alkali, it may be washed upon a filter without passing through, and it dissolves again in acids, which is not the case with titanic acid thrown down by boiling.

Potash, soda, ammonia, and their carbonates, throw down white bulky precipitates from the solution of titanic acid in muriatic acid. The precipitates do not dissolve in an excess of the precipitating alkalies, but readily in an excess of muriatic acid.

When the muriatic solution of titanic acid contains as little free muriatic acid as possible, dilute sulphuric acid, arsenic acid, phosphoric acid, tartaric acid, and oxalic acid (especially this last) throw down white precipitates. All these precipitates are re-dissolved in an excess of the precipitating acids, or in muriatic acid. Nitric acid, acetic acid, and succinic acid occasion no precipitates.

The tincture of nutgalls throws down an *orange-red* precipitate, which is characteristic of titanium. Prussiate of potash throws down a precipitate having very nearly the same colour.

Sulphuretted hydrogen occasions no precipitate; but sulphohydrate of ammonia throws down a white precipitate merely in consequence of the ammonia which it contains.

If a piece of zinc be put into a solution of titanic acid in muriatic acid, the liquid assumes a blue colour, while hydrogen gas is disengaged. After a time a blue precipitate falls, which gradually assumes a white colour. Iron or tin acts in the same way as zinc.

All the titaniates, so far as known, appear to be soluble in muriatic acid.

The analysis of minerals containing titanic acid is attended with so many difficulties, that chemists have not yet been able to overcome them all. We owe much on this subject to the researches of Berzelius and H. Rose.

We shall begin with *titaniferous iron ore*, which, containing both oxides of iron, requires particular management.

Mosander, to whom we are indebted for the latest and best analysis of titaniferous iron ores,* took the following mode to

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* Köng. Vet. Acad. Handl., 1829. p. 221.

determine the state of oxidizement of the iron :—A quantity of the ore, reduced to a fine powder, was introduced into a porcelain tube on a porcelain tray. To the tube was attached an apparatus for the evolution of hydrogen gas, already described in a former part of this work. The tube being filled with hydrogen gas, the porcelain tray with the ore was heated to redness. The oxygen of the iron at that temperature united to the hydrogen, and made its escape in the form of water. The process was continued for half an hour after all evolution of water was at an end, and it lasted altogether from two and a half to three hours. When the apparatus was *cold*, the ore was taken out and weighed. The loss of weight gave the quantity of oxygen disengaged from the iron.

Diluted muriatic acid being now poured upon the ore, the iron dissolved with the evolution of hydrogen. Towards the end of the process it is requisite to add stronger muriatic acid to dissolve out the whole of the iron. The titanic acid remains behind undissolved.

The muriatic acid solution contains all the iron, and the other constituents which (besides titanic acid) may be present. It is digested with some nitric acid to peroxidize the iron. The peroxide of iron is now precipitated with the usual precautions by benzoate of ammonia. Knowing the weight of the peroxide of iron thus obtained, it is easy to deduce the weight of iron, and as the weight of the oxygen in combination with that iron had been already determined, we obviously have the means of ascertaining how much of the iron was in the state of protoxide, and how much in that of peroxide.

The liquid thus freed from iron, is to be evaporated to dryness, and afterwards ignited to drive off the ammoniacal salts. The dry residue is to be digested in muriatic acid. Should any thing remain undissolved, it is to be examined by the blowpipe. It was found on one occasion, by Mosander, to be a mixture of yttria and oxide of cerium.

From the muriatic acid solution, let the manganese be thrown down by sulphohydrate of ammonia.

The lime is to be thrown down by oxalate of ammonia.

Let the residual liquid be evaporated to dryness, and ignited, to drive off the ammoniacal salts. If we now mix it with sulphuric acid, evaporate to dryness, and expose the residual salt to incipient ignition, we shall find it to consist of pure sulphate of magnesia, from which the magnesia may be extracted, and its weight determined in the usual way.

The undissolved titanic acid is to be digested in sulphuric acid, mixed with its own weight of water. By repeated boiling in this acid liquid, the whole titanic acid is dissolved, and what remains is silica.

Let the sulphuric acid solution be evaporated, till as much as possible of the excess of the sulphuric acid is driven off. Dilute with water, and add some sulphohydrate of ammonia. Occasionally a slight precipitate of sulphuret of tin falls. The titanic acid is still contaminated with about one per cent. of iron and manganese.

The same process of analysis will answer for *menachanite, iserine, subsesquititaniate of iron, Crichtonite,* and *nigrin.*

Pyrochlore, so far as we are acquainted with its constitution, is a compound of titanic acid with lime, and oxides of uranium, cerium, manganese, and iron. It was analyzed by M. Wöhler, in the following way:—

It was heated to redness in a small retort made from a glass tube, to determine the quantity of water. The liquid driven off had a sour taste, and contained traces of an acid, probably the fluoric.

A given weight of the mineral reduced to a fine powder, was digested for a long time in dilute sulphuric acid, till the whole was reduced to a white homogeneous looking mass. During this process, some fluoric acid was driven off. The surplus of sulphuric acid was evaporated off, and the bluish-green mass remaining was boiled in a great quantity of water. By this process, the titanic acid was thrown down, while the gypsum was dissolved. The solution was filtered off from the white heavy precipitate, which was well washed.

From the liquid, caustic ammonia threw down a small quantity of brownish-yellow matter. It was heated in caustic potash, and the liquid being saturated with muriatic acid and mixed with ammonia, let fall no precipitate. Hence the pyrochlore contains no alumina. The precipitate being digested in carbonate of ammonia, became dark-brown. The ammoniacal solution was yellow. When diluted with water and heated, it deposited yellow flocks. These flocks before the blowpipe, showed the characters of a mixture of oxides of cerium and tin. The yellow solution being evaporated to dryness, left a little peroxide of uranium. The portion undissolved in carbonate of ammonia, dissolved in muriatic acid, and was found to consist of oxide of cerium, mixed with some oxide of iron, and a trace of oxide of manganese.

The ammoniacal liquid filtered from the brownish-yellow precipitate, was mixed with oxalate of ammonia, which threw down the lime.

The residual liquid was evaporated to dryness and roasted, to drive off the ammoniacal salts. A greyish substance remained which dissolved in water. Phosphate of soda and ammonia detected in it a trace of magnesia, but it consisted almost entirely of sulphate of manganese.

The white undissolved substance, considered as titanic acid, was digested for twenty-four hours in sulphohydrate of ammonia while still moist. It assumed a leek-green colour, derived from a minute trace of iron. The sulphohydrate of ammonia was separated and evaporated to dryness. The residual matter was ignited in an open vessel. It was a dirty yellow powder, which being mixed with carbonate of soda, and heated on charcoal before the blowpipe, yielded globules of tin.

The titanic acid thus treated, was dried, ignited, and weighed. It contained merely a trace of iron, but it might contain both zirconia and columbic acid. To determine whether either of these bodies was present, the following experiments were made:—

A portion was fused with bisulphate of potash. The fusion was complete, and the globule perfectly transparent; a proof that the titanic acid contained no silica. When put into water it became milk-white, and as it dissolved, a white powder separated, which was collected and washed on a filter. From the filtered liquid, ammonia threw down some white flocks, which possessed the characters of titanic acid. The white powder being digested in concentrated muriatic acid, was completely dissolved, a proof that the titanic acid contained no columbic acid, which is insoluble in muriatic acid.

The muriatic acid solution being boiled, deposited a quantity of pure titanic acid. The residual liquid being dropped into a solution of caustic potash, gave a farther precipitate of titanic acid, which was completely soluble in an excess of the alkali. From this and some other experiments, the absence of zirconia was inferred.*

The analysis of æschynite may be conducted nearly upon the same plan; only, as it contains zirconia, that earth will require to be separated from the titanic acid by the methods already pointed out.

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* Poggendorff's Annalen, vii. 420.

Sphene is a compound of titanic acid, silica, and lime. It was analyzed by Klaproth in the following way:

Being reduced to a fine powder, it was digested in muriatic acid, by which a considerable portion was dissolved. The undissolved portion was mixed with five times its weight of carbonate of potash, and fused. The fused mass was digested in muriatic acid, which dissolved it completely. The two muriatic acid solutions were mixed and evaporated to dryness. The dry residue being digested in water acidulated with muriatic acid, the whole was thrown on a filter. The silica was left upon the filter, washed, dried, ignited, and weighed.

The muriatic acid solution, thus freed from silica, was precipitated by caustic ammonia. The precipitate was titanic acid. It was washed, dried, ignited, and weighed.

Nothing now remained in solution but the lime, which Klaproth threw down by means of carbonate of potash.*

Various other modes of analyzing this mineral will easily suggest themselves to those who have made themselves familiar with the preceding part of this work.

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* Beiträge, v. 243.

NOTE.

In the table of fossil plants, page 265, no explanation is given of the abbreviations put after most of the species. They refer to figures of the species. Br. denotes the plates in the *Histoire des vegetaux fossiles* by M. Adolphe Brongniart. L. and H. refer to the plates in the British fossil flora of Messrs. Lindley and Hutton.

The arterisk (*) prefixed to a genus in the table indicates that living plants belonging to that genus still continue to exist.

In the table of animal fossils that follows in page 290 of the same volume, an asterisk (*) after the name of a species indicates that the species exists in more than one formation. Those species after which no asterisk occurs have been observed only in one formation.

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The Roman numerals denote the volume. When there are no Roman numerals the first volume is indicated.

THE END.

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