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A TEXT-BOOK
OF
IMPORTANT MINERALS AND ROCKS.

WITH
TABLES FOR THE DETERMINATION OF MINERALS.

BY

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PREFACE.

THIS book is the slow outgrowth of the efforts to meet the necessities of this institution for a convenient text-book of the important minerals and rocks. The number of mineral species has reached nearly one thousand and is constantly increasing. Of this number less than one-tenth is of common occurrence or can be considered of much economic importance, and a small proportion of this same tenth includes the essential constituents of all rocks. To embrace in descriptive text all mineral species necessarily results in an embarrassing mass of matter for the general student. Similar embarrassment, though to a less extent, is experienced in complete descriptions of all the rocks. To reduce these descriptions to a convenient yet satisfactory form for general students is the object of the present effort.

There are described in the book about seventy-five distinct species of the important and, in the main, common minerals, and the principal members of the different classes of rocks. It is thought that the selection is extended enough for general purposes, and it includes abundant material for the study of both minerals and rocks. The book is primarily prepared to meet the necessities of the Military Academy, whose students are well fitted for the work when they begin it, have excellent opportunity for the examination and comparison of specimens, and for laboratory work in determining them. It is hoped that the book may be of convenience to a larger class of students whose facilities in the study may be less, but whose aim is the same as ours—to acquire a fair knowledge of the important minerals and rocks.

Chapter I of the book contains in brief outline the more fundamental principles of crystallography, followed by a description of the different crystalline systems and of some of the more important crystalline aggregates and irregular forms. The subject-matter of the chapter can be almost indefinitely extended by lecture if so desired. The reason that the crystallographic branch is so briefly treated is stated in the introduction to the book, no other treatment being considered appropriate in a short general course.

Chapter II contains a short description of the general properties of minerals, of the laboratory facilities for determining them, and of the manner of using these facilities.

In Chapter III an effort has been made to give a concise and accurate statement of the more readily observed physical properties of the mineral species and of the ordinary mineralogical tests for distinguishing and determining them. There are also added many desirable facts relating to the use and occurrence of the minerals.

A table for the determination of minerals follows this chapter and is intended for a guide and companion in the practical examinations and tests of the minerals.

The table merely puts in condensed form the described properties and characteristics of the minerals as given in Chapter III. This tabular arrangement has many advantages over a descriptive text-book without tables, or with tables bound in separate form. A statement of the properties of each species in the body of the text as well as in the table has been found advantageous when recitation and practical work are conducted simultaneously.

The tables have been a slow growth, of nearly twenty years, from very simple beginnings, and have during that time been used by our pupils under separate binding. In this preparation I have had valuable suggestions from several officers who have served as instructors in the department, but I would here especially acknowledge my great indebtedness to Capt. J. P. Wisser, 7th U. S. Artillery, who, as Lieutenant Wisser and while serving as Assistant Professor in the Department in 1890 and '91, did the larger part of the work which placed the tables in their present shape.

Part II is devoted to the common rocks. The principles of classification, the classes, and the distinguishing characteristics of each class are given; the appearance of the different members of each class is described and their mineral composition given, to which are added many important facts as to occurrence and use and the more prominent conclusions as to origin.

The greater portion of the matter contained in the book, exclusive of the mineral tables and the contents of Chapter I, has been used at the Academy for the past six years, and has been frequently added to and revised during that time.

The arrangement of mineral species in the text is modeled after that of the late Professor J. D. Dana in his manual of Mineralogy and Petrography. The mineral compounds of the same metals are brought together, except in the case of silicates. The important metals and their ores are consecutively treated, as are the important rock-making minerals. This arrangement has, from experience, been found very satisfactory.

In the preparation of this little book I have consulted many authorities, but would especially acknowledge my obligations for mineralogical matter to the works of Professors J. D. Dana, E. S. Dana, G. J. Brush, S. L. Penfield, H. Bauerman, W. O. Crosby, and D. M. Barringer; for petrographic material to various published papers of the U. S. Geological Survey, to the works of Professors J. F. Kemp, W. B. Scott, and J. D. Dana; for the chapter on Crystallography to the works of Professors G. H. Williams, E. S. Dana, H. Bauerman, and N. Story-Maskelyne.

Through the courtesy of Professor E. S. Dana I have been permitted to use the crystalline figures shown under numbers 2, 3, 4, 5, 18, 20, 22, 25, and 26, which are taken from his Text-book of Mineralogy. Figures 19, 31, 32, 33, and 34 are from Williams's Elements of Crystallography, through the courtesy of the publishers, Henry Holt & Co.

S. E. TILLMAN.

U. S. MILITARY ACADEMY, WEST POINT, N. Y.,
October 1, 1900.

PREFACE TO SECOND EDITION.

In preparing a second edition of this book effort has been made to remove all errors of typography and statement contained in the first. The headings of mineral classes have been more clearly indicated by better paragraphing. All accessory minerals have been grouped together, and the chemical formulæ of all minerals referred to have been inserted.

The principal object of the book and reasons for the treatment adopted and for the proportions assigned to the different parts of the subject are stated in the preface to the first edition, but the author would emphasize the fact that the main object of the book is to make students of a short general course acquainted with the simple blowpipe and chemical tests for, and familiar with the physical characters of the important minerals and rocks; those tests and those characters which usually supply the general student with all that he permanently retains or desires.

The students of this institution for whom the book was primarily prepared have immediate and full practical use, under guidance, of the laboratory facilities referred to in the text, and the descriptive study of minerals and rocks is accompanied by large opportunity to test and examine specimens and compare them with properly labelled sets. Under these conditions minute reference to the details of laboratory facilities or to not-easily-recognized mineral and petrographical characters, which might be of use to more special students, are believed to be not only unnecessary but detrimental to best results in general study.

By the simple testing of specimens and close observation of physical characters, the great majority of the common minerals and rocks can be recognized, and many others very approximately placed. The ability to accomplish these results can be acquired to an astonishing degree, even in a short course of instruction, when the practical method indicated can be satisfactorily pursued. A text-book, as this is intended to be, for such a course should avoid much of the technical matter appropriate for other purposes, but which would be inappropriate here.

WEST POINT, N. Y., Nov. 10, 1902.

PREFACE TO THIRD EDITION.

THE necessity for a reprint of this book has enabled the author to correct a number of typographical errors and to bring all the statistical matter up to date. The chemical formulæ of all mineral species, where they first appear, have been made more legible by having the atomic coefficients which enter the formulæ shown by larger subscript numerals.

S. E. TILLMAN.

WEST POINT, N. Y., January 30, 1908.

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PART II.

COMMON ROCKS.

The following abbreviations are used in the text:

Before blowpipe	B.B.
Color	C.
Hardness	H.
Luster	L.
Oxidizing Flame	O.F.
Reducing Flame	R.F.
Sign of inequality—greater than	$>$
Specific gravity	G.

PART I.

IMPORTANT MINERALS.

CHAPTER I.

INTRODUCTORY REMARKS.

THE natural objects of the universe can in general be included in two great groups or kingdoms, the organic and the inorganic. To the first belong the bodies which originate through the agency of life, to the second the bodies not thus originating.

Those bodies occurring in the inorganic kingdom which have a definite chemical composition are termed minerals. Mineralogy is the science which describes and teaches how to distinguish and determine minerals. The distinction of minerals from each other is based upon the consideration of the composition, external form, and internal structure, all of which must be determined and investigated in the full classification of minerals.

The term 'mineral species' is generally made to include all those minerals which have the same composition and a definite form and structure. With few exceptions minerals at ordinary temperatures are solids, and all minerals in becoming solid, whether from state of vapor, fusion, or solution, tend, under favorable conditions, to form regular geometrical solids bounded by plane surfaces. The regular forms thus assumed by minerals are called *crystals*. The natural bounding-plane surfaces of a crystal are called the *faces*, the lines in which the faces intersect are called *edges*, the angles between edges are *plane angles*, those between faces are *interfacial angles*, and those formed by the meeting of three or more faces are *solid angles*.

In the study of crystal forms it was early observed—

1st. That there was a marked symmetry in the arrangement of their parts, as faces, edges, points, etc.

2d. It was discovered that the forms of the same species obeyed certain laws that made possible a geometrical classification of the crystals of different species.

It was later developed by studying the physical properties of the crystals that there is an intimate and complete accord between these properties and the forms of the crystals, and that the form is but the obvious external evidence of a definite internal structure; that it is the structure that is characteristic, the form and physical properties are the evidences of the structure.

The consideration of the properties or characteristics which distinguish minerals (structure, form, composition) give rise to two distinct divisions of the science of mineralogy.

I. Crystallographic mineralogy, which considers the form and structure of the minerals, and this has two branches:

(*a*) Geometric or morphological crystallography, which considers the external form of minerals and the geometric relations of their faces and plane surfaces.

(*b*) Physical crystallography, which investigates the properties which are mainly the result of structure, i.e., physical properties, such as cohesion, elasticity, and the properties displayed under the action of light, heat, electricity, etc.

II. Chemical mineralogy, which is primarily concerned with determining the chemical composition of the minerals. It also extends to the consideration of the chemical relations between constitution and form.

The knowledge obtained through all the above branches of mineralogy when systematically arranged and presented, together with information as to mode of occurrence, distribution, and association of the different species, constitutes Descriptive Mineralogy.

Thorough acquaintance with all branches of mineralogy is essential to the work of specialists, but for the general student the essentially chemical branch is far more important, for through it the composition can usually be more readily determined, and it is upon the composition that all other relations depend. For this reason only brief reference will be made in this book to the crystallographic branch, and then only to the most fundamental principles.

CRYSTALLOGRAPHIC CONSIDERATIONS.

Elements of Geometric Symmetry in the Form of Solids.—The symmetry of form in solids may be considered with reference to planes of symmetry, axes of symmetry, or centers of symmetry.

Planes of Symmetry.—The form of a solid is geometrically symmetrical with reference to a plane when the plane divides the solid into two precisely corresponding parts, so that every normal to the plane section would meet a corresponding point of the solid at the same distance from the section. A polyhedron placed upon a plane mirror forms with its image a symmetrical figure, of which the mirror surface is the plane of symmetry. Again, a plane passing through the center of a cube parallel to either face divides it symmetrically, and it is at once evident that there are three such planes for a cube. So the planes passing through the diagonally opposite edges of a cube are planes of symmetry. There is generally a distinction between the mineralogical symmetry of crystals and the full geometric symmetry of figure here defined. This distinction will appear subsequently.

Axes of Symmetry.—An axis of symmetry of a solid is a line about which if the body be rotated it will successively occupy the same position, or will fill the same place in space. Axes of symmetry can be distinguished from each other by the number of times the body occupies the same position in space during a complete revolution about each.

A cube turned about a line joining the middle point of opposite faces will occupy the same position in space four times during one revolution; such line is an axis of quaternary symmetry. A line joining the middle points of diagonally opposite edges in a cube is an axis of binary symmetry. In the square octahedron, Fig. 1, the vertical axis *a* is an axis of quaternary symmetry, while *c* and *d* are axes of binary symmetry. The axis about which the third or a higher order exists is a principal axis of symmetry; other axes are secondary axes.

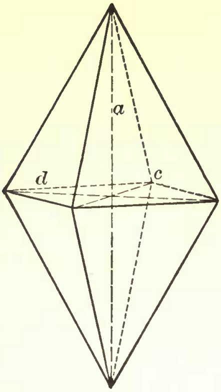

Fig. 1.

Center of Symmetry.—A center of symmetry of a solid exists when a line passing through the center meets similar points in the opposite halves of the crystal at the same distance from the center. A center of symmetry may exist without either axes or planes of symmetry being present.

In every case of a center the crystal polyhedron is bounded by pairs of parallel planes which are at equal distances from the center, and it can always be shown that the points in which a line through the center pierces any two of these planes are corresponding points in two halves into which the crystal may be divided.

Crystallographic Symmetry.—Geometric symmetry, above referred to, relates to the external form of the solid. In crystals, as already stated, the physical properties have a definite, constant and most intimate connection with the external form. Both form and physical properties are determined by the structure of the particular body; the structure is the most essential physical character of the crystal, and the form is only the most important external manifestation of the structure. A solid in the form of a crystal, without the related internal structure, does not constitute a crystal; such a solid is only a model of the external form.

Natural crystals very frequently exhibit geometric symmetry in their external form, and it is thought that if crystallization took place without any disturbance of, or interference with, the most favorable circumstances for the process, geometric symmetry of form would generally result. In such cases crystallographic symmetry would be defined by the relations of geometric symmetry which would result. Crystallographic symmetry, however, exists without being completely expressed in the external form. The form is but one indication of the internal structure, the physical properties are another. The physical character of minerals have been very carefully studied, and in general are found to be the same in all parallel directions. This fact is believed to demonstrate a like internal structure or molecular arrangement in these parallel directions. The intimate relations between the physical character and the faces and planes of a crystal lead to the conclusion that the planes are but external expressions of the internal structure. The faces are accordingly definitive because of their direction or angular position, and not because of their size or distance from any assumed origin. Thus Figs. 2 and 3 are equally symmetrical about a vertical or horizontal plane passing through their centers. Again, a crystal may be a crystallographic cube, though departing widely from the geometric form, as in Figs. 4 and 5, provided it can be shown that the three pairs of faces are alike; this would have to be done from the physical character of the faces, by the kind of cleavage, or by optical means.

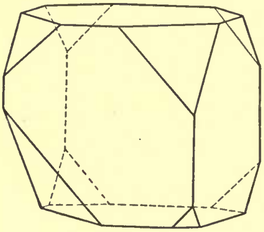

FIG. 2.

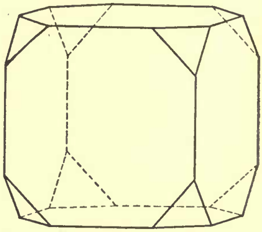

FIG. 3.

The important point to be grasped in regard to crystallographic symmetry is that the symmetry in crystals about lines or planes is one of direction and not of position. In consequence of this fact any plane of a crystal may be considered as shifted parallel to itself without affecting the crystallographic symmetry: hence the corresponding symmetrical faces of a crystal may be of very unequal size and distance from the origin, without disturbing the crystallographic symmetry. In general, for convenience in the discussion and description of forms it is better to consider symmetry of position as well as of direction; in other words, we may readily imagine the similar crystal planes to be shifted in directions parallel to themselves until a solid of geometric symmetry is produced.

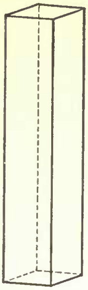

FIG. 4.

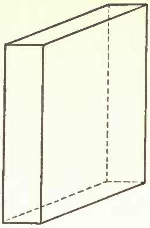

FIG. 5.

Coordinate or Crystallographic Axes.—For studying and classifying crystal forms, and for describing the position of their faces, it is convenient to assume a system of coordinate axes after the manner of analytical geometry. Different sets of axes may, for this purpose, be assumed in crystals, but that set is usually employed which enables expression in the simplest manner of the position of the faces and the relations between different crystalline forms. These considerations have led to the selection of the axes of symmetry as coordinate axes whenever the proper number of these axes are present. If only one axis of symmetry is present, it is employed in connection with two other assumed directions. The axes chosen under the above conditions will differ in their relations to each other in different crystalline forms. They may intersect at right angles, giving *orthometric* forms, or obliquely, giving *clinometric* forms. They may be all equal in length, only two equal, or all unequal; in some cases they connect the centers of opposite faces, in others the middle points of opposite edges, or the apices of opposite solid angles. It should be remembered that the axes usually assumed are not the only ones that could be employed, but are such as afford the simplest relations for the descriptions of forms. The planes in which the coordinate axes lie are called the axial or diametric planes. They correspond to the coordinate planes of analytical geometry, and divide the spaces within the crystal into eight solid angles, and in one system where four axes are used the space is divided into twelve solid angles.

Location of Planes by Reference to Axes.—The position of any plane is known when its intercepts on the assumed axial directions are given. If x, y, z represent the intercepts on the respective axes of a plane, the position of the plane may be expressed by $x : y : z$. The intercepts on the axes are called the parameters of the plane. In general the axes are lettered a, b, c, the vertical axis usually being represented by c, that from right to left b, from front to rear by a; as in analytical geometry, the positions of the semiaxes on opposite sides of the origin have opposite signs, the plus sign ($+$) being applied to the halves in front, to the right, and above the origin, and the minus sign ($-$) to the opposite halves, Fig. 6. If definite lengths on the axial directions be assumed as unit semiaxes, the parameters of any plane may be expressed in these lengths. The unit semiaxes assumed are those belonging to a particular crystal form of each

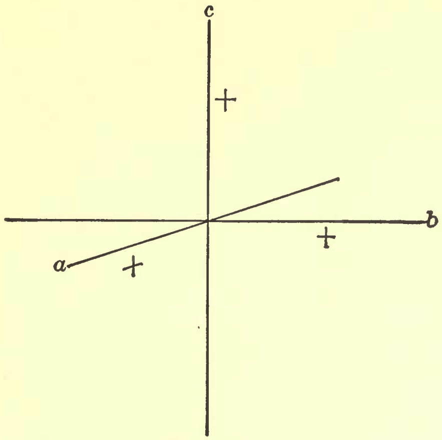

FIG. 6.

species. This particular form is called the *unit form* or *fundamental form.* The unit form and the crystallographic axes in the form are so chosen as to give the simplest expression for the parameters in the different crystals of the species. If we let a, b, and c represent the unit axes, the parameters x, y, and z of any plane may be written $ma : nb : rc$, which is the general expression for a face. The letters m, n, and r are the ratios of the intercepts to the lengths of the semiaxes and are called parameter coefficients. It is evident that the intercepts of all parallel planes bear the same ratio to each other, and since crystallographic symmetry is not affected by shifting a plane parallel to itself, one of the intercepts of a plane may always be assumed equal to unity, and the general expression for the face becomes $a : nb : rc$. It follows from these considerations that all parallel planes lying on the same side of the origin have identical expressions; parallel planes on the opposite sides of the origin have the same expressions except as to sign. Parallelism to any axis is represented by the sign infinity associated with that axial symbol. Thus $a : \infty b : \infty c$ indicates a plane parallel to two of the axes (b and c). The positions of a plane may also be expressed by using the reciprocals of the parameters; such reciprocals are termed indices of the plane. Several systems of notation have been devised, the object in each case being to represent briefly and clearly the position of the faces with reference to the crystallographic axes. It is not practicable to here describe the system of notation.

Definitions Pertaining to Crystals.—Cleavage is the quality which minerals possess of splitting in certain definite directions along plane surfaces. Cleavage is, of course, a result of molecular structure, and a consideration of the molecular arrangements in a mineral which would produce crystal faces explains also the tendency to cleave in directions parallel to the faces. Every cleavage plane is a possible face of a crystal, and is due to the molecular arrangement which produces faces. The more fundamental the face the more perfect is the cleavage in that direction. The natural planes of a crystal are called its *faces;* those obtained by splitting are called *cleavage planes.* As already stated, the intersections of bounding planes are edges. When an edge is cut off by a plane it is said to be *replaced;* when the replacing plane is equally inclined to the original faces the edge is *truncated;* when the edge is cut off by two planes equally inclined respectively to the original faces it is *bevelled.*

Similar planes are those which can be expressed by the same notation except as to signs. Similar edges are produced by the intersection of corresponding pairs of similar planes. Similar angles are formed by the meeting of the same number of corresponding similar planes. Planes which have like positions with respect to the axes, except as to direction from the center, are *like* planes.

Similar planes are always like planes; thus the faces of the cube are *all* like planes, but only the *opposite* faces are similar planes.

Crystallographic Law—Law of Axial Ratios, or Rationality of Parameters or Indices.—From what has preceded we see that symmetry is inherent in nearly all solid minerals and is part of their nature. Crystallographic symmetry may be considered as a natural result of the molecular structure of a mineral. Certain geometric relations have been found to connect all the faces which belong to the crystals of any one mineral.

The law governing these relations is known as *the law of axial ratios,* or *the law of rationality of parameters* or indices. It is an empirical law, but there are no known exceptions to it, and it is the basis of mathematical crystallography. The law may be stated as follows:

The ratios of the intercepts on the same axis by the different planes of a crystal can only be 0, ∞, *or rational numbers; these ratios can never be irrational.* The law may also be expressed thus: *The position of all the planes of a crystal, located by their intercepts, can always be expressed by numbers bearing a simple ratio to the relative lengths of the axes of the unit form.*

The geometric consequences of this law are the exclusion from crystalline forms of all but the simpler types of symmetry about an axis, binary, ternary, quaternary, and senary. Regular solids of a higher order than the cube or octahedron are thus excluded.

Constancy of Angles.—Since the planes of a crystal may be shifted without affecting crystallographic symmetry—provided each plane is moved parallel to itself—it follows that the above law, the constant ratio of the intercepts for the different planes of the crystal, also fixes a constant angle between the intersecting planes, and we may write as a second crystallographic law: *that the angles of inclination between like faces of the crystals of the same species are constant.*

The unequal development of the faces of a crystal during its growth has the same effect as the shifting of the planes in directions parallel to themselves. This does not change the ratios existing among their intercepts; hence the angles between the faces are constant, however much the faces may vary in size in the different crystals of the same species.

All possible classes of crystalline forms can be deduced mathematically, in the same manner that possible geometrical polyhedrons are deduced, and the solution is less complex, for the law of axial ratios excludes the higher orders of symmetry. The possible crystalline classes are found, under the law, to be thirty-two. Natural representatives of all the possible classes are not yet known, though nearly all that do not occur in nature have been produced in the laboratory.

Zonal Relations.—The planes occurring in crystals are frequently arranged in belts extending around the crystal in different directions. A zone includes a series of faces whose intersections are all parallel to each other. An imaginary line through the center of the crystal, parallel to the common direction of intersection, is called the *zonal axis.* All the planes which belong to the same zone are said to be *tautozonal.* The zonal relation establishes the fact that the parameters of the faces of the same zone have constant ratios for two of the axes.

(1) When the positions of two planes of a zone are known, the direction of the zonal axis is determined. The position of a plane belonging to two zones is known when the directions of the zonal axes are known.

(2) The parameter relations between the faces of a zone make it always possible to deduce some simple numerical relation between the faces belonging to the same zone; the relations so expressed give the *zonal equation*. The determination of what planes belong in the same zone is simple in principle, and not especially difficult in practice, but the method to be pursued cannot be here explained.

We have seen that the symmetry of form of crystals can be expressed in their axial relations, according to the number and character of their axes of symmetry. On this basis the possible groups of crystals are generally classed in six systems, depending upon the number, relative lengths, and inclinations of their crystallographic axes.

CRYSTALLINE SYSTEMS.

I. The Isometric System.—This system has three equal axes at right angles to each other, each axis being an axis of quaternary symmetry. The simplest forms under this system are the cube, Fig. 7, the regular octahedron, Fig. 8, and the regular dodecahedron, Fig. 9. The positions of the axes are indicated in the diagrams. Either of these forms can be assumed as fundamental and the others readily derived from it; for example, if in the cube planes be passed parallel to one lateral axis and through the extremities of the vertical and the other lateral axis, the octahedron will result, or pass planes through the extremities of the semi-axes of the octahedron, perpendicular to one axis and parallel to the other two, and the intersections will form the edges of an enclosing cube. The faces of one or more of the above forms are

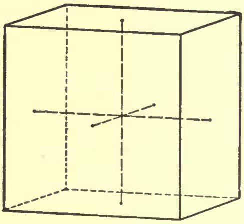

FIG. 7.

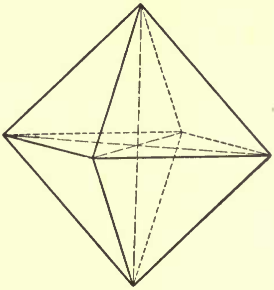

FIG. 8.

sometimes found in the same crystal, as shown at Figs. 10 and 11.

Besides the crystallographic axes of quaternary symmetry referred to in this system, there are other axes of symmetry—six axes of binary symmetry, which connect the middle points of diagonally opposite edges, and four axes of ternary or trigonal symmetry, which join the vertices of opposite solid angles.

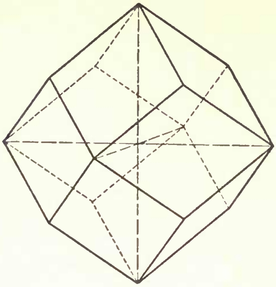
FIG. 9.

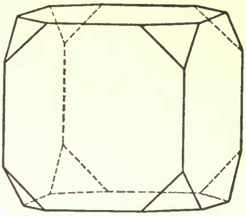
FIG. 10.

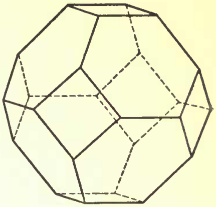
FIG. 11.

II. The Tetragonal System.—In this system there are three axes, at right angles to each other; the two lateral axes are equal in length, and the vertical axis is longer or shorter. The simple forms in this system are the right square prisms, Figs. 12, and 13, and the square octahedrons, Figs. 14, and 15. The cross-sections of these forms, perpendicular to the vertical axes are squares. As mentioned in the preceding system these forms are derivable from each other. In this system the vertical axis is an axis of quaternary or tetragonal symmetry. The lateral axes may join the centers of opposite faces or of opposite vertical edges. The relative lengths of the vertical and horizontal axes may vary, depending upon whether a long or short octahedron be assumed as the unit form. The selection of this form depends upon considerations already mentioned.

III. The Hexagonal System.—This system has two divisions: (*a*) Hexagonal, (*b*) Rhombohedral. (*a*) In the hexagonal division there are four axes, one vertical and three lateral axes; the lateral making angles of sixty degrees with each other, and the vertical axis being perpendicular to the plane of the lateral. The vertical axis is an axis of senary symmetry, while the lateral axes are of binary symmetry. The lateral axes are in sets of three each, the axes of each set being equal in length. (*b*) In the rhombohedral division the arrangement of certain planes around the vertical axis are alternate in the upper and lower halves of the crystal. This arrangement leaves the vertical axis an axis of ternary or trigonal symmetry instead of hexagonal, with three horizontal axes of binary symmetry. Some of the simpler forms of the hexagonal division are shown in Figs.

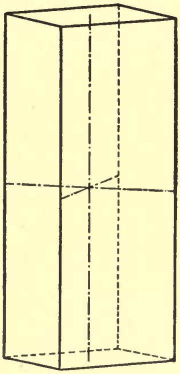

FIG. 12.

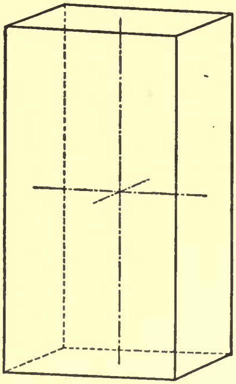

FIG. 13.

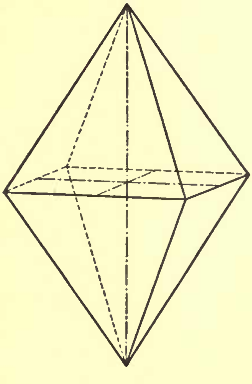

FIG. 14.

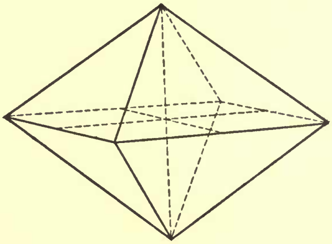

FIG. 15.

16, 17, and 18; Fig. 19 shows the possible positions of the lateral axes in the hexagonal division; Figs. 20 and 21 show two forms of the rhombohedral division.

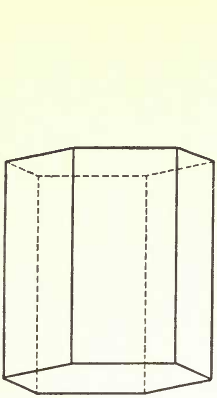

FIG. 16.

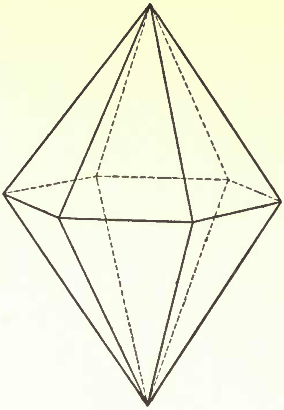

FIG. 17.

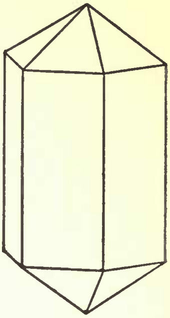

FIG. 18.

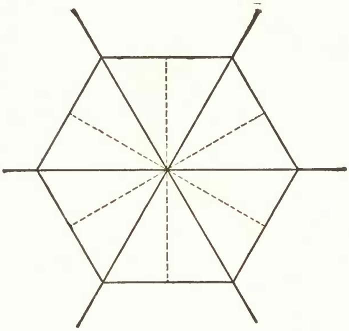

FIG. 19.

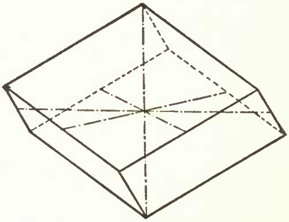

FIG. 20.

IV. The Orthorhombic System.—This system has three rectangular axes, no two of which are of the same length. The simpler forms of the system are the right rectangular prism, Fig. 22, the right rhombic prism, Fig. 23, and the rhombic octahedron, Fig. 24. The planes of these three forms, as well as of others not mentioned, are sometimes found in the same crystal.

In this system each axis is an axis of binary symmetry.

V. The Monoclinic System.—This system has a vertical and two lateral axes, no two being of the same length. One lateral axis is oblique to the vertical axis, and the other lateral axis is perpendicular to the plane of the vertical and oblique lateral axis. The simple forms in the system are the oblique rhombic prism, Fig. 25, the oblique rectangular prism, Fig. 26, and the right rhomboidal prism. As in the other systems, the planes of different forms sometimes occur in the same crystal.

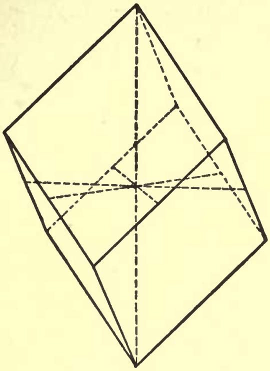

FIG. 21.

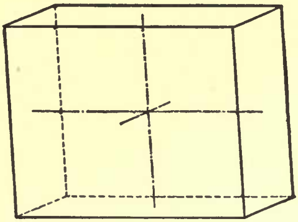

FIG. 22.

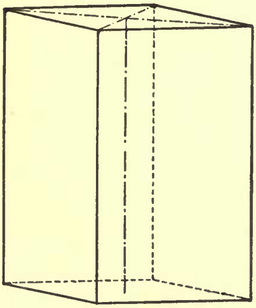

FIG. 23.

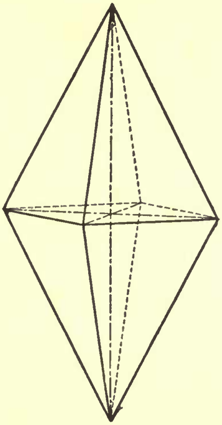

FIG. 24.

In different species belonging to this system the relative lengths and inclinations of the axes vary.

The system has only one axis of binary symmetry.

VI. The Triclinic System.—This system has three axes of unequal length, each being oblique to the plane of the other two. A simple form is the oblique rhomboidal prism. In different species belonging to this system, as in the preceding, both the relative lengths and inclinations of the axes vary.

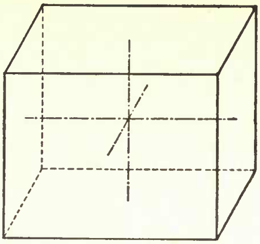

FIG. 25.

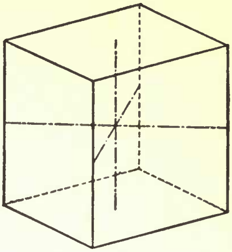

FIG. 26.

There is no axis of symmetry in this system, the symmetry existing only with respect to a point which is a center of symmetry. In this case, if an imaginary plane be passed through the center parallel to one of the faces and the portion of the crystal on one side of the plane be thought of as rotated 180° about a line perpendicular to the plane and passing through the center, the two halves of the crystal would then be mirror images of each other across the plane. The center of symmetry of the polyhedron is also a center of symmetry for every polygonal figure formed by the intersection of the faces of the crystal with a plane passing through the center. Every such polygon rotated in the plane about the center occupies congruent positions after every turn of 180 degrees.

It will be observed that the above systems can be grouped into three classes, depending upon the number of their principal axes of symmetry. A principal axis of symmetry has already been defined as one that is of the third or higher order of symmetry. This, as a general statement, is correct, and any crystal which has trigonal symmetry has a principal axis of symmetry, but an axis of trigonal symmetry is not necessarily a principal axis of symmetry in a system where there are axes of higher symmetry. Thus, in the cube (isometric), the three axes of tetragonal symmetry connecting the middle point of opposite faces are principal axes, while the four axes of trigonal symmetry connecting diagonal opposite angles are secondary axes in this system.

The groups of the above six systems according to the number of their principal axes are:

1st. Those without a principal axis of symmetry. Under this group are included the Triclinic, the Monoclinic, and the Orthorhombic. The first is without linear symmetry, and the other two have only binary symmetry.

2d. Those with one principal axis of symmetry. Under this group are the Hexagonal and Tetragonal; the principal axis in the first being one of senary symmetry, and in the second of quaternary.

3d. Those with three principal axes of symmetry. The Isometric is the only system in this group; the three principal axes of the system being of quaternary symmetry.

Crystal Symmetry about Planes.—In grouping the crystal forms according to their axial relations, only symmetry about lines and points has been described, but it is evident that symmetry about lines involves symmetry with reference to planes. The crystallographic axes assumed in the first four systems of crystallization result from the intersection of planes of symmetry. In the Monoclinic system there is one axis of binary symmetry, which must accordingly be perpendicular to a plane of binary symmetry. In the Triclinic system, there being no axis of symmetry, there is no plane of symmetry. Axes of symmetry are said to be *like* or *equivalent* when they are of the same order of symmetry and of the same length. Planes of symmetry are *like* when they divide the perfect form into identical halves. In general a plane which contains two or more like axes of symmetry is a *principal* plane of symmetry, the others are secondary planes; this statement must be limited in the isometric system, so that the like axes shall be those of the highest symmetry. Principal axes of symmetry are normal to principal planes of symmetry, and secondary axes to secondary planes. From the above definition it is seen that in the isometric system the assumed coordinate or crystallographic axes are the principal axes formed by the intersections of the principal planes of symmetry. In the tetragonal system these coordinate axes are formed by the intersection of one principal plane of symmetry, with two secondary planes of symmetry, all at right angles to each other.

In the Hexagonal the assumed axes are formed by the intersection of one principal plane with six secondary planes meeting at angles of 30°.

In the Orthorhombic system the coordinate axes are formed by the intersection of three secondary planes, all at right angles to each other.

In the Monoclinic system one of the crystallographic axes is the normal to the plane of symmetry; the other two are in that plane and so chosen as to give greatest convenience: the positions of these latter are usually taken as previously stated.

In the Triclinic system there are neither planes nor axes of symmetry, and the choice of coordinate axes is arbitrary.

Hexagonal symmetry, of necessity, includes *trigonal* symmetry, and tetragonal symmetry includes *binary* symmetry.

Crystal Forms—Closed and Open Forms.—A *form* in crystallography includes all of the like faces in the crystal—like faces, as already defined, being those which have like positions with reference to the axes, except as to their direction from the origin. If *all* the faces of the crystal are like, they constitute a closed form; that is, the enclosed solid is entirely bounded by like faces. If the like faces do not enclose the solid, the

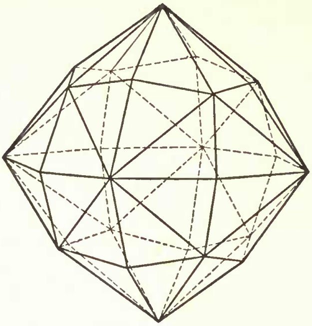

FIG. 27.

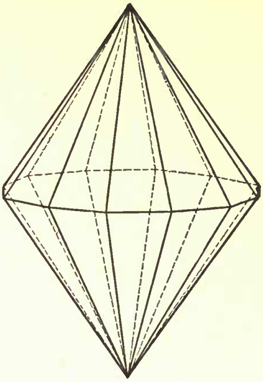

FIG. 28.

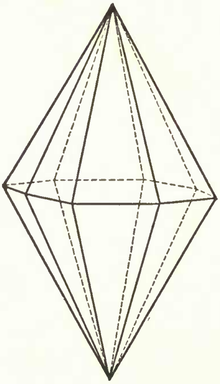

FIG. 29.

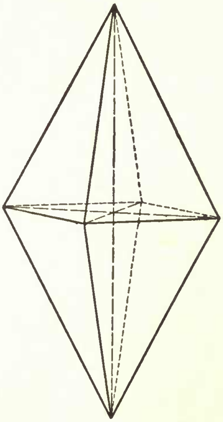

FIG. 30.

form is open. There are no closed forms in the Monoclinic and Triclinic systems—that is, no crystal forms in which all the faces are like; in the other four systems there are closed forms, those in which the crystal faces are all alike. The maximum number of like faces in the closed forms of these systems varies with the symmetry of the system. The number is 48 in the Isometric, 24 in the Hexagonal, 16 in the Tetragonal, and 8 in the Orthorhombic, which are shown at Figs. 27, 28, 29, and 30. The opposite pairs of the faces in these forms are similar planes.

Holohedral and Hemihedral Forms.—When a crystal is contained by all the faces necessary to the complete symmetry of the system, to each face there is a parallel similar face, the total number being even and never less than six; such forms are holohedral. There are occurring forms in which there are only one-half or one-fourth the number of faces necessary to complete symmetry; these are called respectively hemihedral and tetrahedral forms.

These forms, other than the holohedral, may be considered as produced by the suppression of one-half or three-fourths of the planes of the complete forms, and the extension of the remaining planes until they intersect. The surviving and suppressed planes in these forms are always those which fulfill certain definite conditions. One-half or three-quarters of the planes of a *complete* form, *arbitrarily* chosen for suppression or extension, will not produce the other forms. The symmetry of the hemihedral and tetrahedral forms is of a lower order than that of the complete forms in the same system. The symmetrical elements of the lower forms are less in number, but identical with the symmetrical elements in the holohedral forms, and well-defined geometrical laws connect the forms with each other.

DISTORTIONS IN CRYSTALS.

It has been already stated that crystallographic symmetry is not always accompanied by geometric symmetry. For the purpose of describing the systems, it is simpler to consider the ideal forms as we have done, but the perfect forms of the systems seldom occur in nature. The departures from the ideal forms which are due to the unequal development of the faces of the crystal and to the unequal dimensions of like axes are called *distortions*.

Distortions render more difficult the identification of forms, but the constancy of interfacial angles and the identical characters of like faces are the means by which the difficulty is overcome. For example, the perfect cube is not generally met with in nature; if lengthened or shortened in the direction of *one* axis, it assumes the form of a right square prism; if varied in the direction of two axes, it becomes a rectangular prism (see Figs. 4 and 5). In the first case its geometric form would place it in the tetragonal system, in the second case in the orthorhombic. The physical similarity of its faces, or equal cleavage in the three rectangular directions. would place it in its proper system.

Other forms more complex than the cube have distortions not so readily recognized, but the considerations above mentioned, together with a general familiarity with the more common distortions, usually serve to place the specimen under consideration. The faces of crystals are frequently not plane surfaces: they may be either *striated* or *curved.* These imperfections in crystals may result from *oscillatory combinations* or *twinning*, to which reference will be made. Curvature is also sometimes due to mechanical causes, as is thought to be the case in tourmaline, or to the molecular conditions of crystallization, as in the diamond.

MULTIPLE CRYSTALS.

The crystal individuals thus far considered have all been polyhedrons, whose interfacial angles are less than 180°. Such is always the case with the distinct individual. On many crystalline surfaces re-entering angles are found which always indicate a combination of two or more individuals. These groups of crystals conform to certain definite laws. A few of the important groups will be briefly referred to.

Parallel Grouping.—The simplest cases of parallel grouping consist of similar crystals so arranged that the line joining their centers coincides with a crystallographic axis or is parallel to it. These forms are illustrated in Figs. 31, 32, 33. If two cubes were joined as are the forms in Fig. 31, there would result a right square prism which would appear as a single crystal. The re-entering angles denote the junction of separate individuals in parallel growth.

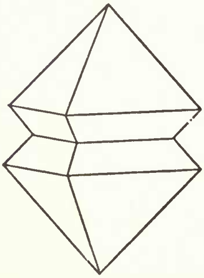
FIG. 31.

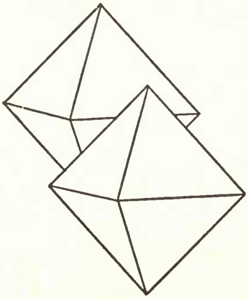
FIG. 32.

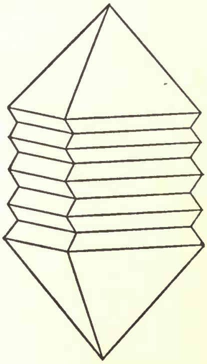
FIG. 33.

If the width of the alternating planes is very small, there results what appears to be a single crystal with striated faces; this arrangement of planes in a surface is termed *oscillatory* combination; there is an approximation to this in Fig. 33.

Often complex crystalline forms result from parallel growths. Many of the delicate dendritic forms are thus brought about. In these parallel groupings the crystal as a whole is symmetrical with reference to some plane which is also a plane of symmetry for each individual form.

Twin Crystals.—In twinning combinations two individual crystals or two halves of the same crystal are joined so as to have either a common crystallographic direction or crystallographic plane, but the parts are not in completely parallel positions. The two crystals or two halves of the same crystal are accordingly symmetrical with reference to a plane which is not a plane of symmetry for the individuals, and this is the main distinction between the parallel grouping and the twinning position.

The relation of the parts in a twin crystal may be understood from Fig. 34, which shows a regular octahedron divided into halves by a plane parallel to an octahedral face; in the figure the front half has been rotated through 180° about an axis normal to the plane.

Contact Twins.—The form of structure shown in Fig. 34 is an example of what is designated as contact twins; this particular form is also termed a hemitrope crystal. Another form of contact-twinning is shown at Fig. 35.

Penetration Twins are those in which the twinning crystals are not joined along a plane, but more or less completely penetrate each other. Such forms are shown at Figs. 36, 37, and 38.

Repeated Twinning.—A third individual may be added to one of the two crystals of a twin according to the same law that joins the first two, thus causing repeated twinnings, giving rise to trillings, fourlings, fivelings, etc. The variations of form resulting from the different applications of the twinning laws are very numerous, and further reference to them cannot be here undertaken.

Pseudomorphs.—Minerals generally belonging to one crystalline system are sometimes found to have the form of another. Such crystals are called pseudomorphs. They are thought to result sometimes through a change of composition in the mineral, or else the pseudomorph is formed by the filling of a cavity left by the removal of a crystal of another form.

ISOMORPHISM.

Some of the compounds of certain elements crystallize in the same form; and not only this, but one of these elements may replace the others in a crystal without destroying

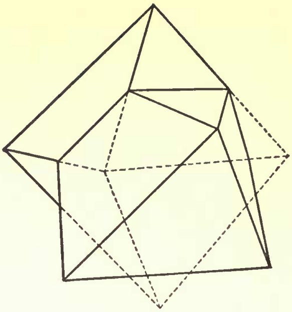

Fig. 34.

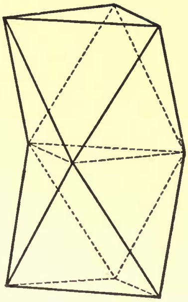

Fig. 35.

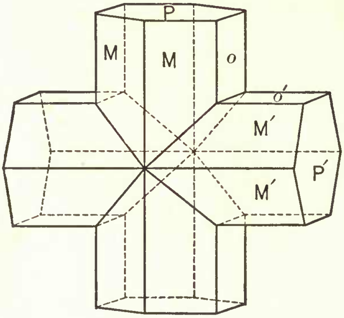

Fig. 36.

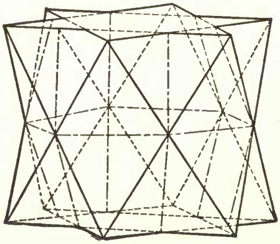

Fig. 37.

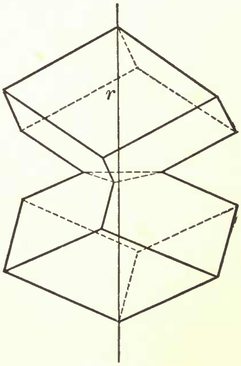

Fig. 38.

the form; such elements are said to be isomorphous. Calcium, magnesium, and iron are notable examples.

CRYSTALLINE AGGREGATES.

Most mineral masses are not composed of distinct crystal forms, but consist of an aggregation of imperfect crystals. Sometimes the aggregation is wholly irregular, and sometimes more or less regular. There are many varieties of aggregates. The planes between the individuals in aggregates are simply planes of fracture; when the fracture gives rise to a coarse rough surface it is called *hackly;* when it gives rise to a smooth flat surface it is called *even;* and when it gives rise to curved surfaces, having shell-like appearances, it is called *conchoidal.* Some of the more important and common aggregates are:

1. *Dendritic.*—Composed of small crystals arranged in such a manner as to give a tree-like appearance, as in native gold and silver. The term is also frequently used for similar forms, whether due to crystals or not, as to those produced by the oxide of manganese

2. *Drusy.*—Composed of many small crystals implanted in a finer ground-mass, giving a very rough surface.

3. *Columnar or Fibrous.*—Composed of columnar or fibrous individuals, sometimes aggregated so as to give the appearance of a heterogeneous mixture, sometimes forming star-like groups, and sometimes giving rise to globular forms. These globules are sometimes arranged so as to give rise to forms resembling bunches of grapes, and therefore called *botryoidal.* If the globular masses be nearly hemispheres, the form is called *mammillary.*

4. *Lamellar.*—Consists of plates or leaves. If the plates are very thin and easily separable, the structure is *foliated,* especially if the plates are minute scales. The varieties of mica well illustrate this structure.

5. *Granular.*—Composed of grains, either coarse or fine; sometimes so fine that they cannot be detected by the microscope, then said to be *cryptocrystalline;* sometimes of

the size of peas, giving rise to *pisolitic* forms; sometimes of the size of the roe of fish, giving rise to *oölitic* forms; sometimes flattened like lenses, giving rise to *lenticular* forms.

6. *Concretions.*—Vary in shape from simple spherical masses to very grotesque aggregations, but always rounded in form. The more perfect forms often consist of concentric layers. The individual grains present in the granular formations are often concretions, as in the oölitic. One form of concretion, intersected by cracks which have been filled by foreign matter, is called a septarium or turtle-stone.

7. *Stalactitic.*—Cylindrical or conical in shape, composed of fine grains, fibers, or lamellæ deposited from solution.

8. *Stratified.*—Composed of layers, sometimes of the same color throughout, sometimes of different colors, giving rise to banded forms; the layers are formed by successive deposition.

9. *Geodes.*—Forms resulting from incomplete filling of a cavity by a mineral, the interior often being covered with crystals.

CHAPTER II.

PHYSICAL AND CHEMICAL PROPERTIES OF MINERALS.

PHYSICAL PROPERTIES OF MINERALS.

THE properties of minerals which are useful in determinative mineralogy are of two kinds, viz., physical and chemical. The more important physical properties and those which can be most readily observed are (1) luster, (2) color, (3) hardness, (4) streak, (5) malleability, (6) taste, odor, and feel, (7) specific gravity.

Luster.—There are two general classes of luster, (1) metallic, (2) unmetallic. Metallic luster includes semi-metallic; the name of the luster indicates the nature in each case. Unmetallic luster includes (1) vitreous, (2) resinous, (3) pearly, (4) greasy; again, the name indicates the character in each case.

Color.—The mineral kingdom displays a great variety of colors. Colors are generally important only in the case of pure specimens. Some of the more common mineral colors are red, yellow, white, gray, brown, and black. A mineral is said to be *opalescent* when a milky, pearly, or glistening reflection is obtained from it; *phosphorescent* when it emits light by friction or by being heated; *iridescent* when it gives rainbow colors from the interior. When a mineral reflects prismatic colors upon being turned in the light it is said to give a *play of colors.*

Streak.—This is the name given to the color of the powder obtained by abrading the mineral, or to the color of the streak obtained by drawing it across a small plate of white porcelain.

Hardness.—The hardness of minerals is determined by the use of a file. Care must be exercised in selecting a portion of the specimen to be rubbed with the file, as the true hardness will not be obtained upon very acute angles, or upon parts altered by exposure. The sound emitted as the file is drawn across the specimen is often as good a guide as the ease with which the specimen is abraded. For purpose of comparison, the following scale of hardness is adopted: **1, talc; 2, rock salt; 3, calcite; 4, fluorite; 5, apatite; 6, orthoclase; 7, quartz; 8, topaz; 9, sapphire; 10, diamond.**

Malleability.—When portions of a mineral can be flattened under the hammer it is said to be malleable

Brittleness.—When a mineral crumbles under the application of a force it is said to be brittle.

Flexibility.—When a mineral, or part of it, will bend and remain bent upon the relief of the force it is said to be flexible; when it will return to the original position upon the relief of the force it is said to be elastic.

Sectility.—Refers to the property possessed by some minerals of being cut into thin slices without crumbling, but which crumble under the hammer.

Odor.—Odors are developed by moisture, heat, or acids; only a few common ones need description:

Argillaceous Odor.—That of moist clay, developed when a clayey mineral is breathed upon.

Alliaceous Odor.—That of garlic, developed when the arsenical minerals are heated by friction or by the blowpipe.

Sulphurous Odor.—That of burning sulphur, developed by heating some of the sulphides in air, or by burning sulphur.

Feel.—Some minerals have characteristic greasy, rough, or smooth feel.

Specific Gravity.—The specific gravity of a substance is the ratio of the weight of a given volume of the substance to the weight of an equal volume of water at a standard temperature. One of the simplest ways to determine specific gravity is to obtain the weight of a small piece of the mineral, and then to obtain the weight of this same piece immersed in water. These observations are sufficient to determine the specific gravity for ordinary purposes. There are specially contrived balances for taking these weights.

For porous minerals the specific gravity is obtained by the use of a bottle of standard capacity by weight. A known weight of water is poured from the bottle and then the powdered mineral is added until the volume of the water is the same as before. From the original weight of water, from the weight of the water removed, and from the weight of the water with the mineral added the specific gravity can be obtained.

This method is of course equally applicable to compact minerals.

For minerals soluble in water a liquid must be used which will not dissolve them and whose specific gravity is known.

The physical properties are of great importance in determinative mineralogy and many common species can be approximately determined by them.

Tables to assist in the determination of the minerals described are included in the text. These tables have been prepared by classifying the minerals according to luster, subclassifying under luster according to color, color of streak, or hardness. Other physical properties are tabulated, and a column of remarks noting characteristics, not elsewhere included, is added.

CHEMICAL PROPERTIES OF MINERALS.

If a specimen cannot be fully determined by the physical tests, the chemical properties must be considered. While the chemical tests will often afford a ready means for determining a specimen, it is always better to consider physical characters first.

For examining the chemical properties of minerals the following facilities are usually to be had in the laboratory: hammer, anvil, steel mortar, agate mortar, forceps, open and closed tubes, charcoal, blowpipe, platinum wire, fluxes, and reagents.

Hammer and Anvil.—These are for removing small pieces from the specimen for subsequent treatment. By holding the specimen on the anvil a sharp blow properly administered will usually separate a suitable fragment.

Steel Mortar.—This is used for powdering the fragment, and the mortar should always be placed on the anvil for use. The agate mortar and pestle are used for further pulverization by friction of the powder obtained from the steel mortar.

Forceps.—Any forceps provided with platinum tips will answer; but those so made that the tips will press together of themselves will be found most convenient. The forceps are used in connection with the blowpipe for fusing, or for detecting a volatile ingredient, which may yield an odor or color the flame. Only a small thin sliver of the specimen should be used, and it should be held so as to project well beyond the point of the forceps. Minerals easily reduced to the elementary state should not be heated in contact with the forceps, and as a rule it is well not to use the forceps with those having metallic luster.

Charcoal.—Charcoal is used as a support upon which various bodies are heated. The heating may be for the purpose of fusing, for volatilizing, or for the production of a sublimate. The odor from the volatilized body and the color of the sublimate, near and at a distance from the assay, are often characteristic. An infusible and non volatile residue can often be subjected to additional treatment.

Besides serving as a support as above indicated, the reducing power of the charcoal is often made use of to deoxidize certain bodies, as metallic oxides. The production of sublimates is often facilitated by the use of fluxes. Easily reducible compounds, as those of lead, zinc, arsenic, and antimony, should always be heated on charcoal and not in the forceps.

Open Tubes.—These are used to heat the mineral in contact with air. A small fragment, or better some of the powdered mineral, is put in the tube and the tube heated, being held as highly inclined as possible; the result to be expected will of course depend upon the particular mineral, and the observations to be noted are indicated in the tabular description of the species.

Closed Tubes.—These are used for heating the mineral out of contact with air and for making tests with liquid reagents. Only a very small quantity of the mineral must be used except in cases particularly specified, and only a small quantity of acid is necessary. Attention is called to the phenomena to be observed, in the tables above referred to.

Blowpipe.—The blowpipe is simply a bent tube, with a very narrow orifice, provided with a platinum tip which can be removed and cleaned. Only very small pieces or amounts of mineral must be used before the blowpipe.

In using the blowpipe it is necessary to blow and breathe at the same time, for results can generally be accomplished only by continued application of the flame for some time. This accomplishment is readily acquired by practice. Care must be taken that the flame be well protected from draft or anything which would cause flickering. The flame should be colorless, for the characteristic colors of many minerals are readily developed before the blowpipe.

Platinum Wire.—This is used for facilitating the action of the fluxes on the minerals and for affording opportunity for observing the action; such action frequently gives characteristic colors. In general the manner of using the wire is as follows: Twist it into a small loop at the end, heat it, and dip it into the flux, and fuse to a clear bead, then into the powdered mineral, and fuse again; repeat the operation and observe carefully the fused mass, which is called a bead. The blowpipe may or may not be used in heating the beads; in some cases the beads have one color in the oxidizing flame and another in the reducing flame, as described in the tables.

Fluxes.—The common fluxes for making beads are borax, (sodium borate), salt of phosphorous (phosphate of sodium and ammonium), and soda (sodium carbonate). They owe their value to the fact that they dissolve or combine with metallic oxides, giving characteristic colors; the mineral should be roasted before making a bead, so that the oxide will be formed if it is not already present.

Soda is a very valuable flux for decomposing the metallic compounds.

Reagents.—The more common and useful reagents are sulphuric, hydrochloric, and nitric acids, ammonia, ammonium sulphide, potassium ferrocyanide, and ammonium oxalate.

SOME IMPORTANT AND COMMON MINERAL TESTS.

(These should be learned at once by the student.)

Before the Blowpipe.—*Copper.*—Copper minerals moistened with hydrochloric acid give the flame an azure-blue color; heated alone the flame is colored green.

Iron.—Minerals containing iron are converted into magnetic oxide in the reducing flame; sometimes soda is required.

Lead.—Lead minerals heated on charcoal with soda give a yellow oxide coating on charcoal and leave a lead globule.

Zinc.—Important zinc ores when heated on charcoal give a coating of oxide, yellow while hot, but white on cooling.

Open-tube Tests.—*Arsenic.*—The common arsenical compounds give a white sublimate of arsenious oxide on the tube, an alliaceous odor, and an acid reaction with litmus paper.

Sulphur.—Sulphides give an odor of sulphurous oxide and an acid reaction.

Closed-tube Tests.—*Arsenic.*—The common arsenic compounds in a closed tube give a coating of arsenic, a coating of red and yellow orpiments if sulphur be present, and emit an alliaceous odor.

Carbon.—Carbon mixed with a nitrate and heated will deflagrate.

Copper.—To test for copper treat with nitric acid and add excess of ammonia; if copper be present, a blue solution is given; copper sulphides must first be well roasted.

Calcium.—To test for calcium treat with hydrochloric acid, neutralize with ammonia, add a soluble oxalate, and calcium oxalate will fall.

Iron.—To test for iron treat with hydrochloric acid, add potassium-ferrocyanide, and a blue precipitate will be formed.

Mercury.—To test for mercury mix a salt-spoonful with twice its volume of soda, heat, and globules of mercury will be deposited on the cool sides of the tube.

Water.—To test for water put the powdered mineral in the tube, heat the latter held in a nearly horizonal position; if present, water will be deposited on the cool sides of the tube.

MISCELLANEOUS TESTS.

Carbonates.—Treated with hydrochloric, nitric, or sulphuric acid, carbonic acid gas escapes with effervescence; decomposition will sometimes take place if a drop is put on the mineral in mass; but in some cases the mineral must be pulverized; in others the application of heat is necessary.

Sulphates.—With few exceptions, heated with hydrochloric or nitric acid treated with a soluble salt of barium, yield a white precipitate of barium sulphate.

Nitrates.—Heated on charcoal deflagration takes place; or better, heated in a tube with powdered charcoal deflagration occurs.

Sulphides.—Heated with soda on charcoal, moistening assay so obtained and placing on a silver plate, the latter will be tarnished if sulphur be present. The sulphides heated with nitric acid often give a mass of sulphur floating on the surface of the acid; sulphides roasted in air give a sulphurous odor.

CHAPTER III.

DESCRIPTIVE MINERALOGY.

NATIVE ELEMENTS.

Diamond.

Isometric.—Commonly in octahedrons, but often in more complex forms, faces frequently curved.

The diamond varies from colorless specimens through various shades of yellow, orange, red, green, blue, brown, and sometimes black. Transparent when white, dark varieties translucent to opaque. The luster is adamantine to greasy. H. = 10. G. = 3.516–3.525 in distinct crystals.

Bort is a rounded variety of diamond, with rough exterior and lacking distinct crystalline structure; its hardness is greater than the ordinary form (distinct crystals), but its specific gravity less.

Carbonado, or black diamond, is massive, but with crystalline structure, sometimes granular to compact; its specific gravity is sometimes as low as 3.01, but it excels in hardness all other forms. It is found mainly in Brazil.

The composition of the diamond is essentially pure carbon, but the different specimens of the gem which have been tested by combustion leave a small quantity of ash, showing impurity varying from one-twentieth of one per cent to two per cent. In this ash, silica and the oxide of iron have been detected. The black diamond leaves the greatest amount of ash.

The diamond heated to a very high temperature with the air excluded is converted into a black mass resembling graphite or coke, without loss of weight; highly heated in the air it is completely oxidized (except the small quantity of ash) yielding CO_2.

The diamond, until the discovery of the South African fields, was found mainly in alluvial deposits of gravel, sand, and clay, often associated with gold, platinum, quartz, topaz, garnets, corundum, tourmaline, and other accessory minerals. The frequent presence of itacolumite in the diamond regions, and the fact that diamonds have been found in this rock in Brazil, have led to a rather general belief that itacolumite (flexible sandstone) is the principal original diamond-bearing rock. The occurrence of diamonds *in place* in the South African mines shows that such is not the case. In these fields the diamonds are found associated and imbedded in a highly basic, brecciated volcanic rock, and it is still undetermined whether the diamonds were present in the original rock from which the breccia came or whether they were produced by the action of the volcanic products upon the carbonaceous material which is found in the region as shale. Prof. H. C. Lewis, who gave able consideration to the subject, advocated the latter theory.

The South African mines have yielded more diamonds than all the previous production of the world. Ninety-five per cent of the world's yearly supply of diamonds is now obtained from these mines, the remainder coming almost entirely from Brazil, India, and Borneo. A few diamonds have been found in the United States and Australia; those obtained in this country have been found mainly in the Southern Alleghanies, and in the Sierra Nevada or Cascade ranges. During the present year (1907) diamonds have also been found in Arkansas.

Graphite, Plumbago, Black Lead.

Hexagonal.—In six-sided laminæ, commonly imbedded in foliated masses. Granular to compact and earthy.

Graphite is carbon with from one to five per cent of mechanical impurities, generally oxides of iron, manganese, and silicon. It varies in color from iron-black to steel-gray; streak black, shining; luster metallic. H.=1 to 2. G.=2.25. Makes dark streak on paper and has greasy feel. It is infusible both alone and with reagents and is not acted upon by acids. Combustible only at very high temperature. Deflagrates when thoroughly mixed with niter and heated in a closed tube. In appearance greatly resembles molybdenite (MoS), but this gives off sulphurous fumes before the blowpipe and is acted upon by nitric acid.

Graphite occurs as scales and grains, nodular masses, and in beds, generally in the crystalline rocks. It is found in many of our States, the most prominent producers at the present time being New York, Pennsylvania, South Dakota, Michigan, Wisconsin, Rhode Island, and New Mexico. Graphite is also now artificially made by subjecting anthracite and other forms of carbon to the high temperature of the electric furnace.

The greater proportion of the graphite used in this country comes from Ceylon, Germany, and Canada. Ceylon, Germany, Austria, and Italy supply most of the foreign graphite. The Siberian deposits are rich and numerous but at the present time are not worked.

Graphite is largely used for the manufacture of lead-pencils, being ground up, and generally mixed with some cementing material and solidified by pressure. Fine clay is used in the harder pencils. It is also largely used as a lubricant for machinery, for coating objects to be electrotyped, for polishing stoves and other iron-work, as a paint for smokestacks, boilers, etc., and for making crucibles; for the latter purpose being mixed with clay.

Native Sulphur.

Orthorhombic.—Most common form, right rhombic acute octahedron. Also various modifications of this form, and massive.

Sulphur when pure is of a clear yellow color, frequently somewhat translucent, but sometimes opaque. Its streak is yellow, sometimes tinged reddish or greenish; it is very fragile and breaks with conchoidal fracture, vitreous or resinous luster. G. = 2.1. H. = 1.5 to 2.5. Readily combustible, burning with blue flame and producing suffocating, acrid fumes. In closed tube wholly volatilizes and deposits on cool part of tube.

The native form is most generally met with as masses or small grains disseminated in other minerals, or as fine yellow powder lining cavities. It often contains clay or bitumen and is sometimes colored orange-yellow by selenium sulphide. The largest deposits of sulphur are found in recent sedimentary strata associated with gypsum or allied rocks, or in regions of extinct or active volcanoes; nearly all active volcanic regions yield it in some abundance. The greater proportion of the supply of native sulphur is obtained from the volcanic districts of Sicily. It is usually purified from earthy impurities by fusion before shipment to the world's market.

Sulphur deposits are found in many places in the United States both in the East and the West. Those in the Eastern States are too small to be of industrial importance except certain beds in Louisiana, which are, in places, over one hundred feet thick and contain a large quantity of pure sulphur, but they are four or five hundred feet below the surface. The difficulty of mining these deposits has until recently proven so great that they have yielded only a small quantity of sulphur. The annual production from these deposits is now very large and still increasing, these mines supplying by far the greater proportion of the sulphur used in the United States. Deposits in the West are numerous and occur in California, Nevada, Utah, Wyoming, New Mexico, and Arizona. Until the development of the Louisiana deposits Nevada and Utah furnished the larger part of the sulphur mined in the United States. Sulphur is very generally deposited around springs whose waters contain hydrogen sulphide in solution, especially in volcanic regions. Immense deposits of sulphur are known to exist in the crater of Popocatepetl. Sicily furnishes the greater part of the world's supply of sulphur.

Native Gold.

Isometric.—Octahedrons and dodecahedrons, but these are rarely found.

Gold has a yellow color in mass, but when reduced to very fine powder it is ruby-red. It is very ductile and malleable. H. = 2.5 to 3, nearly as soft as lead. G. = 19 to 19.3. Fusing-point slightly above 2000° F. Not acted upon by any of the common acids; dissolved by nitro-muriatic acid; does not oxidize in the air.

Gold is seldom found pure. It is most commonly alloyed with silver, sometimes with copper, iron, rhodium, and bismuth. It is occasionally found combined with tellurium. The silver present in the gold varies from a fraction of a per cent to one-third of the whole. An amalgam of gold and mercury has been found in Colombia, S. A., and in Colorado. The native gold of California averages about 88 per cent of gold, the remainder being mostly silver. The native alloys with silver are much lighter in color than gold and occasionally nearly silver-white.

Iron and copper pyrites may closely resemble gold in color and have, by the inexperienced, been mistaken for it; for this reason they are sometimes called "*fools' gold.*" These minerals are brittle and give off sulphurous fumes when roasted in the air, which at once distinguish them from gold.

Gold occurs principally in two ways: 1. In quartz veins intersecting metamorphic rocks, frequently associated with ores of other metals. 2. As grains and nodules in the gravel and sands of the rivers and valleys of auriferous regions. The deposits in the second case result from degradation of the veins. The quartz veins most commonly occur intersecting metamorphic talcose, chloritic and argillaceous schists, less frequently in diorites and porphyries.

The gold occurs irregularly distributed throughout the quartz of the vein, in strings, scales, and grains, and is often invisible to the naked eye. The most perfect crystals and largest masses generally occur in the cavities of the quartz.

The most common minerals accompanying the gold in the vein-stuff are the sulphides of iron, copper, lead, and zinc and the red oxide of iron. The iron pyrite exceeds in quantity all the other minerals and is usually auriferous, the others frequently so.

The quartz of the veins, for some distance below the surface, is often cellular and porous owing to the alteration and removal of the associated minerals by atmospheric agencies. The gold that was present in the removed mineral is thus frequently left in strings or scales in the cavities of the quartz. This weathered portion of the vein is more easily mined and the gold more easily obtained from it than from the unchanged portion. In quartz mining the gold is either obtained from the quartz or from the associated minerals; the pyrite of a gold region is often worked as a gold ore, as is also the galenite.

The method of obtaining the gold from the sands and gravels constitutes "alluvial washing"; in California called *placer mining.* The origin of these deposits is given in Geology. The gold is obtained from the deposits by taking advantage of its great specific gravity, the earthy matter being washed away by water. At first this was accomplished by simple pan or cradle washing, but soon in California it developed into hydraulic mining upon a stupendous scale; water for this purpose being often brought from long distances by artificial channels and turned, under great pressure, on the gravel-beds. Large bodies of sand could by this means be washed over; only by such means would it have been possible profitably to work immense beds of comparatively poor material. The most imposing beds of sand and gravel disintegrate and melt away under the enormous force, aided by the softening power of the water.

The cost of handling a cubic yard of auriferous gravel by the best method of washing employed in 1852 was reduced more than fifty times by the introduction of the California hydraulic process, and as compared with the simple pan-process the cost was reduced a thousand times.

The auriferous beds thus washed over were often from one to two hundred feet thick. Up to the present time the greater portion of the world's supply of gold has come from the alluvial washing and not from the quartz minings.

Gold is very widely distributed over the globe, being found to some extent in nearly all countries. It occurs in crystalline or semi-crystalline rocks of various ages from the tertiary downward.

Up to the year 1890 the United States, Australia, and Russia produced by far the greater proportion of the world's supply of gold; since that year the gold-fields of Africa have added largely to the production. In 1897 rich discoveries were reported on the upper waters of the Yukon, since which date the output from Alaska has been exceeded by only a few of our States.

Gold is mined in many of the States of the United States and also in Alaska. Since 1849, the first year after the discovery of gold in California, that State has almost continually led in the production of gold. The California production rose from five millions in 1849 to sixty millions in 1853. In that year the maximum was reached. Between 1872 and 1878 Nevada produced more gold than California, as has Colorado since 1897 or 1898. At the present time Colorado, California, South Dakota, Montana, Nevada, Arizona, Alaska, Idaho, Oregon, and Utah are our principal producing regions, though many other States are small producers.

The localities of gold-mines in the United States are too numerous to mention in full, but they are spotted from Alabama to Labrador along the Appalachians and are numerous in the Rocky Mountains and along the western slope of the Sierras; the eastern slopes of the Sierras generally produce silver.

Native Platinum.

Isometric.—Native crystals rare, cubes most common; usually in grains, scales, and small masses.

Pure platinum is nearly silver-white, but the native metal nearly steel-gray; streak same; metallic, shining luster; ductile and malleable. H. = 4 to 4.5. G. = 16 to 19; when pure, about 21. It is the most difficult metal to fuse, and is not acted upon by the common mineral acids. Native platinum is usually alloyed with one or more of the metals osmium, rhodium, iridium, palladium, copper, and iron.

Russia supplies much the larger portion of the platinum of commerce. It is found mainly in alluvial material in the Ural Mountains, near Goroblagodat. Brazil, Borneo, Columbia, and St. Domingo supply a small amount. It has also been found in the United States at several places, in Canada, and in Australia. Its great use is for the construction of chemical and philosophical apparatus.

ORES OF SILVER.

Native Silver.

Isometric.—In octahedrons without apparent cleavage, often aggregated into mossy, arborescent, or filiform shapes; occasionally into solid masses.

Silver is white, often tarnished black by sulphur. Malleable and ductile; streak white and shining. H. = 2.5. G. = 10.1 to 11. Fuses at about 1900° F. It is dissolved by nitric acid, and the solution gives a white precipitate by the addition of any soluble chloride. The precipitate blackens in the light and dissolves in solution of ammonia.

Native silver is frequently alloyed with copper, and sometimes with bismuth. It is readily distinguished from tin, bismuth, and other white metals by its high fusing and volatilizing points, its great malleability, and by the wet test above given.

Native silver occurs in veins traversing metamorphic rocks usually accompanied by the ores of silver, and often by the ores of other metals. Four-fifths of the product from the celebrated mine of Kongsberg, Norway, was native silver. This mine was discovered in 1623, and several masses of silver weighing from 100 to 500 pounds have been taken from it.

Silver is found in the Lake Superior region penetrating the native copper. It there exists in strings and masses, and is nearly pure silver. It has also been found in similar forms in the silver-mines of Idaho, Colorado, California, and Nevada. Peru has furnished much native silver, and much has come from Northern Mexico. Both gold and silver are present in sea-water, though to a very small extent.

Argentite, Silver Glance, Ag_2S.

Isometric.—This important ore of silver generally occurs, when crystalline, in some modification of the dodecahedron, also in dendritic, capillary, reticulated forms, and massive.

Argentite has a dull metallic luster; its color on fresh surface is a blackish lead-gray, streak similar to color, and glistening. It is malleable and sectile. H. = 2 to 2.5. G. = 7.2 to 7.4. Fuses before the blowpipe and gives off fumes of burning sulphur, yielding a bead of silver. Acted upon by nitric acid with a separation of sulphur; hydrochloric acid added to nitric acid solution gives precipitate of silver chloride. Solution in HNO_3 deposits silver on copper plate. Silver sulphide is distinguished from the resembling ores of lead and copper by its malleability, by yielding silver on charcoal; it is also heavier than resembling copper ores.

Pyrargyrite, Ruby Silver, Dark Red Silver Ore, Ag_3SbS_3.

Rhombohedral.—Occurs in columnar crystals, faces often rounded, also massive.

This ore in thin fragments has a dark cochineal color, in larger masses nearly black, streak cochineal or brownish red; fuses easily before the blowpipe with spirting, giving white coating of antimony oxide, ultimately a bead of silver. In open tube gives sulphurous fumes and white sublimate, in closed tube red sublimate. Decomposed by HNO_3, depositing sulphur and the sesquioxide of antimony.

Proustite, or Light Red Silver Ore, Ag_3AsS_3.

This ore is closely related to pyrargyrite, but contains arsenic, replacing the antimony in part or whole. The streak and color are brighter red than in pyrargyrite. Heated in air gives sulphurous and arsenical fumes, in open tube white sublimate, in closed tube yellow orpiment.

Stephanite, Black Silver, Brittle Silver Ore, Ag_5SbS_4.

This ore is also a sulphide of silver and antimony, whose composition is represented by the formula $Ag_5SbS_4 = 5(Ag_2S)Sb_2S_3$. It has metallic luster.

Black color and streak; is brittle and usually massive. In the open tube fuses, giving off sulphurous and antimonial fumes; before the blowpipe on charcoal fuses easily, giving a coating of antimony oxide, with soda a globule of silver.

Cerargyrite, Horn Silver, AgCl.

Isometric.—Usually occurs massive or as incrustations, also in cubes without cleavage, rarely columnar; color pearl-gray to greenish gray and occasionally violet-blue; by exposure to light color changes to purplish brown, nearly black. When pure sometimes colorless. Luster waxy, resinous to adamantine; in many cases cuts and looks like horn. H. = 1 to 1.5. G. = 5.5. Fuses in closed tube without decomposition, on charcoal reduced to metallic silver. Soluble in ammonia.

This is a common ore and has been extensively worked in our Western mines and in Mexico.

The native metal furnishes only a small part of the world's supply of silver, the larger portion coming from the other ores of silver, the principal of which are the silver sulphide, the sulpharsenides, sulph-antimonides, the chlorides and bromides and the mixtures of these with the oxides, sulphides, arseniates, and carbonates of other metals. The principal ores of the Comstock Lode were native silver and gold, argentite (silver sulphide), and stephanite (sulphide of silver and antimony). Two hundred and eighty millions in silver and gold were taken from this lode between 1860 and 1880. In the celebrated Ruby Hill mine at Eureka, Nev., the silver occurred mainly as argentite and chloride mixed with limonite, lead sulphite, sulphate and carbonate, and several other minerals. The most important ore of the Leadville region is auriferous galena with lead carbonate and silver chloride. Native gold and silver occur in the ores at both the places last named.

The United States and Mexico for over thirty years have furnished by far the greater portion of the world's supply of silver. In that time the mines of the United States have yielded considerably more than one-third the world's product. Since 1875 the annual yield of silver in this country has varied from 76 to 26 millions of dollars. Montana, Colorado, Utah, Idaho, Nevada, Arizona, Idaho, and California being now the principal contributors.

ORE OF MERCURY.

Cinnabar, HgS.

Cinnabar generally occurs massive with slightly granular texture; when pure, it has a bright red to brownish-red color; streak scarlet; luster adamantine. H. = 2 to 2.5. G. = 9; less when impure. Impure varieties often have slaty structure with darker color; streak tending to brown. Other impure varieties are of a yellowish-red color, little luster, and yellow streak. The hepatic cinnabar or liver ore contains carbonaceous matter and clay. Almost every variety shows glistening specks in the mass. Pure cinnabar is completely volatile. Roasted in air gives sulphurous fumes. Mixed with soda and heated in closed tube is decomposed and deposits globules of mercury on cool sides of tube. These tests readily distinguish it from cuprite and other red minerals.

Cinnabar is the principal ore from which mercury is obtained. It usually occurs in veins associated with slates and shales. At Bahknut, in Southern Russia, it occurs impregnating a bed of sandstone, from which considerable mercury is obtained. The other principal mines are at Idria in Austria, Almaden in Spain, and New Almaden in California. Since the beginning of the present century the mines of Brewster County, Texas, have yielded considerable mercury. The output of these mines in 1905 amounted to 5000 flasks. Utah also produces some mercury; the mines are situated at Mercur. Besides being the chief ore of mercury, pure cinnabar, under the name of vermilion, is used as a paint; for this purpose it is almost wholly an artificial preparation.

Metallic mercury in this country is put up at the mines and transported in iron flasks weighing 75 pounds. In 1904 the weight of the flasks was changed from 76.5 to 75 pounds. The product of the United States since 1900 has been about 3300 flasks annually. In 1887 the product of the United States amounted to 80,000 flasks.

ORES OF COPPER.

The ores of copper are numerous and many of them not distinctly defined in composition. Only the more important will be described.

The common wet test for a copper ore is to act upon the suspected mineral with nitric acid, dilute, and add ammonia; if copper is present, a blue solution is obtained.

Native Copper.

Isometric.—In octahedrons and dodecahedrons, and modified forms. The dendritic forms are frequently composed of aggregations of octahedrons.

Copper has a red color and is very ductile and tenacious; when rubbed, emits a rather disagreeable odor; luster metallic; streak red. H. = 2.5 to 3. G. = 8.8 to 8.95. Fuses before the blowpipe and oxidizes on surface in cooling; is acted upon by nitric acid, and the solution gives a blue color on addition of solution of ammonia.

Native copper is widely distributed, and often contains a little silver. It generally occurs to a greater or less extent in connection with its ores, especially the carbonates and sulphides. Siberia and Cornwall have furnished very beautiful cabinet specimens; Australia and the South American countries afford it in greater quantity, Brazil especially having furnished some very large masses. The Lake Superior region of Michigan, however, is the most important locality in the world for native copper. The metal there occurs in layers, often called veins, distributed through amygdaloid and conglomerate and also in sandstone. Much of the copper contains a fraction of a per cent of silver intimately alloyed. It also very frequently contains scattered grains and penetrating threads of pure silver; such mixture of these metals is found in other countries and has not been successfully imitated artificially. The copper in the Lake Superior region is nearly all in the native state, and very large masses have been taken from the mines; one weighing 420 tons and containing copper of 90 per cent purity was taken from the Minnesota mine in 1857.

The gangue-stone contains generally from one to five per cent of copper. The mining operations of the largest company (Hecla and Calumet) are simple, consisting of crushing and stamping the gangue and separating the metal by difference of specific gravity, the sands being washed away by running water. The machinery for this purpose is very extensive and perfectly adapted. The formations in which the copper occurs are not veins in any proper sense. They are most probably sedimentary formations whose original position has been changed. The most important ores of copper are given below.

Chalcopyrite, Copper Pyrites, Copper and Iron Pyrites, $CuFeS_2$.

Is most commonly massive. Has a slighly greenish, bronze-yellow color, often iridescent by tarnish. Streak and powder greenish black. H. = 3.5 to 4. G. = 4 to 4.3. Heated in the air before the blowpipe gives off sulphurous fumes and fuses to a magnetic globule; this globule powdered and further heated on charcoal will reduce to a bead of iron and copper. Chalcopyrite must be well roasted before it will give the copper test with nitric acid and ammonia.

It sometimes resembles native gold in color, or again iron pyrite. It is distinguished from the first by lack of malleability, and from the second by its softness, richer yellow color, and its greenish-black streak.

Chalcopyrite is the ore from which the bulk of the copper of commerce is obtained.

It occurs in veins intersecting metamorphic rocks and occasionally in cavities or veins in unchanged sedimentary rocks. Its most common associates are the copper carbonates and the sulphides of iron, lead, or zinc.

Chalcocite, Copper Glance, Vitreous Copper, Cu_2S.

Occurs in crystals, but usually massive; metallic luster; color blackish lead-gray, often tarnished blue or green; streak same as color, often glistening; slightly brittle. H. = 2.5 to 3. G. = 3.5 to 5.8. Easily fusible by blowpipe on charcoal, giving sulphurous fumes and leaving a globule of copper. Acted upon by hot nitric acid with separation of sulphur; nitric acid solution deposits copper on iron surface; gives the usual copper test.

The ore is not generally found pure, a portion of the copper being often replaced by iron. It occurs in great abundance and in nearly a pure form in several of the Montana mines. It is also an important ore in Arizona, Colorado, and New Mexico.

Bornite, Erubescite, Variegated Copper $3Cu_2S,Fe_2S_3$.

This in appearance is one of the most striking of the copper ores when in fresh condition. It then has a brilliant purplish-brown color, but changes on exposure to the air to many hues with varied iridescence. When pure it is represented by the formula $3Cu_2S,Fe_2S_3$, which may be written Cu_3FeS_3. The proportions of the constituent elements vary widely without materially affecting the general appearance of the ore. Has metallic luster; the streak is a dark grayish black. H. = 3. G. = 4.5 to 5.5. It is an important ore of the Butte mines.

Before the blowpipe fuses easily to a black magnetic globule; this taken with its peculiar color and brilliant iridescence distinguishes it from chalcocite.

Tetrahedrite, Gray Copper Ore, $4Cu_2S,Sb_2S_3$.

This mineral when pure is a double sulphide of copper and antimony. The antimony is frequently in part replaced by arsenic, and the copper by iron, zinc, silver, or lead. It is an unimportant ore in this country except when it becomes rich in silver, and is then valuable for the silver. This argentiferous form of the ore is found both in Montana and Colorado. The pure tetrahedrite is represented by the formula $4Cu_2S,Sb_2S_3$.

Tennantite. $4Cu_2S,As_2S_3$.

This mineral is essentially a sulphide of arsensic and copper; it often contains antimony and graduates into the tetrahedrite. It is of no importance in this country as a copper ore.

Cuprite, Red Copper Ore, Cu_2O.

Isometric.—Prevailing form the octahedron, also in the derived forms.

It occurs often massive and also earthy. Has different tints of deep red, often reddish gray; luster adamantine or semi-metallic, dull in impure varieties; streak brownish red. H. = 3.5 to 4. G. = 5.8 to 6.1. Heated on charcoal, reduces to metallic copper. Frequently occurs with the other copper ores; outer surface often converted into carbonate. Gives copper test with nitric acid and ammonia.

Melaconite, Black Copper Ore, CuO.

Found as cubes in Lake Superior copper region, but generally in black masses and botryoidal concretions along with other copper ores. Important ore in some of the mines of this country, as in Tennessee.

Tenorite is another variety of the same ore, found in the Vesuvian lavas and in earthy forms about copper lodes.

Malachite, Green Hydrous Copper Carbonate, $CuCO_3,CuO,H_2O$.

Monoclinic.—Crystals (rare in nature) generally tabular prisms.

Usually occurs in incrusted masses with reniform, botryoidal, or mammillary surfaces with fibrous texture, often showing concretionary structure. Also compact or earthy. Color varies from emerald to nearly grass-green. Streak green, but generally lighter than mineral. Luster vitreous, pearly, or silky; earthy varieties have little luster. H. = 3.5 to 4. G. = 3.7 to 4. Acted upon by the common mineral acids and gives the copper test with nitric acid and ammonia.

Malachite is generally associated with other ores of copper; and when in sufficient quantity is a very valuable mineral. The incrustations made by it often have banded shades of green which give a very pleasing effect. It is susceptible of a high polish and is much used in indoor decorations, making beautiful mantels, table-tops, vases, etc. It is too soft for jewelry, though it is sometimes passed off as turquois. The mines of Siberia have given the largest quantity, though it occurs in a good many countries to a smaller extent.

Azurite, Blue Hydrous Copper Carbonate, $2CuCO_3,CuO,H_2O$.

This mineral is very similar to malachite, but the color varies from azure-blue (the color of the powder) to indigo-blue; its streak is also blue. These characteristics distinguish it from malachite; it fulfills the tests given for that mineral. It is valuable when abundant, but occurs much less abundantly than malachite. Sometimes used as a pigment, but is not very permanent. Contains a smaller per cent of copper than malachite.

Chrysocolla, Hydrous Copper Silicate, $2CuOSiO_2,2H_2O$.

This is an amorphous, compact mineral of bluish-green color; sometimes occurs in thin layers, as incrustations; and as botryoidal masses. H. = 2 to 4. G. = 2 to 2.4. Distinguished from the carbonates by its bluish-green color and no visible action with acids; very frequently contains the carbonate. Valuable as an ore when abundant.

The world's product of copper in 1905 was about 690,000 tons, of which the United States furnished more than one-half. Montana, Arizona, and Michigan in that year gave over ten-twelfths of the yield of the United States. Only in the last-named State is the metal obtained in large quantity from the native form, elsewhere it is from the ores. The principal Montana ores are the different forms of copper sulphide in a siliceous gangue. Much silver is associated with the ores. The Arizona ores are largely the oxidized forms, though they frequently change to the sulphides in the lower reaches of the veins.

ORES OF LEAD.

Lead rarely occurs native, but exists in many compounds. It occurs combined with oxygen, sulphur, arsenic, tellurium, selenium, and as carbonates, sulphates, chromates, molybdates, and phosphates. Its principal ore is the sulphide.

Galenite, Galena, Lead Sulphide, PbS.

Isometric.—Usually in cubes or some of the simpler derived forms; also granular. It has metallic luster, bluish-gray color, streak slightly darker. H. = 2.5. G. = 7.2 to 7.6. Before the blowpipe on charcoal it fuses readily and emits sulphurous fumes, coats the charcoal with lead oxide, and leaves a globule of lead. It is acted upon by strong nitric acid with separation of some sulphur; this solution gives black precipitate with ammonium sulphide.

Galena is a very widely distributed ore. It occurs both in veins and in beds or pockets, and both in metamorphic and unchanged rocks. Galena is very frequently associated with the sulphides of iron, copper, zinc, and silver. Some silver sulphide is nearly always present in galena; when the silver becomes worth extracting the ore is called argentiferous galena. The argentiferous galena generally has a more micaceous appearance than the common ore. The gangue in lead-mines is generally calcite, quartz, or baryta, and sometimes fluor-spar.

Abundant lead-ore deposits occur in the States of Iowa, Wisconsin, Missouri, and Illinois. None of these deposits come under the head of true veins, but are in sheets or beds between the strata. The sheets are usually only a few inches thick and are rarely accompanied by gangue or true vein-walls. The bed-deposits in this region are large, thick masses, as though underground caves or chambers had been filled by the ore. It is probable that the solvent waters that produced the caves also deposited the mineral from solution. Casts of fossils in galena are often found in the region, thus showing the aqueous origin of the ore. Galena occurs in true veins in several of the Eastern States and in many of the Western. Of late years the greater portion of the lead produced in the United States has been in connection with the gold and silver mining of the West, the lead being a by-product. In 1905 from this source there were obtained 206,000 tons of lead, while only about 113,000 were obtained from other domestic sources.

The greatest consumption of lead is in the manufacture of white lead, though large quantities are used in making pipes, shot, and sheeting. Galena is sometimes used for glazing coarse stoneware, being finely ground, mixed with other glaze material and applied to the vessels.

Cerussite, White Lead Ore, Lead Carbonate, $PbCO_3$.

Orthorhombic.—Cerussite occurs in orthorhombic crystals, often compound, but more generally the ore is found granular compact, or in earthy masses. The crystalline forms, when pure, vary in color from white to dark gray, almost black; the presence of copper gives blue or green tinge; streak uncolored; luster adamantine, vitreous to resinous, and pearly. H. = 3 to 3.5. G. = 6.4 to 6.6. Brittle. Fuses readily before blowpipe and yields lead in reducing-flame; acted upon with effervescence by nitric acid; in closed tube it decrepitates, loses CO_2, and turns brown or yellow.

The lead carbonate is a very important ore at many mines in the Western States, especially in Colorado, Utah, and Nevada. The carbonate is formed from galena by meteoric agencies, and in these mines is generally found as loose sand or in compact lumps of a yellowish or brown color, due to the iron present; clusters of crystals are also frequently present in the compact masses.

Anglesite, Lead Sulphate, $PbSO_4$.

This ore of lead resembles cerussite and often occurs with it, both being formed from the sulphide. Its crystalline system is the same as that of cerussite. It fuses readily, and in reducing-flame or with soda yields metallic lead. It is slightly soluble in nitric acid, but without effervescence, which distinguishes it from the carbonate. This ore generally accompanies cerussite in the mines of the Rocky Mountain region.

ORES OF ZINC.

If zinc occurs native, it has not been found in any considerable quantity. It has been reported from Australia, South Africa, Colorado, and Alabama, but satisfactory information has not yet been given in regard to these finds. Its compounds are pretty widely distributed; they are the oxides, sulphides, carbonates, and silicates, all of which are used for obtaining the metal.

Sphalerite, Blende, ZnS.

Isometric.—Prevailing forms, the octahedron and dodecahedron and modifications. Often massive and sometimes fibrous.

The color of blende presents various shades of yellow, red, brown, and black; also gray to white and sometimes greenish. Luster resinous to waxy and sometimes semi-metallic. Streak is white to yellowish brown. $H. = 3.5$ to 4. $G. = 3.9$ to 4.2. The purer specimens will often become phosphorescent by friction in the dark. The sulphides of iron, cadmium, and lead are often present in it. It is fusible with difficulty by the blowpipe; heated in open tube gives sulphurous odor; on charcoal gives yellow coating which turns white on cooling. It is acted upon by hydrochloric acid and emits hydrogen sulphide; often shows effervescence.

This ore occurs in many localities and in rocks of all ages. The lead-mines of the Mississippi valley afford it abundantly, as do the zinc-mines of Missouri and Kansas. By oxidation the ore is converted into white vitriol.

Zincite, ZnO.

This ore generally occurs in tabular masses or disseminated grains. Luster adamantine or semi-metallic; its color varies from bright red to dark or brown; streak is orange-yellow. H. = 4.0 to 4.5. G. = 5.6 to 5.8. Acted upon by nitric acid. Yields yellow coating on charcoal, which turns white on cooling. It is a good ore of zinc, and is the ore of Sussex County, N. J.

Smithsonite, Zinc Carbonate, $ZnCO_3$.

Rhombohedral.—Smithsonite seldom occurs distinctly crystallized; generally botryoidal, reniform, or stalactitic; sometimes granular or loosely compacted. This ore is of light color, but seldom white; generally light gray or brownish white, sometimes shaded green, blue, or buff; streak uncolored; luster vitreous to pearly. Brittle. H. = 2 to 4. G. = 4.2 to 4.5. It is infusible before blowpipe alone; with soda on charcoal gives a coating of zinc oxide; effervesces in acid.

This is a valuable ore of zinc, and is found abundantly in the mines of the Mississippi valley, also in Pennsylvania. It very generally accompanies galena and sphalerite. Certain forms of it are termed *dry-bone* by miners. The carbonate in England is often called Calamine.

Calamine, Hydrous Zinc Silicate, $2ZnO,SiO_2,H_2O$.

Orthorhombic.—Crystalline forms seldom distinct. Calamine is a hydrous zinc silicate and closely resembles the carbonate in appearance and physical properties. It usually occurs associated with the carbonate, and is found in the localities named above for that mineral. It gelatinizes, but does not effervesce with acids. It yields water in closed tube.

Willemite, Zinc Silicate, $2ZnO,SiO_2$.

Hexagonal, Rhombohedral.—Occurs in long or short hexagonal prisms; also in massive, granular, and rounded forms.

This mineral differs from calamine in composition in being anhydrous.

Willemite varies in color from white and greenish yellow through light to dark brown. Its streak is uncolored; luster vitreous or resinous. H. = 5.5. G. = 3.9 to 4.2. It fuses with difficulty, and gelatinizes with acids. Its composition is Zn_2SiO_4; a part of the zinc is sometimes replaced by manganese. It is frequently present with zincite and franklinite being thus found in New Jersey.

IRON MINERALS.

The iron minerals are numerous, but the principal ores of iron are the oxides and carbonate; occasionally the sulphide is used as an ore of iron. The oxidized forms and the silicates are very widely distributed as the common coloring matter of soils. The ores, when heated in the reducing flame of a blowpipe, become magnetic, and when treated with hydrochloric acid give a blue precipitate on the addition of potassium ferrocyanide.

Native Iron.

Isometric.—Generally massive. Native iron has gray color and streak; it is malleable and ductile. H. = 4.5. G. = 7.3 to 7.8. Acts on magnet.

Native iron is of very limited occurrence; there are two varieties, meteoric and telluric. Meteorites contain native iron usually alloyed with nickel in considerable quantity, and small quantities of cobalt and copper are often present. A polished surface of meteoric iron, when acted upon by nitric acid, will frequently show triangular figures indicating a coarse octahedral structure in crystallization. These figures are called Wiedmannstädt's figures, and when uniform in different specimens indicate an identical origin. Meteoric iron often contains nodules of iron monosulphide and the phosphide of iron and nickel (Schreibersite). Meteorites have been found in many places varying in size from an ounce in weight up to many tons.* They are believed to have a non-terrestrial origin.

Telluric iron is native iron of terrestrial origin. It is found as imbedded particles or grains in some basaltic rocks. Masses have also been found; one weighing twenty tons was found on Disco Island, Greenland, in 1870. It is thought probable that this telluric iron has been produced by the reduction of the iron-bearing minerals in the passage of the containing rock through carbonaceous strata.

Pyrite, Iron Pyrites, FeS_2.

Isometric.—Usually in cubes, faces frequently striated; striæ of adjoining faces are always perpendicular to each other. Occurs in forms derived from cube, also in globular nodules with radiated structure.

Pyrite has generally a brass-yellow color, sometimes brownish by surface alteration; is brittle, and has metallic luster. H. = 6 to 6.5; will strike fire with steel. G. = 4 to 5. Streak is brownish black. Roasted before the blowpipe gives sulphurous fumes and leaves a globule fusible with difficulty and attracted by the magnet. It resembles copper pyrites, but is of a lighter color, harder, and has different streak. It is readily distinguished from gold by its hardness and brittleness.

Pyrite is one of the most widely distributed of ores, but is more generally employed to obtain sulphur than iron. It occurs in rocks of all ages. In auriferous regions it often contains gold, and is sometimes worked to obtain that metal. Owing to its common occurrence in rocks and its changeable nature it is one of the chief natural causes of rock disintegration. No stone containing it should be used for building purposes. The disintegration of the rock containing it is brought about by the oxidation of the pyrite and the solution of the resulting compound. Other sulphides of iron have the same effect on the containing rock. Pyrite is used in the manufacture of sulphuric acid, alum, green

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* Lieut. Peary in 1894 discovered, at Melville Bay, North Greenland, a large meteorite weighing 37½ tons. This is the largest meteorite yet found; it is now in the American Museum of Natural History, N. Y.

vitriol, and sulphur; occasionally the iron is extracted. Pyrite is sometimes called *mundic* and *fool's gold* by miners.

Pyrrhotite, Magnetic Pyrites, Fe_7S_8.

Hexagonal.—The crystals of this mineral belong to the hexagonal system, but well-defined crystals are rare. It usually occurs massive or disseminated in granular or scaly aggregates.

Pyrrhotite is a sulphide of iron whose general formula is Fe_nS_{n+1}, in which n may vary from 5 to 16; the average composition is accepted to be indicated by Fe_7S_8, which gives the percentage composition S = 39.6, Fe = 60.4. Its color is generally between bronze-yellow and copper-red; it readily tarnishes to a dull bronze; streak grayish black. H. = 3.5 to 4.5. G. = 4.5 to 4.7. Brittle and slightly magnetic; powder attracted by magnet. Its color and magnetic properties distinguish it from chalcopyrite; these characters and its inferior hardness from pyrite. It is acted upon by HCl, yielding H_2S; before the blowpipe on charcoal gives magnetic globule.

Pyrrhotite is found in small quantities at many places, and is sometimes used as an ore of sulphur in the manufacture of sulphuric acid. It is often present in meteoric iron, though the monosulphide FeS, troilite, is the principal sulphide of meteorites.

Mispickel, Arsenopyrite, Sulpharsenide of Iron, FeAsS.

Its color is steel-gray or tin-white. Metallic luster; streak grayish black. H. = 5.5 to 6. G. = 6 to 6.4. It is brittle, and the texture often granular, giving slightly hackly fracture. Heated in closed tube gives red and yellow sublimates of arsenic sulphide and also a metallic-like deposit of arsenic; roasted before the blowpipe gives strong garlic odor of arsenious oxide and leaves a globule attracted by the magnet; when struck sharply with a steel it gives the same odor. It is very frequently associated with the ores of silver and lead and the sulphides of iron, copper, and zinc. Cobalt sometimes replaces some of the iron in mispickel, such compound being one of the ores of cobalt. Mispickel is one of the chief ores of arsenic.

Hematite, Specular Iron Ore, Fe_2O_3.

Rhombohedral.—Often in granular masses, compact or friable; also lamellar, micaceous, and earthy; also in botryoidal and stalactitic forms.

The color of the metallic varieties varies from iron-black to steel-gray, the crystals often iridescent. Luster metallic, of crystals brilliant; streak cherry-red to brownish red. H. = 5.5 to 6.5. G. = 4.5 to5.3. Sometimes slightly magnetic. The compact and earthy varieties have not the luster or color of the metallic, but give the same streak. Acted upon by hydrochloric acid, and gives blue precipitate upon addition of potassium ferrocyanide.

The more important varieties of the hematite are the following:

Specular.—With distinct metallic luster.

Red Hematite.—Dark or brownish-red color, semi-metallic luster.

Micaceous.—In thin scales, schistose structure.

Ocherous.—The red earthy varieties often containing clay; when soft and pulverulent, *red ocher;* when harder, compact, and of fine texture, it is *red chalk.*

Argillaceous.—Includes compact red and brownish-red varieties, often of semi-metallic luster. Composed of the oxide, with sand, clay, and often other impurities. The most compact of these varieties, with a jasper-like texture and appearance, is the *jasper clay ore.* The less hard and jaspery gives the *clay iron-stone* variety. This last name is also applied to the clayey siderite and limonite.

When made up of flattened concretions or grains it is the *lenticular ore.* The argillaceous varieties give the red or brownish-red streak. When heated in the reducing-flame hematite easily becomes magnetic. Acted upon by hydrochloric acid, and gives blue precipitate with potassium ferrocyanide. These tests, with its red streak, serve to distinguish the mineral.

Martite has the same composition as hematite, but crystallizes in isometric forms, octahedrons, dodecahedrons, which are thought to be pseudomorphous of magnetite; the color is iron-black, luster sub-metallic; the streak is purplish-brown, and the mineral but slightly, if at all, magnetic. These characters distinguish it from magnetite. It is of frequent occurrence in magnetic regions.

Hematite is one of the most common and widely distributed of ores, and occurs in rocks of all ages. It is found in so many localities that only a few can be named. The island of Elba has been celebrated for this ore since before the Christian era, and it still produces it. The ore of the two so-called iron mountains of Missouri was mainly hematite; it is an abundant ore of the Marquette region, Michigan, and is found at many other places in the United States; when pure, it is less easy to work than the other oxidized ores.

The pulverized ore is used for metal polishing. The artificially prepared oxide furnishes the Venetian-red paint, and the red chalk is used for crayons and coarse pencils.

Magnetite, Magnetic Iron Ore, Fe_3O_4.

Isometric.—Prevailing crystalline forms the octahedron and dodecahedron; very commonly massive and granular.

The color of the ore is distinct iron-black, luster semi-metallic, streak black. $H. = 5.5$ to 6.5. $G. = 4$ to 5. It is magnetic and sometimes endowed with polarity. Acted upon by hydrochloric acid, and gives blue precipitate upon addition of potassium ferrocyanide. The weight, streak, and magnetic properties distinguish this ore from all other minerals.

Magnetite occurs in beds, principally in metamorphic rocks, and is most abundant in the Archæan. It is found in many places throughout the world. It is the principal ore of Sweden, Norway, and northern Russia, and exists in extensive beds in New York, Minnesota, and to a less extent in several of the New England States.

Franklinite, $(Fe,Zn,Mn)O(Fe,Mn)_2O_3$.

This ore is similar to magnetite, but some of the iron has been replaced by zinc and manganese. Its physical properties are about the same as magnetite, but the streak is generally not so black, often a reddish brown. This ore occurs abundantly in New Jersey and often contains zincite. The franklinite is a valuable ore for the manufacture of zinc-white and Spiegeleisen.

Limonite, Brown Hematite, $2Fe_2O_3,3H_2O$.

This ore occurs in botryoidal, mammillary, and stalactitic forms with fibrous texture; also massive, and as concretions and earthy.

The color is brown to black, and in the earthy varieties yellowish brown. Streak yellowish brown. Luster, when present, semi-metallic, sometimes silky; it is frequently without luster, especially in the earthy forms. H. = 5 to 5.5. G. greater than 4; pulverulent varieties less hard and less heavy.

The principal forms of the ore are the following:

Brown Hematite, which includes the more compact forms, usually with semi-metallic luster, the botryoidal, stalactitic, etc.

Ocherous Ore.—All soft, earthy varieties of brown or yellowish color, giving the brown and yellow ochers.

Impure compact, clayey ores constitute the brown and yellow *clay iron-stone.*

Bog Ore is a soft brownish-black ore when pure. It sometimes takes imitative forms, and when mixed with silica, which is very frequently the case, is quite hard.

These ores readily give off water in a closed tube, become magnetic before the blowpipe, and give the iron test with hydrochloric acid and potassium ferrocyanide. These characters with the streak distinguish the ore.

Limonite is a common and valuable ore and is abundantly and widely distributed in the United States. The localities of its occurrence are too numerous to mention. The ore is the result of the alteration of iron-bearing minerals, brought about by atmospheric agencies. The yellow ocher is used for a common paint. The name *limonite* is from the Greek word for meadow.

Siderite, Spathic Iron Ore, Chalybite, Iron Carbonate, $FeCO_3$.

Rhombohedral.—Occurs also in botryoidal and nodular forms, in compact masses and earthy. Crystalline form shows sparry faces which are often curved.

Color of mineral is ash-gray to yellowish gray, yellow to reddish brown, often brown to brownish black from exposure. Luster pearly to vitreous, also dull. Streak light yellow to yellowish brown. H.=4. G.=4. Before the blowpipe it blackens and becomes magnetic. When powdered, acted upon with effervescence by hydrochloric acid, and gives a blue precipitate upon addition of potassium ferrocyanide.

Spathic Ore is the crystallized form with sparry faces. When the ore is largely mixed with clay it gives the *clay iron-stone*, and when bituminous matter is present it is the *black band.*

It is a valuable ore, occurring as the gangue in certain veins, and in beds, and is abundant as clay iron-stone in the coal formations. It takes the limonite color when exposed to atmospheric agencies due to conversion into that form. Chalybeate waters hold it in solution and deposit it upon coming to the surface, the color around such springs being due to its conversion into hydrated sesquioxide.

The clay iron-stone constitutes the great ore of England. It occurs also in the coal-beds of Pennsylvania, West Virginia, and Ohio. The iron produced in in the United States in 1905 exceeded the combined make of Great Britain and Germany, our two chief rivals.

Chromite, Chromic Iron Ore, $FeCr_2O_4$ or $FeOCr_2O_3$.

Isometric.—Chromite usually occurs in granular or compact masses or in disseminated grains. Color is brownish black to iron-black; streak brown. H. = 5.5. G. = 4.3 to 4.6. Sometimes slightly magnetic. It is distinguished from magnetite by its streak and by giving a green bead indicative of chromium when fused with borax.

Chromite is the source of nearly all the compounds of chromium which are so extensively used as pigments, its principal use being in the production of potassium bichromate.

TIN, ANTIMONY, AND MANGANESE MINERALS.

Cassiterite, Tin-stone, Black Tin, Tin Ore, Tin Oxide, SnO_2.

Tetragonal.—Occurs in crystals of short pyramidal type or slender columns acutely terminated, twins common; also in reniform and spheroidal masses with divergent fibrous texture; in granular masses and in rounded pebbles.

The color is sometimes white, gray, yellow, or red, but more generally brown or black; streak light gray to brown. H. = 6 to 7. G. = 6.8 to 7.1. Before blowpipe infusible alone, gives globule of tin on charcoal with soda.

Stream-tin ore is the detritus from veins and is found in the alluvial deposits of streams which drain tin-bearing regions. The globular masses of tin ore with radiating fibrous texture and concentric structure are sometimes called wood-tin, from the woody appearance.

Cassiterite is the principal ore of tin. It occurs in veins intersecting granite and metamorphic rocks. The largest amounts of tin are produced in the island of Banca and in Great Britain; considerable quantities also come from Germany, Austria, Siberia, Australia, and Bolivia. Tin has as yet been produced only in very small quantity in this country.

Stibnite, Gray Antimony, Antimony Glance, Sb_2S_3.

Orthorhombic.—Crystals prismatic, long columnar or acicular, faces vertically striated; pyramidal faces curved or distorted; common in radiating or divergent groups of acicular crystals, also massive with columnar fibrous texture.

Stibnite is the sesquisulphide of antimony, Sb_2S_3. Its color is lead-gray; luster metallic, very brilliant on fresh cleavage surface; tarnishes black, sometimes iridescent; streak lead-gray. H. = 2. G. = 4.55 to 4.65.

Heated in open tube stibnite gives off sulphurous and antimonial fumes, the latter being partly Sb_2O_3 and partly Sb_2O_4; the first oxide is fusible and volatile, the latter neither. Stibnite is easily fusible and entirely volatile before the blowpipe; when pure it is acted upon by HCl with evolution of H_2S. The above characters distinguish it from galena and graphite, which it sometimes resembles.

Stibnite is the chief ore of antimony, besides being directly used as a substitute for sulphur in some pyrotechnic preparations.

Pyrolusite, Black Oxide of Manganese, MnO_2.

Pyrolusite occurs in orthorhombic crystals, but may be pseudomorphous. Generally occurs in short columns, often parallel fibrous and divergent, granular massive and reniform, also compact.

Pyrolusite is the dioxide of manganese, MnO_2. Its color is dark gray to iron-black, sometimes bluish; luster almost metallic; streak black. Crystals have a hardness of 2 to 2.5, other varieties softer. G = 4.7 to 4.9.

Fused with borax gives violet bead of manganese; acted upon by HCl with evolution of Cl.

Pyrolusite is the most important ore of manganese, being employed both for its manganese and oxygen, and for making bleaching-powder.

Manganite is a hydrous manganese sesquioxide. Its streak is generally less dark than that of pyrolusite; it is also harder and yields water in a closed tube.

Psilomelane and *wad* are minerals largely composed of oxides of manganese of varying degrees of purity, but whose compositions are not definite.

SODIUM AND POTASSIUM MINERALS.

Halite, Rock Salt, NaCl.

Isometric.—Cube the prevailing form.

Rock salt is sometimes transparent and colorless, though often tinged some shade of yellow, red, or green. Its taste is well known. H. = 2. G. = 2.2. Decrepitates when heated, easily fusible, and colors flame yellow. It is soluble in water and gives a white precipitate with silver nitrate.

Salt exists in all geological formations from the Silurian up. It is found in beds extending over large areas and is usually associated with gypsum, anhydrite, clays, or sandstone. In some places the salt is mined, or taken in the solid state directly from the beds; in others the waters from brine-springs are evaporated. The salt-mines of Poland and Hungary are the most celebrated in the world. The first, near Cracow, have been worked for over seven centuries and are almost of inexhaustible extent. Salt is mined in this country in Louisiana, and Kansas, and in Wyoming, Genessee, and Livingston counties, New York.

Most of the salt made in the United States is by the evaporation of brines or waters from salt-springs. Michigan and New York are the chief producers by this method, though other States furnish some. The rock salt taken from mines is generally so impure that it is dissolved and recrystallized by evaporation before going into the market. Ohio, California, West Virginia, Texas, Utah, and Nevada are also salt-producing States. The annual production of salt in the United States since 1900 has been between twenty and twenty-five millions of barrels.

Cryolite, Ice-stone, Double Fluoride of Sodium and Aluminum, Na_3AlF_6 or $3NaF,AlF_3$.

Monoclinic.—Cryolite usually occurs massive, generally white, though sometimes giving shades from red through brown to black; translucent; has an irregular platy or fibrous fracture which is very characteristic. It fuses readily in forceps, coloring flame yellow; on charcoal easily yields clear bead; acted upon by sulphuric acid with evolution of hydrofluoric acid.

This mineral is largely used in the production of aluminum and formerly of sodium. It is principally obtained at the Ivigtut mines of west Greenland, from which place it is largely imported to the United States.

Niter, Saltpeter, KNO_3.

Orthorhombic.—Niter, when pure, is white and very brittle. It has a saline and cooling taste. H. = 2. G. = 1.97. Deflagrates when heated with powdered charcoal. Differs from sodium nitrate in not deliquescing when exposed to the air.

Niter is sometimes found mixed with the earthy flooring of caves; Kentucky, Tennessee, and several Western States have furnished it in small quantity from this source. It forms abundantly as an efflorescence on the soil in certain countries, especially during hot weather after rains. India and Persia are the most noted countries for this natural production. In many countries it is artificially prepared as described in Chemistry.

Carnallite, $KMgCl_3,6H_2O$.

Hydrous chloride of potassium and magnesium.

This mineral occurs in granular masses. It is of white color when pure, but generally reddish; has a bitter taste and is deliquescent; showing greasy luster when fresh.

Carnallite is found in large quantity alternating with beds of common salt at the Stassfurt salt-mines. It is the principal source of potassium chloride.

Its composition is represented by the formula

$$KMgCl_3,6H_2O.$$

CALCIUM MINERALS.

These compounds are very abundant in the mineral kingdom. The most abundant and important are the carbonates, sulphates, phosphates, silicates, and the fluoride. The carbonate is one of the most common of minerals; other native compounds are found less commonly. The compounds named are insoluble or only very slightly soluble in water.

Fluorite, Fluor Spar, CaF_2.

Isometric.—Prevailing form is the cube; also frequently compact and fine granular. It is sometimes colorless and transparent, but usually has some light color, e.g., some tint of green, blue, purple, or yellow; rose-red and violet shades are rare and highly prized. Streak light. H. = 4. G. = 3. Below red heat the mineral phosphoresces, but above that temperature it ceases to phosphoresce and loses its color. The phosphorescent colors are independent of the actual colors. That giving a green phosphorescence is called *chlorophane*. Before the blowpipe the mineral decrepitates. It is very brittle.

Fluorite occurs in veins, also in beds, and sometimes as the gangue in metalliferous veins, especially of lead and tin. It is the most abundant native compound of fluorine. The massive varieties are worked into vases, candlesticks, and ornamental objects. It takes a high polish, but is difficult to work because of its brittleness. It is decomposed by sulphuric acid, with liberation of hydrofluoric acid, and is used to obtain this acid for etching on glass. It is also used as a flux in certain metallurgic operations. The Cumberland and Derbyshire districts of England are most noted for its production.

Gypsum, Hydrous Calcium Sulphate, $CaSO_4,2H_2O$.

Monoclinic. — Crystals frequently of arrow-head form. Occurs massive with foliated and granular texture, also fibrous and in radiating forms.

Gypsum varies in color from white to yellow, red, brown, and black. The crystals are generally more or less transparent, other forms translucent to opaque. Luster silky, vitreous to pearly. H. = 2. G. = 2.3. In thin plates flexible, but not elastic. Before the blowpipe loses water, becomes white, opaque, and exfoliates. In closed tube gives off water easily; dissolves in hydrochloric acid, and after dilution gives a white precipitate with a soluble barium salt.

Gypsum is the most widely distributed of the sulphates, and there are several varieties.

Alabaster.—This has a very fine granular texture, almost compact to the eye.

Selenite.—Includes the crystalline forms, usually in transparent plates.

Satin Spar.—A white, finely fibrous variety. Some of the fibrous varieties have a radiated structure and are then called *Radiated Gypsum.*

Common Gypsum.—Compact and fine granular, may be white, yellow, brown, red, or black. Gypsum occurs in extensive beds in limestone and clay strata. Common salt is a very frequent mineral associate. When three-fourths of its water is driven off from gypsum by heat it constitutes plaster of Paris, so called because the gypsum quarries near Paris have long been famous for supplying it. The plaster mixed with water is used in taking casts, making moldings, etc. Alabaster is carved into various objects, as statuettes, parlor ornaments, etc. The name of alabaster is sometimes applied to a variety of calcium carbonate. Gypsum, finely divided, is also used as a fertilizer.

Anhydrite, $CaSO_4$.

This mineral resembles gypsum, and its tests are the same except that it gives off no water when heated. It is also harder and heavier than gypsum, and its crystalline form is orthorhombic. H. = 3 to 3.5. G. = 3.

Apatite, Phosphate Rock, $Ca(F,Cl)Ca_4(PO_4)_3$.

Hexagonal. — Prevailing form hexagonal prism; also massive, sometimes globular with fibrous texture.

Color is usually some shade of green, but may be white, yellow, reddish yellow, or brown. Luster vitreous to sub-resinous, streak light. H. = 5. G. = 3.2. It often closely resembles beryl in appearance, but is softer and more resinous. It is readily soluble in hot nitric and hydrochloric acids. Solutions treated with sulphuric acid give a white precipitate. Nitric acid solution added to molybdate of ammonium in excess gives immediately, or upon warming, a bright yellow precipitate.

Apatite is essentially calcium phosphate containing some chlorine and fluorine. Coprolites and guano are the fossil excrements of birds, and are chiefly composed of calcium phosphate, but contain also the phosphates of ammonium, sodium, and magnesium.

Apatite occurs in veins in Quebec and Ontario, often of great purity, but generally mixed with rock material, such as pyroxene, hornblende, calcite, and many others. Immense deposits of phosphatic nodules occur in the Tertiary formations of South Carolina and Florida. These nodules contain from fifty to sixty per cent of tricalcic phosphate mixed with sand, calcium carbonate, and some organic matter. The great importance of guano and apatite is due to the phosphoric acid in their composition. Both are valuable fertilizers. The apatite, before use, is converted into the soluble superphosphate of calcium by treatment with sulphuric acid. The phosphate industries of the United States are very important and extensive.

Calcite, Calcspar, $CaCO_2$.

Rhombohedral.—Often coarse and fine fibrous, granular, compact, and earthy.

There are many varieties of this mineral, and they vary very much in color, from transparent white to yellow, red, and mottled in the crystalline forms; the compact forms may be almost any dull shade to black. Typical crystals have vitreous luster, sometimes pearly; fibrous variety is often silky; the others, from common to earthy in appearance. Hardness (of crystals) 3. G. = 2.5 to 2.8. Some of the earthy forms are very soft. Calcite is infusible, but when heated gives off carbon dioxide and is reduced to quicklime, which when moistened gives alkaline reaction; it is acted upon readily, with effervescence, by the mineral acids even when cold; the solution in hydrochloric acid diluted gives a white precipitate upon addition of sulphuric acid.

Calcite is one of the most abundant and widely distributed of minerals, probably coming next to quartz in this respect. Some of the most important varieties are mentioned below.

Limestone.—This term is sometimes, and not improperly, applied to all calcspars, but it is generally limited to the granular and compact varieties. The granular include those of a distinct crystalline granular texture, often glistening owing to the facets of the grains; architectural and statuary marbles are the best examples. The latter must be of fine grain, homogeneous texture, and pure color. The architectural varieties may be of various shades of color and is used for decorations as well as in structures.

The compact limestones include the crypto-crystalline and non-crystalline varieties. *Hydraulic limestone* is one of these; it contains clay as an impurity, and produces a lime that yields a mortar that will set under water. Slow effervescence, conchoidal fracture, and argillaceous odor incicate, but do not insure, hydraulic properties.

Lithographic Limestone.—A very fine-grained compact limestone; its use is indicated by the name.

Oölitic Limestone.—Compact and often composed of concretionary grains somewhat resembling the roe of a fish, hence the name, from the Greek *oön*, an egg. If the grains are larger, the stone is called *pisolite*, from the Latin *pisum*, a pea. The grains are not always concretionary, but sometimes comminuted and rounded fragments. In each case the grains are cemented together by calcium carbonate.

Chalk.—A compact but soft variety, mainly composed of rhizopod shells.

Chemically deposited Limestone.—Under this head are included the limestones deposited from water holding them in solution. Some of the most important are:

Travertine.—Deposited from rivers and springs; it is often in variegated layers and makes a most ornamental marble. *Mexican onyx* is an illustration.

Stalactites.—The cones and cylinders found depending from the roofs of many caves.

Stalagmites.—Calcareous formations over the bottoms of caves and often rising in cones, meeting similar projections from above. These cave formations are frequently arranged in different colored curved layers, and when broken across give very beautiful effects. The cave deposits are made by the waters which percolate into the caves. Luray Cave in Virginia is one of the most celebrated in the world for these formations.

Calcareous Tufa.—An irregular porous deposit frequently incrusting twigs or similar objects and usually made by small springs and rather turbulent waters.

Rock Milk.—White and earthy like chalk, but softer; deposited from spring-waters.

In the case of all the deposited varieties the mineral is first taken into solution by water holding carbon dioxide in solution, and is deposited when the gas escapes from the water, or in some cases by the evaporation of the water itself.

Of the non-massive, crystalline varieties of calcspar it is only necessary to mention a few:

Iceland Spar.—The name applied to the limpid, crystalline specimens.

Dog-tooth Spar.—Composed of crystals of scalenohedral form; frequently occurs as an incrustation.

Satin Spar.—The delicately fibrous variety, affording a fine satin luster after polishing.

In addition to the varieties above described calcite occurs in many other forms. The living and often fossil shells of the mollusca are mainly composed of it as well as the many forms of shell-limestone and coral-rock. It is also an essential constituent of marls. The granular and compact limestones constitute immense rock formations in nearly all geological ages and are found widely distributed. True chalk is abundant in Europe, especially in England, but has only been found in Texas and Kansas in this country. Marble is a term applied to any limestone susceptible of a polish. Besides its use in structures, limestone is the source of quicklime, which is employed in enormous quantity throughout the world for making common mortar.

Arragonite, $CaCO_3$.

This mineral has the same chemical composition as calcite, but differs in crystalline form, being orthorhombic; it is also slightly harder and heavier. The action under the blowpipe and acids is the same as that of calcite, except that it crumbles to powder more easily after heating. It receives its name from Arragon in Spain, where very fine crystals have been found.

Dolomite, Calcium-magnesium Carbonate, Magnesium Limestone, $CaMg(CO_3)_2$.

Rhombohedral.—Granular and massive.

The massive varieties of dolomite vary in color from white to gray, yellow, reddish, green to brown or black. The lighter varieties have vitreous or pearly luster. H.=3.5 to 4. G. = 2.8 to 2.9, slightly harder and heavier than calcite. Before the blowpipe reacts the same as calcite. It gives sluggish effervescence with cold dilute acid, sometimes has to be powdered for this action. It often cannot be distinguished from calcite without a chemical analysis.

Dolomite is a double carbonate of calcium and magnesium and forms beds in rocks of all ages. It occurs mainly in two forms:

1. The distinctly crystalline granular variety, usually of white or yellowish-white colors, is generally designated as *Dolomite*. Its external characters are often hard to distinguish from granular limestone.

2. The finely granular, almost compact variety is generally called *Magnesium limestone;* it is often difficult to distinguish from siliceous limestone.

Dolomite is a common marble in New York and the New England States, and is largely used as a building-stone. It is also very common in Kansas and other of the Western States. Dolomite is a good building-stone where anthracite coal is the fuel, but in cities where bituminous coal is the fuel the greater amount of sulphur present in the coal is found to result very injuriously to the stone. This stone was selected for the new Houses of Parliament in London, after the old ones were destroyed by fire in 1838. The effects of the bituminous fuel in London have rendered it necessary to protect the buildings by artificial preparations such as soluble glass, etc. Some of the dolomites, such as the Sing Sing marble, by cautious reduction, reducing the magnesian carbonate with perhaps some (but not all) of the calcium carbonate, gives a lime possessing hydraulic properties.

SILICA.

Quartz, SiO_2.

Hexagonal.—Common form, the hexagonal prism, with corresponding pyramidal ends. Granular, cryptocrystalline and compact.

Quartz occurs under a great variety of forms, but certain properties are common to them all. H. = 7. G. = 2.5 to 2.8. Alone it is infusible before the blowpipe, but when heated with sodium carbonate it fuses with effervescence, due to the escape of carbon dioxide. It is not acted upon by the common acids and shows no cleavage. Quartz may be conveniently divided into two series, the distinctly **crystalline** or **vitreous** series and the **cryptocrystalline** or **chalcedonic** series. Some of the more important varieties of each series will be briefly described.

Crystalline or Vitreous Series.

The vitreous series have glassy luster and fracture and include:

Rock Crystal.—Which is pure quartz, colorless, and transparent. It is used in jewelry under the name of white-stone and occidental diamond.

Amethyst.—Has a purple or bluish-violet color; perfect specimens are highly prized. Color supposed due to manganese.

Rose Quartz.—Has rose color, which becomes paler after long exposure to light. Usually occurs massive, slightly transparent. Color probably due to titanic acid and manganese.

Smoky Quartz, Cairngorm.—Of a smoky or brownish-black tint, believed to be due to organic matter.

Milky Quartz.—Of a milky color and sometimes a slightly greasy luster, usually massive and almost opaque.

Cat's-eye.—A gray or greenish variety, presenting opalescence when cut in convex form. Appearance due to penetrating *asbestus*.

Aventurine.—Aventurine is a form of quartz with glistening spangles, due to the presence of scales of mica, iron oxide, or other mineral. The basic color is usually red or brown. The aventurine is frequently imitated in glass, but such imitations can be detected by the inferior hardness.

There are several other varieties of vitreous quartz. Some authors describe all the vitreous varieties as rock crystal more or less pure.

Quartz is an important rock-making mineral.

Cryptocrystalline or Chalcedonic Series.

Chalcedony.—Waxy or horn-like in appearance; varies much in color, generally translucent; frequently shows its origin by deposition from siliceous waters; occurs as stalactites, lining cavities, and as incrustations.

Agate.—A mottled or cloudy chalcedony with different colored layers made by successive depositions. When a section is made across the layers the colored edges are shown in more or less regular lines or bands. If the layers are very irregular the section shows zigzag lines and the stone is called *fortification agate*.

An agate containing moss-like or dendritic forms is called *moss-agate*. The colored layers are believed due partly to organic matter, partly to metallic oxides (Fe and Mn), and largely to rate of deposition. The colors of agates may be changed artificially, and this is sometimes done in agates cut for ornaments.

Onyx.—An agate with plane layers; these render it suited for cutting into cameos. If the layers are alternately white and sard, the stone is a *sardonyx*.

Carnelian.—A light red chalcedony.

Sard.—A deep red or brownish-red chalcedony, especially by transmitted light.

Chrysoprase.—An apple-green chalcedony, colored by nickel oxide.

Flint.—A compact chalcedony usually dark brown or gray. It occurs in great abundance in nodular forms in the chalk-beds. It has conchoidal fracture and leaves sharp edges in breaking.

Jasper.—An impure opaque chalcedony, color some shade of yellow, red, brown, or black. Occasionally gray or green. If in striped bands of such colors, it is called *ribbon* or *riband jasper.*

Heliotrope or Bloodstone.—With green color and spots of red; the green color is due to some chlorite, and the red to iron oxide. All the above varieties of quartz are susceptible of polish and are used as gems or in ornamental work.

Granular Quartz.—In addition to the above varieties many rocks consist of silica nearly pure, or quartz grains firmly cemented together; such are quartzite and quartz sandstone. Buhrstone is a cellular quartz rock having much the appearance of coarse chalcedony.

Silica is the most common petrifying material. It sometimes replaces calcite and fluorite in their crystalline forms, thus giving pseudomorphous quartz. Silica is the common petrifying agent of shells and wood. Silicified wood is found in great abundance in Arizona, Wyoming (National Park), Colorado, and other Western States. The petrified forests of Arizona and Wyoming are very extensive; the first named have furnished specimens of agatized wood of unsurpassed beauty.

Tridymite, SiO_2.

Hexagonal.—This mineral is a variety of silica whose crystalline form belongs to the hexagonal system, but it usually occurs in minute, thin tabular forms. The crystals are generally minute and six-sided, often in twins or fan-shaped groups. Its properties are the same as quartz except that it is completely soluble in a boiling solution of sodium carbonate. It occurs chiefly filling cavities in acidic volcanic rocks, often associated with sanidin, hornblende, or augite, and sometimes opal. G. = 2.28 to 2.33.

Opal, $SiO_2,(H_2O)_n$.

Opal is an amorphous form of silica with from three to thirteen per cent of water. There are several varieties differing widely in color. Opal is slightly less hard and heavy than common quartz, has a glistening, resinous luster, and dissolves entirely in heated solution of potash; frequently decrepitates when heated. The finest specimens give beautiful internal rainbow-reflections as the stone is turned in the light.

The luster and the evident amorphous texture usually sufficiently distinguish opal. Like other silica it is frequently a petrifying material.

Fiorite, Siliceous Sinter.—These terms include the siliceous incrustations from hot springs; they are usually more or less porous, sometimes almost fibrous.

Geyserite.—Includes the concretionary siliceous deposits from geysers; these deposits are very varied in shape, and occur in great beauty and abundance in the Yellowstone Park. The terms fiorite, geyserite, and siliceous sinter are very often used synonymously.

Tripolite, or *Infusorial Earth* is another form of opal resulting from the accumulation of diatom shells and the spicules of sponges. The polishing powder known as *Electro-silicon* is composed of this material.

ROCK-FORMING SILICATES.

Silica is the abundant acid oxide of the earth's crust, and forms silicates with various metallic bases. The silicates are the most important rock-making minerals.

An entirely satisfactory classification of the silicates, based upon their composition, has not been accomplished, as the definite constitution of the acids from which the silicates result is not known.

The ordinary classification of the silicates is based upon what appears to be the ratio between the oxygen in the basic and acid anhydride parts of the silicate. The principle of this classification is readily seen when the formulæ of the silicates are written after the dualistic method so as to show this oxygen relation. Thus representing by *R* a dyad metallic element, in the following table are written the general formulæ of the silicates named, with the formulæ of the acids from which they are supposed to be formed:

	General Formula.	Oxygen Ratio.	Formula of Acid.	Name of Acid.
Orthosilicate .... Unisilicates (Dana)	$R_2O_2.SiO_2$	1 to 1	$SiO_4H_2 = SiO_2.2H_2O$	Orthosilicic
Metasilicate .... Bisilicates (Dana)	$RO.SiO_2$	1 to 2	$SiO_3H_2 = SiO_2.H_2O$	Metasilicic
Trisilicate	$2RO.3SiO_2$	1 to 3	$Si_3O_8H_4 = 3SiO_2 2H_2O$	Trisilicic
Disilicate............	$RO.2SiO_2$	1 to 4	$Si_2O_5H_2 = 2SiO_2.H_2O$	Disilicic

There are many species in which the oxygen ratio is less than 1 : 1, as 3 : 4, 2 : 3. Such species are called subsilicates, and it is evident that they contain a larger proportion of the basic radicle than the examples given in the table. In addition it is thought probable that there are other silicic acids from which natural silicates may result. Neither can a distinct line of demarcation be drawn between hydrous and anhydrous silicates.

The majority of the silicates come under the head of metasilicates or orthosilicates, and are considered as derived from the corresponding acids, SiO_3H_2, metasilicic acid, and SiO_4H_4, orthosilicic acid. The normal orthosilicates would then be represented by R_2SiO_4 or $R_2O_2SiO_2$, and the normal metasilicate by $RSiO_3$ or $ROSIO_2$, in which R represents a dyad metal. When a greater proportion of the acid or basic radical is contained than the formulæ indicate there result respectively polysilicates or subsilicates. The grouping here adopted for the principal silicates is mainly intended to emphasize and fix in mind their relationship and importance as rock-forming minerals.

PYROXENE AND AMPHIBOLE GROUPS.

The members of these groups are silicates of various bases, among which generally appear calcium, magnesium, iron, and aluminum; manganese and zinc less often, potassium and sodium still more rarely. More than one base is usually present, though some members of the group contain but one. The two groups are closely related in composition and crystalline form. Each group shows forms belonging to different systems of crystallization, either orthorhombic, monoclinic, or triclinic. The monoclinic species are most important, the triclinic least important. The amphibole group has prismatic cleavage of 124° 30′ and 55° 30′, while that of the pyroxene group is nearly 90°. This cleavage angle taken in connection with the build of the crystal establishes the chief distinction between the groups. With pyroxene the distinct crystals are usually short prisms, often complex, in massive specimens lamellar or granular; with amphibole the distinct crystals are long prisms and simple, in massive kinds columnar and fibrous. Only the more important species of each group are here described. The general formula for these groups is $RSiO_3$, in which R stands usually for more than one of the metals named above.

(A) Pyroxene Division.

(1) *Monoclinic Section.—Pyroxene*, $RSiO_3$.

Distinct crystals usually in short stout prisms, often complex, massive, granular or lamellar, sometimes fibrous or compact. The more important varieties of this species are silicates of two or more of the bases calcium, magnesium, and iron, calcium being generally present, with either iron or magnesium or both; aluminum in certain cases. The color is usually some shade of green, brown, or black; also occurs white. Luster varies from dull vitreous through imperfectly resinous to slightly pearly. H. = 5 to 6. The rectangular cleavage when evident distinguishes it from amphibole. The more important varieties are:

Augite.—This is a very abundant and important mineral, and is a silicate of calcium, magnesium, iron, and aluminum. It is black or greenish black in color and opaque. It is the common form of pyroxene in the basic eruptive rocks. The term augite is sometimes used synonymously with pyroxene, but more generally it is limited to the variety just described.

Diallage is a thinly foliated or lamellar variety of augite.

Malacolite.—This is sometimes called white augite, and is a calcium-magnesium pyroxene. The granular form is frequently called white *coccolite*, from *coccos*, a grain. The green granular form, green coccolite, contains calcium and iron.

The varieties of the pyroxene species are very important rock-making minerals.

(2) *Orthorhombic Section.—Pyroxene*, $RSiO_3$

The orthorhombic pyroxenes are magnesium, or iron and magnesium, silicates. The species of the pyroxene group under this section are:

Enstatite.—Which contains the smaller proportion of iron oxide—not over five per cent—and sometimes iron is absent. The color varies from grayish, yellowish, or greenish white to brown. Luster vitreous to pearly. H. = 5.5. G. = 3.1 to 3.3. It is infusible and not attacked by acids; strongly resembles the monoclinic pyroxenes.

Enstatite in a very pure state is a frequent constituent of meteorites.

Bronzite.—This contains more iron than the preceding and its color deepens from grayish yellow-green to olive-green. The amount of iron oxide generally ranges from

5 to 14 per cent; with a greater per cent of iron the bronzite passes to the next variety.

Hypersthene.—This mineral contains more iron than either of the preceding, the amount of iron oxide varying from 14 to 30 per cent. Color is a dark greenish brown or black, sometimes approaching a copper-red. Streak gray or brownish gray. H. = 5 to 6. G. = 3.4 to 3.5.

Hypersthene often has a characteristic iridescence due to minute, interspersed foreign crystals, symmetrically arranged. B.B. it fuses to a black enamel, and on charcoal yields a magnetic mass. This species is a common constituent of certain of the eruptive rocks.

(B) Amphibole Division.

(1) *Monoclinic Section.—Amphibole,* $RSiO_3$.

The species of the amphibole group form a series closely related to those of the pyroxene group; the general distinction between the two groups has already been indicated. The amphibole species of this group are analogous to the pyroxene species of the pyroxene group, being silicates of the same bases, though potassium and sodium are more frequently present.

Amphibole usually occurs in columns less stout than those of pyroxene, often in bladed crystals, also fibrous and granular; the cleavage more oblique than that of pyroxene. The color of the amphibole varies from black to white through many shades of green; streak lighter than color. Luster vitreous to pearly on fresh surfaces, fibrous varieties often silky. H. = 5 to 6. G. = 2.9 to 3.4. The principal varieties of this species are:

Tremolite.—A white lime-magnesia amphibole. It usually occurs as blades or needles penetrating the gangue with which they are associated, sometimes radiated or aggregated into columnar masses of silky luster. Tremolite most often occurs with dolomite.

Actinolite.—Of the same composition as tremolite with iron in addition, and occurring in the same way as aggregations of needles or blades or in radiating forms. It usually occurs with serpentine.

Asbestus.—Both varieties of amphibole pass into asbestus. Asbestus includes the finely fibrous forms, fibers easily separable and resembling flax; when the fibers are more like silk it is called *amianthus.* When the fibers adhere closely and the stone resembles petrified wood, it is called *ligniform asbestus.* When the fibers are interlaced so as to make tough sheets, it is called *mountain leather.*

Asbestus is the only variety of the amphibole species used in the arts. It is sometimes woven into lamp-wicks, fire-proof cloths, etc. It is incombustible, and articles made of it may be cleansed by throwing them into fire. Asbestus is found at many localities in the United States, but generally of inferior quality and only adapted for grinding, and use for paints, cements, boiler and steam-pipe coverings, safe-linings, etc. The greater portion of the mineral called asbestus, suitable for weaving into cloth is a variety of serpentine and does not fall under this species. Canada supplies this serpentine form in large quantity.

Crocidolite.—This species of the amphibole group is a silicate of iron and sodium. It occurs asbestiform, also massive and earthy. The color is lavender-blue or light green. Luster silky or satin to dull. H. = 4. G. = 3.2 to 3.3. In closed tube gives a little water which is slightly alkaline. B.B. fuses easily with intumescence to a black magnetic glass coloring flame yellow.

An altered form of this mineral is found abundantly in South Africa and popularly called "tiger-eye" or "cat's-eye." The alteration is due to the oxidation of the iron and infiltration of silica. The altered mineral has a delicate but distinct fibrous texture and chatoyant luster, with amber-yellow to brown color. This form of the mineral has come into frequent use as an ornamental stone.

Hornblende.—This term is often used as synonymous with amphibole, but it is more generally applied to the dark-colored varieties containing a larger per cent of iron; it occurs in dark green or black crystals, massive and compact. Hornblende, like pyroxene, is an important rock-making mineral. It is an essential constituent of the plutonic rocks. Such difference as exists between hornblende and pyroxene is probably mainly due to the different conditions under which they were formed, the composition being substantially the same.

MICA GROUP.

This term embraces a group of minerals which are essentially hydrous silicates of aluminum and an alkali metal. Potassium is the alkali metal most abundantly and commonly present. Sodium is often present, and in one variety it entirely replaces the potassium. The next most important constituents are lithium, iron, and magnesium, the last named being the most abundant metal in one variety. Alkali metals, one or more, are present in all micas. Some of the micas contain fluorine. The formulæ for the different varieties of mica have not been precisely determined.

The micas belong to the monoclinic system and are characterized by a highly laminated structure and perfect cleavage. The laminæ are flexible and elastic.

Muscovite is one of the common micas, being a hydrous silicate of aluminum and potassium. It has white or silvery color, passing to various shades of yellow, brown, and green. $H. = 2$ to 2.5. It is a common constituent of granite, gneiss, and mica schist, and in these rocks usually occurs in minute silvery scales. Its essential formula is

$$2H_2O . K_2O . 3Al_2O_3 . 6SiO_2,$$

with generally some replacement by sodium, iron, or magnesium.

Biotite, like muscovite, is a hydrous silicate of aluminum and potassium, but in addition contains a large per cent of magnesium and iron. It is generally greenish black to black in color. It is even more common in the granitic and metamorphic rocks than muscovite.

Lepidolite is a mica containing a little lithium, which gives it a delicate lilac or rose-colored shade found only in this variety.

Mica, in the clear transparent forms, has long been used for furnace and stove doors and lamp-protectors. It is now very largely used as an insulator in the construction of dynamo machines. For this purpose the color is immaterial, but perfect cleavage is necessary, as the plates must be of uniform thickness and often very thin. For insulating purposes small laminæ can be fastened together by suitable mucilage so as to form large sheets. Mica is also ground up and used for mural painting and in the manufacture of wall-paper. It can thus be made to produce a metallic, frosted, or spangled surface. The ground mica is also used as an absorbent of nitroglycerin in certain mica powders. For grinding, waste mica is generally used. Mica is chiefly mined in this country in North Carolina, New Hampshire, South Dakota, and Idaho. Most of that now used in this country is imported from India and Canada, this being better fitted for electrical purposes.

FELDSPARS.

The feldspars are essentially silicates of aluminum, potassium, sodium, and calcium. They all contain aluminum, the other metals alternating in the different species. The common and important forms of feldspar all belong to the triclinic system, except orthoclase, which is monoclinic. The group has a hardness of from 6 to 7, and a specific gravity of from 2.4 to 2.7.

Orthoclase, Common Feldspar, Potash Feldspar, $KAlSi_3O_8$.

Monoclinic.—Prevailing forms, oblique prisms or derivatives. Also massive, with lamellar or granular texture. Sometimes finely compact.

A silicate of aluminum and potassium containing a little sodium. Generally light or flesh color, though dark colors are not uncommon, and there are various intermediate shades. It is similar in other respects to albite, except that it has two cleavage planes at right angles to each other, which, when evident, is sufficient to distinguish it from that form. It is a common constituent of many of the igneous and metamorphic rocks; abundant in the gneiss about West Point. Ground orthoclase is extensively used as a glaze and flux in the manufacture of pottery.

Sanidin.—Is a transparent and glassy form of orthoclase, frequently in crystals imbedded in lava.

Adularia.—Is a white, clear orthoclase, often with pearly opalescence.

Albite, Soda Feldspar, $NaAlSi_3O_8$.

Triclinic.—Usually in crystalline masses with more or less lamellar structure.

In composition a silicate of aluminum and sodium; color generally white or gray, often of shades of blue, red, or green; subtranslucent. Is not acted upon by acids; fuses with difficulty and colors flame yellow.

Albite is a constituent of many crystalline rocks, such as diorite, granite, and gneiss. The finest crystalline specimens occur in granite veins. Albite frequently shows fine striæ on cleavage surfaces due to intersection of faces of crystalline laminæ.

There are many other varieties of feldspar, the more important of which are Anorthite, Labradorite, Andesine, and Oligoclase. The first named is a calcium feldspar, and the others are calcium and sodium feldspars. Anorthite and Labradorite are sometimes called basic feldspars because they contain less than 60 per cent of silica; the others are termed acid feldspars. Microcline is in composition nearly the same as orthoclase, but more generally contains sodium. It is, however, triclinic, though the cleavage angle varies but slightly from a right angle. Plagioclase is a general term often used to include all the triclinic feldspars except microcline. The feldspar species is one of the most important rock-making minerals.

FELSPATHOID GROUP.

This group includes several silicates of aluminum and an alkali metal, and in this respect is closely related to the feldspars. The group, however, shows different crystalline forms and physical properties, and in the arrangement of the silicates already referred to they do not fall in the same class as the feldspars. The more important species of the felspathoid group are given below.

Leucite, Amphigene, $KAl(SiO_3)_2$.

Isometric.—Leucite generally occurs in crystals, grains, or granular masses. The larger crystals often show inclusions of foreign matter symmetrically arranged.

Leucite is a silicate of aluminum and potassium, the latter being sometimes replaced in small quantity by sodium. Color usually dull white to dark gray; streak white. H. = 5.5 to 6. G. = 2.4 to 2.5. Brittle with conchoidal fracture. B.B. infusible, blue color with cobalt solution by ignition.

Generally found in recent eruptive rocks.

Nephelite, Nepheline, $K_2Na_6Al_8Si_9O_{34}$.

Hexagonal.—Occurs in white columnar crystals, six- or twelve-sided, also in granular masses and compact.

Nephelite is a silicate of potassium and sodium; its color is white or yellowish, massive varieties dark green, bluish gray, brown or red; luster vitreous to greasy. H. = 5.5 to 6. G. = 2.55 to 2.65. Brittle, with semi-conchoidal fracture. B.B. fuses to a colorless glass; gelatinizes with acids.

Nephelite occurs in both recent and ancient lavas, also in certain plutonic rocks.

Analcite, Analcime, $NaAl(SiO_3)_2+H_2O$.

Isometric.—Occurs in trapezohedra, also massive and granular; cleavage cubical but imperfect.

Analcite is a hydrous silicate of aluminum and sodium.

Color is white, sometimes shaded gray, green, yellow, or red; luster vitreous. H. = 5 to 5.5. G. = 2.2. Brittle, with semi-conchoidal fracture. Gives water in closed tube. B.B. fuses without difficulty to a colorless glass. Gelatinizes with hydrochloric acid.

Analcite is of frequent occurrence in cavities and seams in basic volcanic rocks, also in granite and gneiss.

Of the species here included in the felspathoid group, leucite and nephelite are richer in alkali than the feldspars, and analcite is a hydrous silicate.

KAOLINITE, $Al_2O_3,2SiO_2,2H_2O$.

Kaolinite is a hydrous silicate of aluminum resulting mainly from the decomposition of the feldspars. In the course of time rocks containing these minerals, such as granite, gneiss, etc., are disintegrated by aqueous and atmospheric agencies, the disintegration being due to the decomposition of the feldspars.

The feldspars in passing to kaolinite lose their alkaline and lime bases and part of their silica and take up water. It is thought that the carbon dioxide of the atmosphere and other organic acids are the essential agents in removing the bases from the minerals. With the change in the feldspar, the rock crumbles, and both the kaolinite and the associated constituents are eroded and carried away by the running waters and eventually deposited.

Kaolinite is ordinarily called kaolin. When pure it has a soapy feel, white color, and when touched to the tongue adheres strongly. When breathed upon it gives the well-known clay odor, it is infusible, not acted upon by acids under ordinary conditions, and yields water when heated in a closed tube.

Common clays contain more or less kaolinite mingled with eroded material from the parent rock and from the rocks over which the depositing waters have passed. The minerals most frequently mingled with the kaolinite are finely divided quartz, feldspar, and mica.

Common clays usually contain some of the compounds of iron, and if these are of such nature as not to withstand heat, the clay will generally burn red, due to the transformation of the iron compound into the red oxide. The ordinary alterable iron compounds in clay are the limonite, carbonate, or perhaps iron combined with some organic acid. If the iron be in some of the silicated forms, the clay does not change color by heat. The well-known cream-colored Milwaukee bricks are made of such clay.

The use of clay in brick-making is well known. If of good clay, brick is one of the best building-stones to resist heat. Porcelain is made of the purest kaolin, stoneware of the less pure varieties. Fire-bricks are generally made of a fine quality of clay, though they are sometimes composed of a large per cent of silica.

MAGNESIUM AND IRON SILICATES.

Talc, $3MgO,4SiO_2,H_2O$.

Talc is a hydrous silicate of magnesium and nearly always contains a little iron. Generally occurs in foliated masses with a pearly luster, readily peeling off in layers; masses also compact and of fine scales, occasionally granular and less often fibrous. Talc is usually of a greenish-white color, but varies to other shades of green and to nearly pure white. In the laminated variety H. = 1 to 1.5. The scales are flexible but not elastic. Yields water with difficulty when heated in closed tube. Infusible and not acted upon by acids. All varieties have a greasy feel.

There is a number of varieties of this mineral, of which the more important will be mentioned.

Talc.—This term is commonly limited to the more distinctly foliated varieties.

Steatite, Soapstone.—Fairly compact or finely granular in texture, usually greenish gray or gray.

French Chalk.—The white laminated variety, used for marking on cloth.

Indurated Talc.—An impure variety of a somewhat shaly texture, with hardness of 3 to 4.

Talc occurs in many of the States and in Canada. Pennsylvania furnishes the greater quantity of the steatite, though it is also mined in Virginia, North Carolina, and South Carolina. It is trimmed into slabs for various uses—as bath-tubs, laundry-tubs, frames to hot-air registers, etc. In the powdered form it is largely employed as a *filler* in mineral paints and in fire-retarding paints. Fibrous talc is extensively mined at Gouverneur, N. Y., and is largely used to give weight and filling in the manufacture of paper. This form passes under the name of *mineral pulp*. The powdered form is also used as a lubricant for machinery and for diminishing machinery friction generally. Boot-powder is composed of it.

Serpentine, $3MgO,2SiO_2,2H_2O$.

This mineral, like talc, is also a hydrous silicate of magnesium, but contains more water and less silica than talc. It generally occurs massive and compact and finely fibrous. Color is usually some shade of green, more often green tinged with yellow, though sometimes nearly white. Luster faintly resinous to oily. H. = 2.5 to 4; often has greasy feel, but less so than talc. Yields water readily when heated in closed tube, and changes color to brown.

Precious Serpentine.—When the color is a bright tint of yellow-green and the mineral translucent. When the mineral is opaque and the color dull it is *common* serpentine.

Chrysotile.—This is the finely fibrous variety and is largely used under the name of asbestus. This is the mineral that is, in this country, generally woven into fire-proof roofing, clothes, etc. Nearly all the chrysotile used in this country is imported from Canada, being called *asbestus*.

Verd Antique, *Ophiolite.*—This name is applied to a mineral composed of a mixture of serpentine and limestone. When polished it gives a marble, mottled, and often of much beauty. Serpentine itself gives a marble, but generally not so variegated as when calcite is present. Pennsylvania furnishes a serpentine which is used as a building-stone.

Chrysolite, Olivine, $(Mg,Fe)_2SiO_4$.

Chrysolite is the most important species of a group of silicates of the same name. It is an iron and magnesium silicate, color usually olive-green, but has different shades passing to a yellowish brown or red; streak uncolored, sometimes yellowish or brownish. Hardness is about the same as quartz. H. = 7.

Olivine is the most common variety of chrysolite; it has a dark olive-green or yellow-green color. It occurs very generally disseminated through basaltic rock, sometimes in masses.

Chlorite Group.

Chlorite is a general term applied to a group of minerals which are hydrous silicates of magnesium and aluminum, and in which iron and other metals are usually present in small quantity; less silica is present than in serpentine. There is a number of varieties of this group which differ slightly each from the other, so that one formula is not applicable to all the varieties. The chlorites are laminated and split readily into thin leaves, resembling the micas, from which they may be distinguished by the fact that the leaves are flexible but not elastic. A majority of the varieties is characterized by a green color. The term chlorite itself was formerly generally applied to these varieties, and is yet to a certain extent, but the varieties are now more usually distinguished by special names, as Pennine, Clinochlore, Ripidolite, Prochlorite, etc. When the term chlorite is used in the limited sense it refers to the dark-green varieties which occur foliated and massive and also in fine granular, almost compact forms and finely fibrous. H. = 1 to 2. Streak is whitish or slightly greenish, yields water in closed tube. Color due to the large per cent of iron present.

ACCESSORY MINERALS.

The term *accessory* is here applied to those minerals which are not present in sufficient quantity to be considered as essential ingredients of the rocks or mineral masses in which they occur. Their occurrence may to a certain extent be considered as fortuitous. Some of them are of slight industrial importance and others are of value as gems.

Beryl, Emerald, $Be_3Al_2(SiO_3)_6$.

Hexagonal.—The prevailing form of beryl is the hexagonal prism, sometimes massive.

Beryl is essentially a silicate of aluminum and beryllium (glucinum). There are several varieties of this mineral; some are pellucid, but they are generally some shade of yellow, green, or blue. Luster vitreous to resinous, streak uncolored. H.=7.5 to 8. G.=2.67 to 2.76. Infusible, though it changes color under the blowpipe. The common varieties with less delicate shades of color are all included under the name of *Beryl* simply; color supposed to be due to iron oxide. *Emerald* is of a rich green color; it contains a small per cent of chromium oxide, to which its color is generally ascribed. *Aquamarine* includes the transparent forms of very delicate shades of green or blue.

Fine specimens of beryl come from Siberia, Ceylon, Colombia, and Brazil; they have also been found at many places in the United States—in Maine, New Hampshire, and North Carolina, and several of the Western States. Very large ones have been obtained in the two States first named. Beryl in color and form often resembles apatite, but is much harder.

Garnet, $R_3''R_2'''(SiO_4)_3$.

Isometric.—Prevailing forms are the dodecahedron and trapezohedron. Also occurs massive and granular.

Garnet is a complex silicate which may contain two or more of the metals calcium, magnesium, aluminum, iron, and chromium, the varieties being due to the different proportions of these elements. Garnets vary much in color. Luster vitreous to resinous. H.=6.5 to 7.5. G.=3.1 to 4.3. The darker varieties may be fused without difficulty. The more important and common forms are the following:

Almandite, or *Almandine*.—Various shades of light red to brown. Those with clear color and considerable transparency are the *precious garnets.* Almandite is an iron-alumina garnet.

Essonite, or *Cinnamon-stone.*—An alumina-lime garnet of a cinnamon color.

Pyrope.—An alumina-magnesia garnet of a deeper red color than almandine, sometimes almost black. It is also called *precious garnet* when it is fairly transparent and has a pure color. Pyrope is frequently found in small rounded masses and grains.

Colophonite.—A lime-iron garnet, consisting of a mass of grains of a brownish-red to brownish-yellow color; has resinous luster and generally gives iridescence when turned in the light.

The different forms of garnet often occur disseminated through metamorphic rocks; are found in the gneiss rocks about West Point. In this class of rocks the garnets are usually almandine. The fine red garnets constitute the *carbuncle* of the ancients.

Garnets are found at many places. Ceylon is noted for its red garnets, but the richest gems come from Burmah. Garnets are found at many places in the United States. Fine specimens of pyrope abound in Arizona, New Mexico, Colorado, and other Western States, and are the so-called *Arizona rubies.*

In the formula given for garnet R'' represents a bivalent and R''' a trivalent metal.

Lapis Lazuli.

Isometric.—Usually massive. This mineral is a complex silicate of aluminum and sodium and contains copper, iron, sulphur, and chlorine. It has an azure-blue color and vitreous luster. Its color is thought to be due to sodium sulphide. When powdered it is dissolved by hydrochloric acid with separation of gelatinous silica. The finest specimens are much esteemed for making ornaments and for inlaid work. The powdered mineral was formerly used as a paint under the name of *ultramarine;* this color is now prepared artificially, and is very much cheaper than the natural paint.

Topaz, $Al(O,F_2))AlSiO_4$.

Orthorhombic.—Crystals commonly prismatic, generally differently modified at the two extremities, faces usually striated vertically; also massive in columnar aggregates, coarse or fine granular. Perfect cleavage parallel to base.

Topaz is a silicate of aluminum with part of the oxygen replaced by fluorine. Its color varies from yellow, through gray and white to shades of green, blue, or red; luster vitreous; streak white; brittle. H. = 8. G. = 3.4 to 3.6. B.B. infusible; not affected by acids, except partially by H_2SO_4. Distinguished by its hardness, infusibility, brilliant and easy basic cleavage.

Topaz most generally occurs in the acidic igneous rocks, as granite and rhyolite; also in metamorphic schists. It is frequently accompanied by fluorite, tourmaline, beryl, and apatite. The transparent and colorless varieties are used as gems, the pink crystals being most valuable.

Tourmaline, $R_{18}B_2(SiO_3)_4$.

Hexagonal.—Prism the prevailing form, with three (or some multiple of three) sides. Sides usually striated or channeled. Ends of crystals frequently unlike. Also occurs massive.

Tourmaline is a complex silicate, essentially of aluminum and boron, but with several other bases, the proportions of which are believed to give the many different varieties.

The common forms are usually brown or some shade of black, but there are various shades of red, yellow, and green. Generally translucent to opaque. H. = 7.5. It is brittle, fractured surface uneven. Tourmaline when in crystals is distinguished by the number of faces being some multiple of three. Its hardness is usually sufficient to distinguish the dark varieties from resembling minerals.

Rubellite is the red tourmaline.

Indicolite is the blue tourmaline.

Tourmaline is also found in white, blue, and green colors.

This mineral usually occurs penetrating crystalline rocks; it is not an essential constituent. The fine specimens are highly prized as gems.

Specimens that rival any in the world in beauty have been found in Maine, at Paris and Hebron. Fairly fine specimens have been found in many other States of the Union. Ceylon and Brazil have also given celebrated crystals.

Rutile, TiO_2.

Tetragonal.—Often in twinned crystals; in prisms of four, eight, or more sides, faces of prisms usually striated vertically; often in fibrous acicular aggregates penetrating quartz; sometimes massive.

Rutile is the dioxide of titanium, TiO_2. Its color is reddish brown to red, passing through violet, bluish to black, sometimes yellowish; luster adamantine or metallic; streak pale brown. H. = 6 to 6.5. G. = 4.2 to 4.3.

It occurs in the more distinctly crystalline rocks, both metamorphic and plutonic.

It is frequently found penetrating quartz in acicular needles or hair-like fibers; polished stones of this kind are sometimes very beautiful and constitute what the French have called "flèches d'amour."

Corundum, Al_2O_3.

Rhombohedral.—Generally in combinations of six-sided prisms and acute pyramids, often with uneven and irregular surfaces, also massive and fine or coarse granular.

Corundum is the sesquioxide of aluminum; the uncrystallized varieties usually show a small per cent of iron.

It is sometimes colorless, but generally some shade of blue, red, or yellow, massive forms often brown or black; streak uncolored; luster adamantine to vitreous, sometimes pearly on bases. H. = 9. G. = 3.9 to 4.1. B.B. infusible.

Corundum is distinguished by its great hardness, infusibility, high specific gravity, and its luster.

Sapphire or oriental ruby are the names applied to clear crystals of fine colors; blue is the true sapphire color; true ruby is red, highly prized as a gem.

Corundum is the name applied to the dull irregularly colored crystals and masses as well as to the species.

Emery includes the granular varieties, usually of dark color from presence of magnetite.

Corundum, the species, occurs in crystalline rocks, both plutonic and metamorphic. Burmah and Ceylon are celebrated for their rubies and sapphires; many fine gems have been secured in this country, the finds in North Carolina and Montana being most numerous. Corundum is mined in North Carolina, and emery in Massachusetts and New York. Corundum and emery are crushed to powders of different fineness and used for polishing.

Diaspore is the hydrous oxide of aluminum, Al_2O_3,H_2O; it is usually found with corundum.

Bauxite, Beauxite, $Al_2O_3,2H_2O$.

Bauxite is a clay-like mineral found also in grains, concretions, and massive. It is a hydrated aluminum oxide, $Al_2O_3,2H_2O$; iron is frequently present, replacing some of the aluminum.

Its color varies from white through gray to yellow and brown; in its purer forms it is largely used in France in the preparation of the alums and also in the manufacture of aluminum.

Turquois, $2Al_2O_3,P_2O_5,5H_2O$.

Turquois is a hydrous aluminum phosphate. It has a bluish-green color, vitreous to waxy luster. H. = 6. G. = 2.6 to 2.8. When heated before the blowpipe it gives off water and turns brown; infusible, but dissolves quietly in hydrochloric acid. It often contains from one to five per cent of copper, also a little iron and manganese.

It has been found in New York, Arizona, and Nevada in this country, and in several places abroad. It is susceptible of high polish and is used as a gem.

Monazite $(Ce,La,Di)PO_4$.

Monazite is a phosphate of a group of rare metals. It has come into considerable prominence in recent years as the source of cerium oxide and other infusible earths. It contains cerium, lanthanum, didymium, thorium, and silicon, with traces of erbium and ytterbium. It is now found in greatest quantity in rolled sands in Brazil; under similar conditions considerable quantity has been obtained from North Carolina.

Spinel, MgO,Al_2O_3.

Isometric.—Occurs only in crystals, usually in octahedrons.

Spinel is an aluminate of magnesium (MgO,Al_2O_3); the magnesium is often partly replaced by iron or manganese, and the aluminum by iron or chromium. The color is occasionally white, but more generally some shade of red, brown, blue, or green; streak white; luster vitreous. H. = 8. G. = 3.5 to 4.1. B.B. infusible. Its most evident distinctions are its hardness, infusibility, and octahedral form.

Spinel occurs imbedded in granular limestone, serpentine, and other metamorphic rocks; also in volcanic rocks. The spinels of fine color are prized as gems; the red spinel is the common ruby of jewelry; it often resembles the true ruby (corundum), but the latter never occurs in octahedrons.

Chrysoberyl, BeO,Al_2O_3.

Orthorhombic.—Occurs in short columnar or thick tabular crystals. Often forms compound crystals, like irregular six-pointed stars.

Chrysoberyl is an aluminate of beryllium. Its color varies through several shades of green, occasionally raspberry by transmitted light, pleochroic; streak uncolored;

luster vitreous. H. = 8.5. G. = 3.5 to 3.8. B.B. alone infusible.

Its hardness, infusibility, tabular crystals and high specific gravity, taken in connection with its greenish color, are its most evident characteristics which distinguish it from resembling minerals.

Chrysoberyl is found in this country in Connecticut, Maine, New Hampshire, and New York. The finest crystals make beautiful gems. Two varieties of the species are:

Alexandrite, which is an emerald-green chrysoberyl, supposed to be colored by chromium.

Cat's-eye has a greenish color and exhibits chatoyant effects.

MINERAL COAL.

This important substance is essentially composed of carbon, hydrogen, oxygen, a little nitrogen, and sulphur, together with some earthy matter which gives the ash. There may also be a little moisture present and sometimes occluded hydrocarbons, but these are accidents in the coal. Coal occurs massive and uncrystallized, is from brown to black in color. H. = 1.5 to 2.5.

Perfect coal when pure may be divided into two general classes, Anthracite and Bituminous, depending upon the per cent of volatile ingredients present.

Anthracite.—This coal has a high luster, between vitreous and metallic, color glistening-black, often iridescent. H. = 2 to 2.5. G. = about 1.6. Often gives conchoidal fracture; it burns with a pale blue flame. In this coal 90 to 95 per cent of the combustible matter is fixed carbon. It contains from 5 to 12 per cent of earthy matter, which is left as ash in burning. The volatile matter in the coal ranges from three to seven per cent. It is sometimes called *stone-coal* or *glance*.

Bituminous Coal.—This coal has a dull or slightly resinous luster. H. = 1.5 to 2. G. = about 1.3. It burns with a smoky yellow flame.

In this coal the combustible matter contains from 45 to 85 per cent of fixed carbon, from 15 to 55 per cent of volatile matter; there is present from 1 to 8 per cent of earthy matter. When the combustible matter contains from 80 to 85 per cent of fixed carbon and 15 to 20 per cent of volatile matter it is called *semi-bituminous.* When the volatile matter rises to 30 or 40 per cent it is full bituminous, and when beyond this per cent it is highly bituminous.

Common bituminous coals are generally divided into two kind, caking and non-caking. Caking coal softens and becomes pasty in the fire, so that pieces in contact adhere, forming a solid mass. Non-caking coal burns freely without softening. These varieties cannot be distinguished by external characters, nor has the chemical difference between them been determined.

Cannel Coal.—A highly bituminous variety, of compact texture, with little luster, and conchoidal fracture. It burns brightly with much flame. It is very valuable for making gas as well as for open-grate burning.

Brown Coal.—An imperfectly formed coal, in which the conversion of the vegetable matter into coal has not been completed. It contains from 15 to 35 per cent of oxygen. It is of a brownish-black or black color, streak brown. When the woody structure is still clearly visible it is called *lignite.*

Jet.—This is a very black, compact variety of brown coal. It takes a high polish and is used for cheap ornaments.

In addition to these varieties a *native coke* has been found in Virginia, probably resulting from the action of eruptive rocks on bituminous coal. It resembles common coke, but is more compact.

All the varieties of coal may contain greater or less proportions of mineral impurities, giving other divisions depending upon the degree of impurity. If the ash does not amount to more than 8 or 10 per cent in anthracite, the coal may be considered as pure. The pure anthracite gives more ash than the pure bituminous, which was to be expected, as the former results from a condensation of the latter. The mineral matter making up the ash of pure coal comes from the plants out of which the coal was formed. It consists mainly of silica, alumina, oxide of iron, lime in small quantity, and a little potash and magnesia.

The origin of coal and the location of the beds are given in Geology.

TABLES FOR USE IN THE DETERMINATION OF MINERALS.

THESE tables have been constructed with the view of facilitating the determination of the minerals of the text. The order of arrangement and the directions for use of the tables are intended to develop and improve the powers of comparison and observation, as well as to bring about a correct determination of the mineral species.

The minerals are classified under three general subdivisions, A, B, and C.

A includes all the minerals with a distinctly metallic luster.

B includes all minerals that have not a distinctly metallic luster, but have a colored streak.

C includes all minerals with an unmetallic luster and an uncolored streak.

In the first subdivision (A) the minerals are again classified according to color; in the second (B) according to streak; and in the third (C) according to hardness; and in each of these smaller classes the minerals are arranged in the order of their hardness.

The tables consist of two principal parts; in the first are given the external characteristics of the minerals; in the second are described the effects of acids and of heat. The former should always be examined first. Some specimens can be determined from external characteristics alone, and many others can be limited to a small number of species. The method of procedure in the determination of minerals should be as follows:

Take up the specimen and note its *luster*, whether metallic, semimetallic, or unmetallic; if metallic, note its *color;* if semimetallic or unmetallic, determine its *streak.* Finally, determine the *hardness* of the specimen. Now try to place it as rapidly as possible in the table: in A by its color first, then by its hardness; in B by its streak first, then by its hardness; in C by its hardness alone. When the specimen under consideration is thus approximately determined, see if the other characters given in its description correspond to what is observed in the specimen. This is all that can be accomplished by the use of the first part of the tables; for further verification the directions in the second part of the tables must be followed and the effects of acids and heat observed. For a proper use of the tables the student must be familiar with the contents of Chapter II, which precedes, and must also have instruction and assistance in the use of the appliances of the mineralogical laboratory.

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Streak.	Hardness and Tenacity.	Remarks.
I.—RED OR BROWN.					
1	**Copper**	Copper red	Copper red	H.=2.7 Malleable	Crystals isometric; occurs usually massive and in plates or strings penetrating the gangue; clings to a file. G.>8
2	**Proustite**	Scarlet vermilion	Scarlet, vermilion, sometimes orange yellow	H.=2.5 Brittle	Generally found with other ores of silver, especially with pyrargyrite, cerargyrite, and native silver
3	**Bornite** (Erubescite)	Brownish red	Dark grayish black	H.=3.0 Brittle	Color decidedly more red than that of chalcopyrite
4	**Cuprite**	Red to brown	Brownish red	H.=3.5 to 4 Brittle	Sometimes in octahedrons, but often massive, granular, and earthy; frequently contains iron oxide. G.=5.8 to 6.1
5	**Rutile**	Red to brownish red	Gray to yellowish brown	H.=6 to 6.5 Brittle	Distinguished from tin ore by not giving tin with soda on charcoal
6	**Cassiterite**	Brown to reddish brown	Gray to light brown	H.=6 to 7 Brittle	Practically the only ore of tin. G.=6.8 to 7.1
II.—YELLOW.					
7	**Gold**	Golden yellow	Yellow	H.=2.5 Malleable	Crystals isometric, occurs usually in grains, strings, or plates in a gangue of quartz, the latter being often discolored by iron. Clings to a file. G.>15
8	**Chalcopyrite**	Bronze yellow	Greenish black	H.=4.2 Brittle	Often tarnished and iridescent, sometimes green on surface; purer varieties have deeper color

No.	Composition.	Action of Acids.	Effects of Heating.
1	Cu	Acted upon by HNO_2; addition of ammonia to diluted solution gives blue color	
2	Ag_3AsS_3	Acted upon by HNO_3 with separation of sulphur	On charcoal fuses easily and gives odors of sulphur and arsenic oxide; white sublimate in open tube. With soda and reducing flame, bead of silver
3	Cu_3FeS_3	After careful roasting partially acted upon by HNO_3, and addition of ammonia to diluted solution gives blue color	Fuses readily to a black magnetic globule
4	Cu_2O	Acted upon by HNO_3 and diluted solution gives blue color with ammonia	Fuses easily in forceps and colors flame green; yields bead of copper on charcoal
5	TiO_2	No action	B. B. infusible alone
6	SnO_2	Not perceptibly acted upon by acids	B. B. alone infusible; with soda on charcoal reduced to metallic tin and gives white coating; requires long blowing
7	Au	No action	Fuses without difficulty, but no action with fluxes
8	$CuFeS_2$	After careful roasting partially acted upon by HNO_3, and addition of ammonia to diluted solution gives blue color	Carefully roasted and mixed with soda and heated on charcoal, gives a globule of copper

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Streak.	Hardness and Tenacity.	Remarks.
II.—YELLOW.					
9	**Pyrrhotite**	Bronze yellow	Grayish black	H.=3.5 to 4 Brittle	Usually slightly magnetic. Composition varies, but conforms to the general formula Fe_nS_{n+1}
10	**Pyrite**	Brass yellow	Brownish black	H.=6 Brittle	Isometric; sometimes massive, but generally in crystals disseminated through rocks. Sides of cubes often striated at right angles to each other. Harder than chalcopyrite
III.—WHITE.					
11	Silver	Silver white	Silver white	H.=2.5 Malleable	Isometric; occurs in strings or plates disseminated through the gangue; clings to a file; generally tarnished on exposed surface. G.=10.5
12	Arsenopyrite (Mispickel)	Tin-white to grayish	Grayish black	H.=5.5 Brittle	Hard, strikes fire with steel and emits odor of garlic. G.=6
IV.—GRAY.					
13	**Graphite**	Iron gray	Black, shining	H.=1 Friable	Feels greasy, soils paper; micaceous or scaly, rarely compact. Often disseminated through rock in fine scales. G.=2.25
14	**Molybdenite**	Lead gray, inclining to black	Bluish gray, shining	H.=1.5 Friable	Feels greasy; occurs thin, tabular, or scaly; soils paper. G.>4
15	**Stibnite**	Lead gray	Dark grayish black	H.=2.5 Brittle	Burns in flame of candle; slightly sectile. Principal ore

No.	Composition.	Action of Acids.	Effects of Heating.
9	Fe_7S_8	Acted upon by HCl with liberation of hydrogen sulphide	B. B. fuses easily to a black magnetic globule
10	FeS_2	Roasted first; slightly acted upon by HCl; addition of K_4FeCy_6 gives blue precipitate	B. B. sulphurous odor and fuses to magnetic globule
11	Ag	Acted upon by HNO_3; addition of HCl gives a white curdy precipitate, soluble in ammonia. Copper plate placed in nitric solution becomes coated with silver	
12	FeAsS		On charcoal alliaceous odor, giving white coating on coal; leaves magnetic globule. In closed tube gives a black sublimate of arsenic; sometimes red and yellow sublimates
13	C	No action	Mixed with niter and heated in closed tube, deflagrates
14	MoS_2	Acted upon by HNO_3, giving a grayish residue of molybdic oxide	In forceps colors flame green; finely powdered, gives sulphurous odor in open tube
15	Sb_2S_3	When pure, acted upon by HCl; HNO_3 causes a separation of sulphur and antimony pentoxide	Fuses easily and gives white fumes and volatile white coating on charcoal

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Streak.	Hardness and Tenacity.	Remarks.
IV.—GRAY.					
16	Argentite	Blackish lead gray	Blackish lead gray	H.=2.5 Malleable	Can be cut like lead when massive; is usually finely disseminated through the gangue. Most common ore of silver. G.=7.3
17	Galenite	Bluish gray	Dark gray	H.=2.7 Friable	Is chief ore of lead. Often has characteristic cubical cleavage which is easily obtained. Also occurs in granular masses; very often contains some silver sulphide. The ore becomes more micaceous as the silver sulphide increases. G.>7
18	Chalcocite	Blackish lead gray	Dark lead gray to black	H.=2.5 to 3 Brittle	Somewhat resembles argentite, but is not sectile
19	Tetrahedrite	Dark gray to black	Dark gray to black, and inclining to red	H.=3 to 4 Brittle	Often a valuable ore of silver, the copper being in part replaced by silver
20	Tennantite	Blackish lead gray to black	Dark gray to black, sometimes reddish	H.=3 to 4 Brittle	Closely related to tetrahedrite, the antimony being wholly or partly replaced by arsenic
21	Hematite Specular iron ore	Between iron black and dark steel gray	Cherry red, brownish red	H.=6.5 Brittle	Hexagonal; occurs compact, scaly, fibrous; sometimes slightly magnetic. G.=4.9 to 5.3
V.—BLACK.					
22	Graphite	Iron black	Black, shiny	H.=1 Friable	Other characteristics the same as the gray variety, 13 above

No.	Composition.	Action of Acids.	Effects of Heating.
16	Ag_2S	Acted upon by HNO_3, with separation of sulphur; addition of HCl gives a white curdy precipitate, soluble in ammonia. Copper plate placed in nitric solution becomes coated with silver	Sulphurous odor in open tube; fuses easily on charcoal and gives globule of silver
17	PbS	Acted upon by HNO_3, with separation of sulphur and formation of some lead sulphate; addition of ammonium sulphide gives black precipitate	On charcoal decrepitates; sulphurous odor; gives yellow coating on coal and yields globule of lead
18	Cu_2S	Acted upon by hot HNO_3, with separation of sulphur; solution coats knife blade with copper	On charcoal powder gives sulphurous odor and leaves globule of copper
19	$Cu_8S_7Sb_2$	Acted upon by HNO_3, and addition of ammonia to dilute solution gives blue color. (Copper test)	Fuses easily on charcoal, giving sulphurous odor and white sublimate; a globule of copper after long heating with soda
20	$Cu_8S_7As_2$		
21	Fe_2O_3	Acted upon by HCl; addition of K_4FeCy_6 to dilute solution gives blue precipitate	Infusible, but easily becomes magnetic on charcoal
22	C	No action	Same as 13 above

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Streak.	Hardness and Tenacity.	Remarks.
V.—BLACK.					
23	**Argentite**	Grayish black	Gray black	H.=2 to 2.5 Malleable	Same as 16 above
24	**Pyrolusite**	Iron black to bluish black	Black, bluish black, sometimes shining	H.=2 to 2.5 Brittle	The common ore of manganese ; occurs compact to unconsolidated. G.=4.8
25	**Pyrargyrite**	Black, red by transmitted light	Purplish red	H.=2 to 2.5 Brittle	Occurs with other ores of silver. G.=5.8
26	**Stephanite**	Black to iron black	Black to iron black	H.=2 to 2.5 Brittle	Brittle with uneven fracture. G.>6
27	**Chalcocite**	Grayish black	Grayish black	H.=2.5 to 3 Brittle	Often tarnished blue or green. G.=5.5 to 5.8
28	**Melaconite**	Black to gray	Black	H.=3 to 4 Brittle to earthy	Black masses and concretions along with other ores of copper. G.=5.8 to 6.2
29	**Chromite**	Black, iron black, brown black	Yellow, gray or dark brown	H.=5 to 5.5 Brittle	Generally magnetic, sometimes strongly so. G.=4.3
30	**Magnetite**	Iron black	Black	H.=5.5 Brittle	Isometric ; granular or compact ; black streak and magnetic property usually distinguish it. G.>5
31	**Franklinite**	Iron black	Brownish black	H.=5.5 to 6.5 Brittle	Isometric. Resembles magnetite, but generally has more earthy black color, usually feebly magnetic
32	**Hematite**	Between iron black and dark steel gray	Cherry red, brownish red	H.=6.5 Brittle	Hexagonal. Occurs compact, scaly, fibrous, sometimes slightly magnetic. G.=4.9 to 5.3

No.	Composition.	Action of Acids.	Effects of Heating.
23	Ag_2S	Same as 16 above	Same as 16 above
24	MnO_2	Acted upon by HCl with evolution of chlorine	Amethystine bead with borax in oxidizing flame
25	Ag_3SbS_3	Acted upon by HNO_3, with separation of sulphur and antimony oxide. Copper plate in nitric solution becomes coated with silver	On charcoal fuses easily with spurting, giving white coating of antimony oxide. With soda in reducing flame gives silver; red sublimate in open tube, white in closed
26	Ag_5SbS_4	Acted upon by HNO_3, with separation of sulphur. Copper plate in nitric solution becomes coated with silver	On charcoal gives sulphurous odor; fumes and coating of antimony. With soda a globule of silver
27	Cu_2S	Same as 18 above	Same as 18 above
28	CuO	Acted upon by HNO_3, and gives copper test with ammonia as in 4 and 8	Gives copper with soda on charcoal
29	$FeCr_2O_4$	Not acted upon	Gives emerald green color to bead of borax and salt of phosphorus
30	Fe_3O_4	Acted upon by HCl. Gives iron test, same as 21 above	B. B. infusible
31	Oxides of iron, zinc, and manganese	Acted upon by HCl with occasional evolution of chlorine. Gives iron test as in 21	Amethyst bead with borax, bluish green bead with soda
32	Fe_2O_3	Gives iron test with K_4FeCy_6, same as 21	Same as 21

A.—MINERALS WITH EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Streak.	Hardness and Tenacity.	Remarks.
V.—BLACK.					
33	**Rutile**	Black	Gray to light brown	H.=6 to 6.5 Brittle	Distinguished from tin ore by not yielding tin with soda on charcoal. G.=4.2
34	**Cassiterite**	Black	Gray to light brown	H=6 to 7 Brittle	Principal ore of tin. G.=6.8

B.—MINERALS WITHOUT EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
I.—STREAK GRAY, BLACK, OR GREEN.					
35	**Graphite**	L. Semi-metallic C. Iron black to dark gray	Black or dark gray	H.=1 Friable	Luster sometimes dull or earthy black, other characters same as 13
36	**Coal** (Bituminous)	L. Resinous to vitreous; sometimes silky C. Black	Grayish black Brownish black	H.=2.5 Friable Brittle	Usually shows lamination; the cannel coal is compact with large conchoidal fractures. Decomposing pyrite in coal produces a gray or yellowish powder with inky taste. G.=1.03
37	**Melaconite** Tenorite	L. Unmetallic C. Black	Black	H.=2.5 Friable	A black powder or massive and compact; often stained greenish; soils fingers when massive or pulverulent. G.>5.5
38	**Coal** (Anthracite)	L. Semi-metallic; vitreous C. Black	Black	H.=2.75 Very brittle	Hard, with high luster; breaking with small conchoidal fracture. G.=1.6
39	**Amphibole** (Hornblende	L. Vitreous C. Black to greenish black	Dark gray to greenish gray	H.=5–6 Tough Brittle	Monoclinic; crystals long and slender, cleavage oblique, 124°; massive specimens have black color, common luster, are often made up of bladed crystals intersecting in all directions. G.=3.3

No.	Composition.	Action of Acids.	Effects of Heating.
33	TiO_2	No action	Infusible alone
34	SnO_2	Not perceptibly acted upon by acids	B. B. alone infusible; with soda on charcoal yields metallic tin and gives white coating; requires long blowing

METALLIC LUSTER; STREAK COLORED.

No.	Composition.	Action of Acids.	Effects of Heating.
35	C	No action	Thoroughly mixed with niter deflagrates in closed tube
36	Carbon with some hydrogen and oxygen	No action	In forceps burns with yellow flame. Thoroughly mixed with niter, deflagrates in closed tube
37	CuO	Acted upon by HNO_3; addition of ammonia to diluted solution gives blue color	Gives copper with soda on charcoal. Moistened with HCl, colors B. B. pipe flame azure blue
38	Carbon		Burns without flame; gives no odor. Thoroughly mixed with niter, deflagrates in closed tube
39	Magnesium, calcium, iron and aluminum silicate		Anhydrous; fusible with intumescence in forceps or on charcoal

EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
I.—STREAK GRAY, BLACK, OR GREEN.					
40	**Pyroxene** (Augite)	L. Vitreous C. Grayish black, greenish black	Dark gray, greenish gray	H.=6 Tough Brittle	Monoclinic; crystals short and stout, cleavage nearly rectangular; granular varieties are called coccolite; massive specimens are often composed of stout crystals with ends projecting on the surface. G.=3.4
41	**Franklinite**	L. Semi-metallic to dull vitreous C. Black	Black	H.=6.25 Brittle	Isometric; occurs in octahedrons; usually slightly magnetic due to Fe_3O_4. Often occurs with red zincite
42	**Magnetite**	L. Semi-metallic, vitreous C. Black	Black	H.=6.25 Brittle	Isometric; in small octahedrons; usually in granular masses; magnetic, heavy. G.>5
II.—STREAK BROWN.					
43	**Lignite**	L. Dull, generally; if shining, resinous C. Brown, black	Brown, verging on black	H.=2.5 Friable	Sometimes laminated; generally showing woody structure; often earthy; peat contains rootlets; air-dried contains considerable water. G.=1.2
44	**Cuprite** (impure)	L. Common C. Brown	Brown	H.=4 Brittle	Impure with clay; often stained green on surface. G.>4
45	**Sphalerite**	L. Resinous Adamantine Vitreous C. Black, brown	Yellow to brown	H.=4 Brittle	Isometric; cleavage distinct. G.=4

No.	Composition.	Action of Acids.	Effects of Heating.
40	Magnesium, calcium, iron, and aluminium silicate		Anhydrous; fusible with intumescence in forceps or on charcoal
41	Oxide of Zn, Fe, and Mn	Same as for 31	Becomes magnetic; when fused with soda and some niter on platinum foil the manganese present usually colors the mass green
42	Fe_3O_4	Acted upon by HCl; after dilution addition of K_4FeCy_6 gives blue precipitate	Borax bead is bottle-green in R. F., in O. F. it is yellow while hot, colorless when cold
43	Carbon, hydrogen, oxygen		Burns with yellow flame in forceps; gives off empyreumatic odors. Mixed with niter deflagrates in closed tube
44	Cu_2O	Acted upon by HNO_3; after dilution, addition of ammonia colors solution blue	Fuses easily in forceps and colors flame green. Yields bead of copper on charcoal
45	ZnS	Effervesces in hot HCl with evolution of H_2S	Pulverized and heated on charcoal gives sulphurous odor; slight zinc fumes; coating near assay which is yellow while hot, white on cooling. In open tube, very little (if any) sublimate of sulphur; slight odor of SO_2 and an acid reaction

EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
II.—STREAK BROWN.					
46	**Limonite**	L. Vitreous, resinous, silky, pearly C. Brown	Yellowish brown	H.=5.5 Brittle	Usually earthy or botryoidal, with a fibrous texture. G.>4
47	**Amphibole** (Basaltic hornblende)	L. Common C. Black	Yellowish brown, gray to light brown	H.=5.5 Brittle	Monoclinic; cleavage of crystals oblique 124°; massive specimens often are made up of bladed crystals intersecting in all directions. G.=3.3 When of composition given sometimes called basaltic
48	**Cassiterite**	L. Adamantine C. Brown to black	Gray to light brown	H.=6.5 Brittle	Principal tin ore. G.=6.8
49	**Rutile**	L. Adamantine C. Reddish brown to red, black	Light brown	H.=6 to 6.5 Brittle	Very like tin ore, distinguished as stated in 33
III.—STREAK RED.					
50	**Hematite** (Red chalk)	L. Common C. Dark red	Brownish red	H.=2 Friable	Massive, pulverulent, or compact; earthy; rather light
51	**Cinnabar**	L. Adamantine C. Cochineal red	Scarlet	H.=2 to 2.5 Friable	Massive granular, glistening in specks; earthy when impure; volatile. G. from 3 to 8, > 8 when pure

No.	Composition.	Action of Acids.	Effects of Heating.
46	$2Fe_2O_3,3H_2O$	Acted upon by HCl; after dilution addition of K_4FeCy_6 gives blue precipitate	Gives off much water easily in closed tube. Borax bead is bottle green in R. F.; in O. F. yellow while hot, colorless cold. On charcoal becomes black and magnetic
47	Magnesium, calcium, iron, and aluminum silicate		Anhydrous. In forceps or on charcoal fuses with intumescence
48	SnO_2	Not perceptibly acted upon by acids	B. B. alone infusible; with soda on charcoal yields metallic tin and gives white coating; requires long blowing
49	TiO_2	Not acted upon	Infusible alone
50	Fe_2O_3	Slightly acted upon by HCl; addition of K_4FeCy_6 to dilute solution gives blue precipitate	On charcoal becomes magnetic if not too impure. Often gives off water in closed tube, due to clay present
51	HgS	Not acted upon by either nitric or hydrochloric acid: attacked by aqua regia with separation of sulphur	Heated in closed tube with sodium carbonate gives sublimate of mercury in small globules; alone gives a black sublimate, wholly volatile when pure. In open tube gives sulphurous odor

EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
III.—STREAK RED.					
52	**Proustite**	L. Adamantine to dull C. Scarlet vermilion	Scarlet vermilion	H.=2 to 2.5 Brittle	Generally found with other ores of silver. See 2, G. =5.6
53	**Pyrargyrite**	L. Adamantine to dull C. Black to deep red	Purplish red	H.=2.5 Brittle	Occurs with other ores of silver. G.=5.8
54	**Cuprite**	L. Adamantine, semi-metallic, common C. Carmine red, reddish lead gray	Brownish red	H.=4 Brittle	Cleavage distinct; often impure from clay; copper ores are often stained green on the surface. G. =.5.8 to 6.1
55	**Hematite**	L. Common, semi-metallic C. Dark red. Partly steel gray	Brownish red	H.=5 (variable) Brittle	Massive, granular, fibrous, lenticular, pulverulent, rarely botryoidal. G.>4
IV.—YELLOW.					
56	**Limonite** (Yellow ocher)	L. Common C. Yellow	Yellow	H.=1 Friable	Usually earthy, containing much clay; very light
57	**Sulphur**	L. Resinous, adamantine C. Sulphur yellow, grayish yellow	Straw yellow	H.=2 Brittle Friable	G.=2

No.	Composition.	Action of Acids.	Effects of Heating.
52	Ag_3AsS_3	Acted upon by HNO_3, with separation of sulphur	On charcoal fuses easily and gives odors of sulphurous and arsenic oxides. White sublimate in open tube. With soda and reducing flame bead of silver
53	Ag_3SbS_3	Acted upon by HNO_3, with separation of sulphur. Copper plate in nitric solution coated with silver	On charcoal fuses easily, with spurting, giving white coating of antimony oxide. With soda in reducing flame gives silver; red sublimate in closed tube, white in open
54	Cu_2O	Acted upon by HNO_3; addition of ammonia to dilute solution gives blue color	B. B. colors flame green and fuses readily, yielding metallic copper on charcoal
55	Fe_2O_3	Acted upon by HCl; addition of K_4FeCy_6 to dilute solution gives blue color	Anhydrous; becomes magnetic on charcoal
56	$2Fe_2O_3,3H_2O$	Acted upon by HNO_3; addition of K_4FeCy_6 to dilute solution gives blue precipitate	Becomes magnetic, if not too impure. Gives much water easily
57	S		Burns with blue flame and sulphurous odor

EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
IV.—YELLOW.					
58	**Cinnabar** (impure)	L. Common C. Yellowish red, cochineal red	Yellow	H.=2.25 Friable	Massive granular, glistening in specks; earthy, containing clay
59	**Sphalerite**	L. Resinous, adamantine C. Gray, brown	Light yellow to brown	H.=4 Brittle	Isometric; cleavage of crystals eminent; massive Missouri blende is glistening on a fresh surface; often contains iron. G.=4
60	**Siderite**	L. Vitreous to pearly C. Yellow, yellowish gray to yellowish brown	Pale yellow, brown when weathered	H.=4 Brittle	Rhombohedral; crystals often curved; often brown or black by weathering. G.=4
61	**Zincite**	L. Adamantine C. Red, orange, brown	Orange yellow, brownish yellow	H.=4 Brittle	Cleavage distinct, often in laminated aggregations; occurs with Franklinite. G.>4
62	**Limonite**	L. Common, silky C. Brown	Brownish yellow, ocher yellow	H.=5.5 Brittle	Usually earthy or botryoidal, with a fibrous texture; bog ore is sometimes loose, porous and earthy. G.>4
63	**Amphibole** (Basaltic hornblende)	L. Common C. Brownish black	Grayish yellow, ocher yellow	H.=5.5 Brittle	Monoclinic; cleavage oblique, 124°; crystals usually long and slender, often acicular or bladed; massive specimens are nearly black and sometimes made up of bladed crystals intersecting in all directions. When of composition given sometimes called basaltic hornblende

No.	Composition.	Action of Acids.	Effects of Heating.
58	HgS	Not acted upon by either nitric or hydrochloric acid. Attacked by aqua regia with separation of sulphur	Mixed with soda and heated in closed tube gives small globules of mercury on side of tube; alone gives a black sublimate. In open tube gives sulphurous odor
59	ZnS	Acted upon by HCl, producing effervescence, evolving H_2S	On charcoal sulphurous odor, zinc fumes; coating (near assay) which is yellow while hot, becoming white on cooling
60	$FeCO_3$	When powdered, hot HCl acts upon it, producing effervescence; addition of K_4FeCy_6 to dilute solution gives blue precipitate	Blackens and becomes magnetic in reducing flame
61	ZnO	Acted upon by acids	On charcoal, zinc fumes; coating (near assay) which is yellow while hot, becoming white on cooling
62	$2Fe_2O_3,3H_2O$	Acted upon by acids; addition of K_4FeCy_6 to dilute solution gives blue precipitate	Becomes magnetic in reducing flame; gives much water in closed tube
63	Magnesium, calcium, iron, and aluminum silicate		Anhydrous; on charcoal or in forceps fuses with intumescence

EXTERNAL CHARACTERISTICS.

V.—STREAK GREEN.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
64	**Chlorite**	L. Common, pearly C. Dark green	Grayish green	H.=2.5 Friable	Schistose in structure; often earthy by weathering; its fracture is micaceous, compact, or earthy; cleavage eminent, folia flexible but not elastic
65	**Serpentine** (impure)	L. Resinous (weak) C. Green, yellow, and sometimes white; rarely dark	Grayish green	H.=3 (variable) Friable Brittle	Amorphous; massive; when impure it is earthy, when pure its fracture is splintery; unctuous feel; when breathed upon smells bitter; often mixed with calcite
66	**Chrysocolla**	L. Vitreous to earthy, resinous C. Green	Bluish green to white when pure	H.=2.4 to 3 Friable Brittle	Amorphous; often reniform; compact in texture and fracture; accompanies other ores of copper, especially malachite; seldom pure
67	**Malachite**	L. Vitreous, pearly, silky C. Emerald green	Emerald green, paler than color	H.=3.5 Brittle	Often reniform; compact, fibrous, or earthy. G.=4
68	**Crocidolite**	L. Silky to dull C. Lavender blue or leek green	Same as color	H.=4 Fibers slightly elastic	Opaque
69	**Pyroxene** (Common augite)	L. Common C. Blackish green	Grayish green	H.=5.5 Brittle	Monoclinic; crystals short and stout, cleavage distinct, nearly rectangular; usually massive granular or composed of stout crystals with ends projecting on surface

No.	Composition.	Action of Acids.	Effects of Heating.
64	Hydrous, magnesium, iron, and aluminum silicate		Gives off water readily; does not change color
65	Hydrous, magnesium silicate	H_2SO_4 and HCl act upon it with a separation of silica	Gives off much water very readily; color changes to brown
66	Hydrous, copper silicate	Acted upon slightly by HNO_3; addition of ammonia to dilute solution gives blue color. In HCl decomposes with separation of SiO_2 without gelatinization	Gives off much water readily
67	Hydrous, copper carbonate	Acted upon by HNO_3; diluted, addition of ammonia colors solution blue. Effervesces with acids	B. B. decrepitates and blackens; colors flame green; gives off much water easily
68	Iron and sodium silicate; a form of asbestos	Not acted upon by acids	In closed tube gives a little water. B. B. fuses to a black magnetic glass, coloring flame yellow
69	Magnesium, calcium, iron, and aluminum silicate		Fusible with intumescence

EXTERNAL CHARACTERISTICS.

No.	Species.	Luster and Color.	Streak.	Hardness and Tenacity.	Remarks.
V.—STREAK GREEN.					
70	**Amphibole** (Common hornblende)	L. Common C. Blackish green	Grayish green	H.=5.5 Brittle	Monoclinic; crystals long and slender, often acicular; cleavage oblique, 124°; granular or lamellar; usually a mass of bladed crystals
VI.—STREAK BLUE.					
71	**Chrysocolla**	L. Vitreous, resinous C. Blue	Greenish blue, smalt blue	H.=2.4 to 3 Friable Brittle	Amorphous; often reniform; compact in texture and fracture; accompanies other ores of copper, especially malachite
72	**Azurite**	L. Vitreous C. Lazuli blue	Smalt blue	H.=3.75 Brittle	Often in incrustations; compact, fibrous, or earthy. G.=4
73	**Lapis Lazuli**	L. Vitreous C. Lazuli blue	Smalt blue	H.=5.5 Brittle	Often contains scales of mica; usually compact. G.=2.5

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
I.—VERY SOFT.					
74	**Calcite** (Rock milk)	White	Common	H.=0.5 to 1 Pulverulent	Usually a soft, white, porous, earthy mass; very light

No.	Composition.	Action of Acids.	Effects of Heating.
70	Magnesium, calcium, iron, and aluminum silicate		Fusible with intumescence
71	Hydrous, copper silicate	Acted upon by HNO_3; addition of ammonia to dilute solution gives blue color. In HCl decomposes with separation of SiO_2, without gelatinization	Gives off much water easily
72	Hydrous, copper carbonate	Acted upon by HNO_3; solution diluted, gives blue color on addition of ammonia. Effervesces with acids	B. B. decrepitates and blackens; colors flame green. Gives off much water easily
73	Sodium, aluminum silicate, with sodium sulphide and sulphate	Slowly acted upon by HCl, giving odor of H_2S	Fusible; loses its color

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
74	$CaCO_3$	Acted upon with effervescence by HNO_3 and HCl; addition of H_2SO_4 to diluted solution gives white precipitate	Infusible; assay after ignition reacts alkaline

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

I.—VERY SOFT.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
75	**Kaolinite**	White	Pearly	H.=1 Friable	Usually a soft, white, impalpable earthy mass, with unctuous feel and clayey taste and odor. Ordinary clay consists largely of kaolinite
76	**Talc**	White, green	Eminently pearly	H.=1 Friable Sectile	Usually in foliated or compact masses, with an unctuous feel; folia flexible; cleavage eminent
77	**Calcite** (Chalk)	White, gray to brown	Common	H.=1 Friable	Usually a compact, white mass, composed of shells of foraminifers
78	**Cerargyrite** (Horn silver)	Gray to brown, green, and blue	Resinous to dull	H.=1 to 1.5 Highly sectile when pure	Very valuable ore of silver; easy of treatment; common in South America, Mexico, and southern United States. Plate of iron rubbed with it becomes silvered. G.=5.5
79	**Niter**	White	Vitreous	H.=1.75 Friable Brittle	Taste saline and cooling; occurs in incrustations or crystallized in right rhombic prisms
80	**Gypsum**	White, gray, yellow, red, and brown	Vitreous, silky, pearly	H.=2 Friable to brittle	Occurs compact, fibrous, and foliated, sometimes fine granular; cleavage eminent; folia flexible. G.=2.3
81	**Sulphur**	Yellow, gray, brown	Adamantine, resinous	H.=2 Brittle to friable	Compact, in crusts or pulverulent. G.=2
82	**Mica** (Muscovite)	Gray, white, pale yellow or brown	Pearly	H.=2.5 Friable	Usually in foliated or micaceous masses or thin sheets; cleavage eminent; folia tough and elastic

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
75	Hydrous, aluminum silicate	No action	Gives off much water readily
76	Hydrous, magnesium silicate	No action	Exfoliates before blowpipe. Yields very little water (if any) with difficulty
77	$CaCO_3$	Acted upon by HNO_3 and HCl with effervescence; H_2SO_4 added to dilute solution gives white precipitate	Infusible; assay after ignition reacts alkaline
78	AgCl	Not acted upon by HNO_3 or HCl, but soluble in ammonia	Fuses in flame of candle; on charcoal, metallic bead of silver
79	KNO_3		Fuses in closed tube; bits of charcoal dropped in cause deflagration
80	$CaSO_4,2H_2O$	Dissolves in hot HCl or HNO_3; after dilution addition of barium chloride gives white precipitate	Fuses; leaves assay which is alkaline. Gives off water easily
81	S		Burns with a blue flame; sulphurous odor
82	Hydrous, potassium, aluminum silicate		Yields little water in closed tube

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
I.—VERY SOFT.					
83	**Mica** (Biotite)	Black	Pearly	H.=2.5 Brittle to friable	Usually in foliated or micaceous masses or thin sheets; cleavage eminent; folia tough and elastic
84	**Chlorite**	Green; rarely bluish red	Pearly	H.=2.5 Friable	Schistose in structure; often earthy by weathering; its fracture is micaceous, compact, or earthy; cleavage eminent; folia flexible but not elastic
85	**Halite**	White, gray, red	Vitreous to resinous	H.=2.0 Brittle to friable	Isometric, in cubes; massive, compact, or granular; taste saline
86	**Cryolite**	White to brown	Vitreous to greasy	H.=2.5 Brittle	Massive; fracture uneven. G.=3
87	**Anglesite**	White, gray to yellowish	Adamantine to vitreous	H.=2.7 to 3 Brittle	G.=6.1 to 6.4
88	**Carnallite**	Red	Vitreous to greasy	H.=2.7 Sectile	Soluble in water, bitter taste, deliquescent
II.—SOFT.					
89	**Calcite**	All colors; white, gray, and reddish common	Vitreous	H.=3 Brittle	Crystals and cleavage rhombohedral; usually compact, granular, or fibrous; sometimes tufaceous; impure varieties often contain clay and silica. G.=2.7
90	**Anhydrite**	Gray, white, and bluish gray	Vitreous, resinous, pearly	H.=3 Brittle	Usually compact; harder and heavier than gypsum; fracture often splintery. G.=3.0

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
83	Hydrous, potassium, magnesium, iron, aluminum silicate		Yields little water in closed tube
84	Hydrous, magnesium, iron, aluminum silicate		Gives off a moderate quantity of water rather readily; does not change color
85	NaCl	Soluble in H_2O; addition of solution of silver salt gives white, curdy precipitate of silver chloride.	Fusible; colors flame yellow
86	Fluoride of sodium and aluminum		Fuses easily in flame of candle; colors flame yellow
87	$PbSO_4$		Fuses easily; metallic lead on charcoal
88	Mixture of potassium and magnesium chlorides		Fuses easily
89	$CaCO_3$	Acted upon by HCl and HNO_3, effervesces. Solution diluted, addition of H_2SO_4 gives white precipitate	Infusible; assay after ignition reacts alkaline
90	$CaSO_4$	Dissolves in hot HCl and HNO_3; addition (after dilution) of barium chloride gives white precipitate	Fuses; assay after ignition reacts alkaline; gives off little or no water

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
II.—SOFT.					
91	**Cerussite**	White to gray	Adamantine to vitreous	H.=3 to 3.5 Brittle	Occurs massive and stalactitic. G.=6.5
92	**Witherite**	White	Vitreous to resinous	3 to 3.5 Brittle	G.=4.3
93	**Chrysocolla**	Verdigris green, sky blue	Shimmering (vitreous, silky)	H.=3.5 Brittle	Amorphous; often reniform; compact in texture and fracture; accompanies other ores of copper, especially malachite
94	**Arragonite**	White, gray, pale yellow	Vitreous, silky	H.=4 Brittle	Common in columnar aggregations; harder than calcite. G.=2.9
95	**Serpentine**	Yellow, green, and sometimes white; rarely dark green	Resinous (weak)	H.=4 Brittle, friable	Amorphous; massive; when pure its fracture is splintery, when impure it is earthy; unctuous feel; when breathed upon smells bitter; often mixed with calcite
96	**Sphalerite**	Yellowish	Adamantine	H.=4 Brittle	Isometric; cleavage of crystals eminent; massive Missouri blende is glistening on a fresh surface. G.=4
97	**Fluorite**	White, grayish, light greenish and bluish, common	Vitreous	H.=4 Brittle	Isometric; cleavage octahedral, distinct; occurs crystallized, also massive, granular; generally light colors. G.=3
98	**Dolomite**	White or grayish	Vitreous, pearly	H.=4 Brittle	Rhombohedral; usually a crystalline mass; often brown by weathering; a little harder and heavier than calcite. G.=2.9

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
91	$PbCO_3$	Readily acted upon by HNO_3, effervesces	Yields lead with soda on charcoal, alone if heated carefully
92	$BaCO_3$	Acted upon by HCl with effervescence and dilute acid solution gives white precipitate with H_2SO_4	Fuses easily, color flame to yellowish green.
93	Hydrous, copper silicate	Acted upon by HNO_3; addition of ammonia colors solution blue. Decomposed by HCl with separation of white silica, without gelatinization	Gives off much water easily
94	$CaCO_3$	Acted upon by HCl with effervescence; after dilution, addition of sulphuric acid gives white precipitate	Infusible; assay after ignition reacts alkaline Anhydrous
95	Hydrous, magnesium silicate		Gives off much water very readily; changes color to brown
96	ZnS	Effervesces with HCl; strong odor of H_2S	Pulverized, heated on charcoal, sulphurous odor; slight zinc fumes; coating (near assay) yellow while hot, white on cooling
97	CaF_2	Dissolves quietly in HCl; solution diluted, netralized with ammonia and oxalic acid added, gives a white precipitate	Phosphoresces and decrepitates; fuses; assay after ignition reacts alkaline
98	$CaMg(CO_3)_2$	When powdered, acted upon by HCl with effervescence; after dilution, addition of H_2SO_4 gives white precipitate	Infusible; assay after ignition reacts alkaline

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
II.—SOFT.					
99	**Siderite**	Yellow, yellowish gray, yellowish brown	Vitreous to pearly	H.=4 Brittle	Rhombohedral; crystals often curved; often brown or black by weathering. G.=4
100	**Smithsonite**	Gray, green, blue, brown to white	Vitreous, pearly to dull	H.=4.5 to 5 Brittle to friable	Found in veins, but more generally in deposits of limestone; usually results from alteration of ZnS. G.=4.4
101	**Calamine**	Gray, yellow to brown	Vitreous to dull	H.=4.5 to 5 Brittle	Stalactitic, botryoidal, fibrous, also massive and granular. G.=3.5
III.—HARD.					
102	**Pyroxene** (Diallage)	Dark green, brown or gray	Semi-metallic, pearly	H.=4.75 Brittle	Monoclinic; lamellar or tabular; cleavage nearly rectangular. G.=3.4
103	**Amphibole** (Tremolite)	White gray, greenish white	Vitreous, silky	H.=4.75 Brittle	Monoclinic; crystals long, slender and bladed, often fibrous (asbestos); frequently in crystals disseminated through a mass of dolomite; cleavage oblique, 124°. G.=3
104	**Amphibole** (Actinolite)	Green	Vitreous, silky	H.=4.75 Brittle	Monoclinic; crystals long and slender, sometimes fibrous (asbestos); usually in fibrous crystals disseminated through a mass of talc or serpentine. G.=3
105	**Analcite**	White to pale red	Vitreous	H.=4.5 to 5.5 Brittle	Isometric; trapezohedrons, rarely massive. G.=2.3 to 2.4. Transparent to opaque

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
99	$FeCO_3$	When powdered acted upon with effervescence by hot HCl; after dilution addition of K_4FeCy_6 gives blue precipitate	Blackens and becomes magnetic in reducing flame
100	$ZnCO_3$	Acted upon by HCl, effervesces	Coating of zinc oxide with soda on charcoal
101	Hydrous, zinc silicate	Gelatinizes perfectly in HCl	Yields water in closed tube
102	Calcium, magnesium, iron, silicate		Fusible with intumescence
103	Magnesium, calcium, silicate		Fusible with intumescence
104	Calcium, magnesium, and iron silicate		Fusible with intumescence
105	Hydrous, silicate of sodium and aluminum		Water in closed tube; fuses easily to colorless glass

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
III.—HARD.					
106	**Apatite**	Usually green, sometimes brown, etc.	Vitreous to somewhat resinous	H.=5 Brittle	Hexagonal; crystals are hexagonal prisms with pyramidal terminations, having a more resinous luster than beryl; often massive. G.=3.2
107	**Willemite**	White to gray, yellow, green, brown	Vitreous	H.=5.5 Brittle	Usually massive; also in hexagonal crystals. G.=3.9 to 4.2
108	**Enstatite**	Gray, yellow, green to brown	Vitreous to pearly	H.=5.5 Brittle	Orthorhombic; occurs massive, fibrous, and lamellar; translucent to opaque. G.=3.1 to 3.3
109	**Bronzite**	Gray, yellow, green to brown	Vitreous to pearly	H.=5.5 Brittle	Enstatite contains little or no iron, bronzite contains over 5 per cent of iron
110	**Monazite**	Red to dark brown, reddish or yellowish brown	Adamantine or resinous	H.=5 to 5.5 Brittle	Monoclinic; generally found as rounded grains of sand, sometimes known as thorium sand; translucent
111	**Hypersthene**	Darkish green to brown and black	Vitreous, resinous, pearly, almost metallic	H.=5 to 6 Brittle	Orthorhombic; massive, tubular and lamellar. G.=3.4 to 3.5
112	**Amphibole** (Hornblende)	Black	Vitreous	H.=5.75 Tough	Monoclinic; crystals long and slender; cleavage oblique, 124°; granular; massive specimens have common luster and often consist of a mass of interlaced bladed crystals. G.=3.3

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
106	Calcium phosphate	Soluble in hot HCl or HNO_3. Solution treated with H_2SO_4 gives precipitate of calcium sulphate. The nitric acid solution added to excess of ammonium molybdate produces immediately, or by gentle warming, a bright yellow precipitate, which shows the presence of phosphoric acid	
107	Zinc silicate		Anhydrous. Fuses with difficulty; coating of zinc oxide with soda on charcoal, yellow while hot, white on cooling
108	Magnesium, iron silicate		Fusible with difficulty
109	Magnesium, iron silicate		
110	Phosphate of cerium, lanthanum, and didymium	Soluble with difficulty in HCl	B. B. infusible
111	Iron and magnesium silicate, aluminum sometimes present		B. B. on charcoal fusible with difficulty to a black magnetic mass
112	Magnesium, aluminum, calcium, iron silicate		Fusible with intumescence

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
III.—HARD.					
113	**Pyroxene** (Malacolite)	White or gray	Vitreous	H.=5.75 Brittle	Monoclinic ; crystals short and stout; cleavage nearly rectangular ; granular varieties are called coccolite ; massive specimens often composed of crystals with ends projecting on surface. G.=3.4
114	**Leucite**	White to gray	Vitreous to resinous	H.=5.5 to 6 Brittle	Isometric; trapezohedrons, sometimes massive, translucent to opaque
115	**Nephelite**	White to gray or yellow	Vitreous to greasy	H.=5.5 to 6 Brittle	Hexagonal, transparent to opaque
116	**Pyroxene** (Augite)	Grayish black, greenish black	Vitreous	H.=6 Tough, brittle	Monoclinic; crystals short and stout; cleavage nearly rectangular; granular varieties are called coccolite; massive specimens are often composed of crystals with their ends projecting on the surface. G.=3.4
117	**Orthoclase**	Reddish, gray, white, yellow, rarely green	Vitreous, pearly on cleavage surface	H.=6 Brittle	Monoclinic ; two cleavage planes at right angles; cleavage eminent, seen when broken with a hammer ; breaks into pieces resembling rhombohedrons. G.=2.6
118	**Albite**	White	Vitreous, pearly on cleavage surface	H.=6 Brittle	Triclinic; usually a mass of interlacing bladed crystals. G.=2.62
119	**Turquois**	Bluish green	Somewhat waxy	H.=6 Brittle	Massive, reniform, without cleavage. G.=2.7
120	**Opal**	White, yellowish, or brownish, common	Resinous	H.=5.5 to 6.5 Brittle	Amorphous ; generally in rounded masses with a compact, conchoidal fracture; opalescent, presenting internal reflections

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
113	Magnesium, calcium silicate		Fusible with difficulty, intumescence
114	Silicate of aluminum and potassium	Decomposed by HCl without gelatinization	B. B. infusible
115	Silicate of aluminum and potassium	Gelatinizes with acids	B. B. fuses quietly to a colorless glass
116	Magnesium, calcium, iron, aluminum silicate		Fusible with intumescence. Anhydrous
117	Potassium, aluminum silicate	No action	Fuses with difficulty
118	Sodium, aluminum silicate	No action with acids	Fusible with difficulty, coloring flame yellow
119	Hydrous. aluminum silicate	Soluble in HCl	Infusible; becomes brown. Gives off water
120	SiO_2	No action with acids	Gives off water; fuses with effervescence when heated with soda on charcoal

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
III.—HARD.					
121	**Microline**	White to light cream yellow, also red, green	Vitreous, sometimes pearly	H.=6 to 6.5 Brittle	Same in composition as orthoclase, but triclinic; translucent to transparent
122	**Rutile**	Red to brown	Adamantine	H.=6 to 6.5 Brittle	Tetragonal, often prismatic and striated; translucent to opaque. G.=4.2
IV.—VERY HARD.					
123	**Olivine** (Chrysolite)	Green, yellow	Vitreous	H.=6.75 Brittle	Occurs usually in grains, or granular disseminated through basalt in small glassy crystals; transparent to translucent.
124	**Quartz** (Vitreous)	White, gray, light pink, and amethyst blue are common	Vitreous	H.=7 Brittle	Hexagonal, rhombohedral division; crystals transparent, in hexagonal prisms with pyramidal terminations; no cleavage apparent; occurs also massive, either compact or granular
125	**Quartz** (Chalcedonic)	Brown, yellow, white, and red are common	Somewhat waxy	H.=7 Tough	Cryptocrystalline; translucent; mamillary, nodular, or in layers lining cavities; compact, breaking with conchoidal fracture
126	**Quartz** (Jaspery)	Red, brown, green, and yellow are common	Common dull	H.=7 Tough	Cryptocrystalline; opaque; usually in compact masses, sometimes banded
127	**Garnet**	Yellow, brown, red, and black are common	Vitreous to resinous	H.=7 Brittle	In separate disseminated crystals (dodecahedrons or trapezohedrons) or in granular masses; transparent to opaque. G.>3 and <5. Pyrope is in small granules

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
121	Potassium, aluminum silicate	No action with acids	Fuses with difficulty
122	TiO_2	Not acted upon	Infusible alone
123	Magnesium, iron silicate		Infusible (whitens).
124	SiO_2	No action with acids	Fuses with effervescence with soda on platinum wire or on charcoal
125	SiO_2	No action with acids	Fuses with effervescence with soda on platinum wire or on charcoal
126	SiO_2	No action with acids	Fuses with effervescence with soda on platinum wire or on charcoal
127	Calcium, magnesium, iron, aluminum silicate	No action with acids	Dark varieties are fusible, usually leaving a magnetic globule; others infusible

C.—MINERALS WITHOUT METALLIC

EXTERNAL CHARACTERISTICS.

IV.—VERY HARD.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
128	**Tourmaline**	In all colors, black most common	Resinous to vitreous	H.=7 Brittle	Usually in separate crystals disseminated through quartz, etc.; number of sides of crystals some multiple of three; terminations low three-sided pyramids ; aggregations of crystals often coarse columnar; faces of crystals deeply striated. G.=3 to 3.2
129	**Andalusite**	White to gray, red, yellow, green, brown	Vitreous to dull, earthy	H.=6 to 7.5 Brittle	Orthorhombic, often in square prisms transparent to opaque. G.=3.1 to 3.2
130	**Beryl**	Green to yellowish and bluish green, white to light yellow, sometimes blue and red	Vitreous; yellow varieties sometimes resinous	H.=7.5 Brittle	Sometimes massive; usually in separate crystals (hexagonal), terminated by plane bases; faces often striated; usually shows cleavage parallel to base when broken. G. =2.7
131	**Spinel**	Black, red, gray, yellow, green, blue	Vitreous	H.=7.7 to 8 Brittle	Isometric; usually in octahedrons and rounded grains, transparent to opaque. G.=3.5 to 4.1
132	**Topaz**	Pale yellow, white, blue, red, and green	Vitreous to adamantine	H.=8 Brittle	In right rhombic prsims usually differently modified at the two extremities. G.=3.4 to 3.66
133	**Chrysoberyl**	Various shades of green to yellow	Vitreous	H.=8.5 Brittle	Orthorhombic; transparent to translucent. G.=3.5 to 3.85
134	**Corundum** (Sapphire, ruby)	Blue, red, white, gray, yellow, green, and brown	Adamantine to vitreous	H.=9 Brittle to tough	Rough hexagonal crystals, massive to fine granular, transparent to opaque. G.=3.9 to 4.1

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
128	Complex silicate	No action	Dark varieties are fusible with difficulty; and after fusion decomposed by H_2SO_4; others infusible
129	Silicate of aluminum	No action	Infusible
130	Beryllium, aluminum silicate	No action	Infusible
131	Aluminate of magnesium	No action	Infusible
132	Aluminum silicate with silicon fluoride	No action	Infusible
133	Aluminate of beryllium	No action	With borax fuses with great difficulty
134	Al_2O_3	No action	Infusible

EXTERNAL CHARACTERISTICS.

No.	Species.	Color.	Luster.	Hardness and Tenacity.	Remarks.
	IV.—VERY HARD.				
135	**Diamond**	White or colorless, sometimes pale shades of yellow, red, orange, green, blue, brown, and occasionally black	Adamantine, greasy, brilliant	H.=10 Brittle	Isometric; commonly in octahedrons; usually transparent, translucent to opaque; conchoidal fracture. G.=3.516 to 3.525

LUSTER; STREAK WHITE OR LIGHT GRAY.

No.	Composition.	Action of Acids.	Effects of Heating.
135	Pure carbon	No action	At temperature of electric arc in air burns to CO_2; out of air changes to a sort of coke

PART II.

THE COMMON ROCKS.

The term *rock* is applied to the more extensive mineral masses which make up the earth's crust. Some of these constituent masses are composed of a single mineral, but most rocks are mineral aggregates. Pure limestone or pure siliceous sandstone are examples of rocks consisting of a single mineral; the first is composed of calcium carbonate and the second of silica. Nearly all rocks, however, are mineral aggregates, being composed of two or more minerals; even those composed essentially of a single mineral usually contain small quantities of other minerals. The term rock is ordinarily held to imply a solid, hard mass, but in geological usage it is not so restricted, but is equally applicable to soft clay, loose sand, and hard granite.

Although there have been distinguished and more or less fully described about nine hundred distinct mineral species, a small number of these make up the great mass of the earth's crust: only about twenty species are of prime importance as rock constituents; these are the *essential* constituents of the rocks; all other species are *accessory* or *accidental* minerals.

CONSTITUENTS OF ROCKS.

The principal rock-making minerals may be included under two general heads, *siliceous* and *calcareous* minerals. The first includes silica and the silicates; the second the carbonates, sulphates, and phosphates of calcium.

The principal rock-making minerals are:

SILICA, quartz, the most abundant mineral of the earth's crust.

- THE SILICATES.
  - The Feldspars.
    - Monoclinic,—Orthoclase.
    - Triclinic—, Plagioclase.
      - Albite, Oligoclase, Andesine, Anorthite, Labradorite.
  - Feldspathoid group.
    - Nepheline.
    - Leucite.
    - Analcite.
  - The Micas,—Biotite, Muscovite, and Hydrous Mica.
  - Amphibole group.
  - Pyroxene group.
  - Talc.
  - Serpentine.
  - Chlorite.
- CALCAREOUS MINERALS.
  - Calcite and Arragonite
  - Dolomite.
  - Gypsum.
  - Apatite.

In addition to these most abundant rock-making species, the metallic ores, coal, peat, salt, and a few other minerals form limited, but, from an economical point of view, most important rock deposits. The metallic ores and coal have been already described as minerals.

THE CLASSIFICATION OF ROCKS.

The classification of rocks can be based upon their physical condition and texture, as *crystalline and uncrystalline;* upon their mineral characters, as *calcareous aud siliceous;* upon their mode of origin, as *igneous* and *sedimentary;* upon their structure and texture, as *stratified* and *unstratified;* upon whether *transformed* from original condition, as *metamorphic* or not.

A classification from any single point of view is unsatisfactory, because it fails to display important relationships among rocks and fails to give much desirable information in regard to the characters and properties of rocks.

For the purposes of the general student the most useful and instructive arrangement must involve to a certain degree all of the above distinctions. While, therefore, none of these distinctions is ignored, the fundamental divisions here observed are *geological* and depend upon structure, mode of origin, and transformation.

GENERAL CLASSES.

The three most general classes under this arrangement are:

I. Sedimentary or stratified rocks.
II. Igneous or unstratified rocks.
III. Metamorphic rocks.

The sedimentary rocks appear far more extensively at the surface of the earth, and as a rule their constituents have simpler composition than those of the other classes; they will be first described.

I. SEDIMENTARY ROCKS.

The sedimentary rocks have resulted from the deposition of sediments or comminuted material, the material being primarily derived from the decomposition and disintegration of pre-existing rocks. The rocks are therefore derivative or secondary. The sedimentary rocks have been generally deposited from water, and one of their most obvious and common characteristics is stratification. So common is this origin and structure that the terms *aqueous*, *stratified*, and *sedimentary* are frequently used synonymously.

All the sedimentary rocks, however, have not been laid down under water; very limited masses have been accumulated on land: this fact gives rise to two divisions of the sedimentary rocks:

A. Aqueous; those laid down under water.
B. Terrestrially deposited; those accumulated on land.

It is true only in a very general sense that some of the aqueous rocks can be termed stratified, and the same is true to a greater extent as regards the terrestrial. It is evident, therefore, that the terms *aqueous*, *sedimentary*, and *stratified* are not strictly synonymous.

A. AQUEOUS ROCKS.

The aqueous rocks may be further subdivided into:

(*a*) Fragmental or mechanically deposited.
(*b*) Chemically deposited.
(*c*) Organic origin.

(a) Fragmental Rocks.

The fragmental rocks are uncrystalline and are usually either arenaceous or argillaceous, and are mechanically deposited.

1. *Arenaceous.*

The arenaceous, mechanically deposited rocks are composed of angular or worn fragments resulting from the disintegration and wear of older rocks. The principal component of the arenaceous rocks is silica, though small quantities of the more common silicates are often present, as feldspar, mica, etc. To the arenaceous group the following varieties belong:

SAND.—Sand is comminuted rock material in an incoherent state; common sand is mainly quartz-grains, though some sands contain fragments of other minerals, as feldspar, mica, garnet, and iron oxide. Calcareous matter is also sometimes present. The roundness of the grains of sand depends upon the attrition to which they have been subjected; river and land sands are accordingly less likely to be round than those of sea-beaches.

GRAVEL.—Gravel is composed of water-worn pebbles which range in size from a pea to a hen's egg. Various rock material may be present in the gravel, but, owing to its permanence, quartz is most common. A gravel beach usually has some sand mixed with the pebbles. The larger pebbles and cobblestones with or without gravel are usually called *shingle*.

SANDSTONE.—Sandstone is a consolidated rock made from sand. The cementing material may be calcium carbonate, ferric oxide, or silica. The two cements last named give the more durable stone.

Varieties of sandstone are extensively used as a building-stone. It is quite durable and is easily quarried and cut. The "brownstone" used much in New York city and elsewhere for building is quarried in Connecticut and New Jersey. Sandstones when used for a building or wall should be placed with the bedding horizontal, since that is the position in which the stone will stand the greatest pressure and absorb the least moisture from the foundation. When pyrite is present in a building-stone it is likely to cause disintegration. Sandstone is usually more or less laminated, especially if it contains clay.

When sandstone splits readily into even plates or slabs, it is called *flagstone* or *paving-stone.* Even-grained, friable sandstones of various degrees of fineness are used as *grindstones* or *scythe-stones.*

NOVACULITE.—This is an exceedingly fine-grained sandstone, often called *oilstone.* It is found extensively in Arkansas and is valuable for whetstones. Sandstones often contain a considerable amount of clay, to indicate which they may, very properly, be termed *argillaceous* sandstones.

QUARTZ CONGLOMERATE.—A siliceous rock made up of sand, pebbles, or angular fragments of rocks cemented together. If the pebbles are rounded the conglomerate is a *pudding-stone*; if angular, a *breccia.* The term "conglomerate" is often appled to the pudding-stone alone.

GRIT.—A *grit* is a hard, siliceous conglomerate, the grains being less rounded than in common sandstone. It is composed of *vitreous* quartz and was formerly sometimes used for millstones.

2. *Argillaceous.*

CLAY.—Soft, very fine grained, almost impalpable, more or less plastic material, chiefly kaolinite in composition, and of various colors, as white, gray, yellow, red, brown, or black. When wet it can be kneaded between the fingers;

when dry it is soft and friable and adheres to the tongue. It often contains much quartz-sand, and pulverized feldspar. Marl is a clay containing carbonate of lime, and the amount of carbonate may be so large as to place the rock among the chemically deposited.

SHALE.—Shale is a soft, fragile, argillaceous rock, having an uneven, slaty structure, splitting along planes parallel to the planes of deposit. Gray, brown, black, red, and other shades; consists essentially of clay with some fine sand or pulverized feldspar. It is fine mud consolidated. Shales, by the addition of sand, graduate into fissile sandstones; by the addition of calcareous matter into limestones; by the addition of carbonaceous matter into coaly shales.

FIRE-CLAY.—A clay nearly free from alkalies and iron and capable of standing a great heat without fusing. It is usually of a light color and is found abundantly beneath the coal beds.

(b) Chemically Deposited Rocks.

OÖLITE.—Is a limestone composed of minute spherical grains resembling the roe of a fish, each grain being composed of concentrically deposited layers of calcite. PISOLITE is a similar rock in which the grains are as large as peas. The unconsolidated oölitic grains are found as beach sand at Pyramid Lake, Nev.; similar but finer sand is now forming at Great Salt Lake. An oölitic rock is also found composed of calcareous, rolled sand cemented by calcium carbonate. This last is a fragmental rock. Extensive deposits of oölitic rock are known to exist.

GYPSUM.—Is composed of calcium sulphate, and is a chemically deposited rock formed by the evaporation of the water holding it in solution. The deposition is hastened by the presence of an abundance of common salt in the solution.

SALT.—Common salt, like gypsum, is deposited by evaporation from waters holding it in solution. Salt and gypsum are generally associated, the latter being deposited first. Salt occurs as an ingredient of other deposits, as salt shales; also in thin sheets and enormously thick beds.

TRAVERTINE.—A massive limestone, formed by deposition from calcareous springs or streams. It is usually cellular and more or less concretionary. A handsome compact, banded kind, translucent and of great beauty, comes from Mexico, and is sometimes called *Mexican onyx.*

STALACTITE AND STALAGMITE.—These are deposits, usually more or less columnar, formed on the roofs and floors of caves by deposition from solution.

SILICEOUS SINTER.—Is composed of opal silica. Occurs in compact, porous, and concretionary forms. It is deposited from hot siliceous waters, and is thus frequently found around geysers, forming mounds and occasionally terraces. From this fact it is sometimes called GEYSERITE. The deposit is mainly due to the evaporation of the water, but in some cases to the action of algæ.

CHERT, FLINT.—A dark, compact rock occurring in nodules and in beds and composed almost entirely of chalcedonic quartz. Its mode of origin is not thoroughly understood. Under the microscope the siliceous spicules of sponges and siliceous shells of diatoms, also calcareous shells or spines converted into silica, have been observed in it. The first two facts would indicate that the rock is, in part at least, formed from the segregated remains of organisms, while the last indicates a substitution of silica by a chemical process. The mass of the rock is believed to come more properly under Chemical Deposits, though in some cases it might be placed among those organically formed. The nodules occur abundantly in chalk formations.

BUHRSTONE.—Is a highly siliceous, compact, though cellular rock. It is principally found in the Tertiary rocks of the Paris basin, and occurs in beds associated with sand and argillaceous marl deposits. The rock often contains land and fresh-water shells as well as in the stems and seeds of land and aquatic plants, all converted into silica. The exact mode of deposition is not known, but it was probably the action of siliceous waters on a previously existing fossiliferous rock, the silica replacing other material. The rock is chalcedonic quartz and is largely used for millstones in flouring-mills, cement-factories, potteries, chemical works, and other similar establishments. It has also been found in the Tertiary of South Carolina.

MARL.—Marl is a clay containing a greater or less proportion of $CaCO_3$, from a small per cent to over one-half. Though testacea are usually abundant in marl beds, the $CaCO_3$ has more generally been deposited from waters holding it in solution; to this extent marl is a chemically deposited rock. When the clay is taken into consideration marl might be classed, as already stated, as an argillaceous sedimentary rock. The marls are used as fertilizers.

(c) Organic Origin.

The rocks of organic origin are those mainly composed of the remains of organisms. These remains have in many cases been acted upon, and to a certain extent the rocks formed by mechanical agencies, so that some of them might properly be classed as mechanically deposited rocks, but their essential origin rather than their accumulation is their more distinctive characteristic.

LIMESTONE.—This is a general term which includes all those rocks mainly composed of $CaCO_3$, though they vary greatly in degree of purity.

Most limestones are of organic origin and are marine deposits, though, as already seen, some are chemically deposited by streams or springs. The organic limestones show every gradation of structure and texture. The deposits range from thin laminæ to beds several thousand feet in thickness. In some the organic remains are shown in almost perfect preservation, in others the organic origin is only evident under the microscope, and in still others the organic structure is no longer visible. From formations now being made in coral regions it is known that rocks of evident organic origin do not always show this origin in their texture; some of the more important and distinctive organic limestones are the following:

SHELL-MARL.—This is a friable rock mainly composed of shells and their fragments cemented together by calcium carbonate. Clay and sand are usually present. Such deposits are generally formed in lakes and ponds. When compacted into solid stone they constitute fresh-water limestones.

COQUINA.—Shell-limestone. Coquina is a marine, porous shell-limestone made up almost entirely of fragments of shells, though occasional shells are entire. When first removed from the ground the rock is soft and may be easily cut; by exposure to the air it is greatly hardened. This rock is found in Florida and is extensively used in the forts and structures of St. Augustine. In the Florida rock the spaces between the shells are often partially filled with clear quartz sand. The stone is now being formed at numerous points along the Florida coast. Shell-limestones are formed at other places, but they differ from coquina in that they are more compacted; such a rock is found along the Genesee river, near Rochester, N. Y.

CHALK.—Is a white earthy, friable limestone, composed mainly of the shells and shell-remains of rhizopods.

HYDRAULIC LIMESTONE.—This is an impure limestone containing clay and, when calcined, yields a lime which furnishes hydraulic cement; that is, a cement which sets under water. The indications of hydraulic properties in a limestone are compact texture, argillaceous odor, conchoidal fracture, and sluggish effervescence.

DOLOMITE.—Is not distinguished by the eye alone from calcite limestone. It is calcium-magnesium limestone and occurs in beds often associated with gypsum and rock salt, also in irregular bands traversing limestone. The origin of dolomite is not fully understood. In some cases it seems to have been deposited as calcium carbonate and subsequently a portion of the calcium carbonate was replaced by magnesium carbonate, by the chemical action of the magnesium salts in sea-water.

In other instances this action seems highly improbable, and the rock was more likely formed as suggested by Hunt, being deposited in closed oceanic basins whose waters were rich in magnesium carbonate. Dolomite contains less than fifty per cent of magnesium carbonate, the remainder being calcium carbonate. Sing Sing marble, a typical dolomite, gives an hydraulic lime by cautious reduction, reducing the $MgCO_3$ with perhaps some of the $CaCO_3$. Reduction at high temperature gives a fat lime.

CALCAREOUS CONGLOMERATE.—A rock composed of fragments of calcite or dolomite cemented by calcium carbonate. If the pebbles are rounded the conglomerate is a *pudding-stone;* if angular, a *breccia.* The term "conglomerate" is often applied to the pudding-stone alone.

Other massive limestones are often named from the character of the predominating organic remains—such are *coral rock*, which consists of fragments of coral and other marine remains cemented by $CaCO_3$; *crinoidal limestone* is composed largely of the disks and stems of crinoids cemented together; *nummulitic limestone* is a cream-colored rock consisting of nummulites, little flattened, disk-shaped fossils, cemented by calcite. Some of the pyramids of Egypt, including that of Cheops, are made of this rock.

GREENSAND.—An olive-green sand-rock, friable, consisting mainly of grains of glauconite (hydrous silicate of aluminum, iron, and potassium) with more or less sand. Many of the glauconite grains, under the microscope, are seen to be the casts of foraminiferous shells, and the probabilities seem to be that the glauconite was originally deposited in organisms.

SILICEOUS LIMESTONE.—A limestone containing siliceous sand. It has a gritty feel under the fingers and may be distinguished by dissolving the pulverized rock in hydrochloric acid, when the sand will be left as a gritty powder which is capable of scratching glass.

MARBLE.—Any limestone which occurs in large masses and is capable of receiving a polish is included under the general term marble; a more restricted use confines it to the metamorphic, crystalline limestones. If the marble has colors distributed in blotches or streaks it is called *variegated;* if it contains angular fragments it is called *brecciated* marble. Many of the calcareous rocks referred to give marbles.

TRIPOLITE.—An infusorial earth, consisting chiefly of siliceous shells of diatoms with the spicules of sponges, and is silica in the opal state. It resembles clay or impure chalk in appearance, but is a little harsh between the fingers and scratches glass when rubbed on it. It forms thick deposits, and is often found in old swamps beneath the peat. It derives its name from Tripoli in Africa, where it was first obtained.

CARBONACEOUS DEPOSITS.—Peat and the various forms of coal come under this head, all being of vegetable origin. Peat is a mass of partially disintegrated and decomposed vegetable matter. It has a black or brown color and is much richer in carbon than unchanged vegetable matter. In recent peat, or that in which the carbonization has not greatly progressed, the vegetable structure is readily detected by the unaided eye, but in the more perfect forms it can be seen only by the microscope. It occurs in many places and is valuable as a fuel. The various forms of coal have been already referred to as minerals.

B. TERRESTRIAL OR LAND-FORMED ROCKS.*

This division includes the rocks accumulated on land or areas not habitually covered by water. Such rocks are principally produced and accumulated by meteoric agencies. The most important of this class is the soil.

SOIL.—This is a general term for the products which result from the subaerial decomposition and disintegration of the more compacted rocks of the earth's surface. It is

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* There is no general agreement in the classification of the rocks here included under the term *terrestrial.* Nearly the same formations have been included under the terms *aerial*, *subaerial*, and *æolian*, but none of these is thought to be as appropriately applicable as that adopted.

an intimate mixture of such material and generally contains some animal and vegetable matter. The mineral matter of the soil often results from the rocks immediately below it, but it may be more or less transported. All fertile soils contain organic matter.

ALLUVIUM.—Is a term applied to the soil brought together by the ordinary operations of water, especially during times of flood. It generally constitutes the flats on either side of streams and is usually in layers varying in fineness, due to successive depositions.

BLOWN SANDS.—Loose sands, of whatever origin, may be blown into mounds or heaps, forming *dunes* or *downs*, and if they be calcareous sands or contain considerable calcareous matter, they may by the action of rain-waters be converted into compact stone.

LOESS.—Is a term applied to certain widely distributed deposits which have the same general characteristics, but probably all have not been deposited in the same way. The material under consideration is a light-colored loamy earth, generally unstratified. It covers immense areas in northern China, in the pampas of South America, and occurs as extensive bluff-deposits along the Mississippi and its tributaries, along the Rhine, Danube, and other European rivers. Somewhat similar deposits occur in the basin regions of our western country. The origin of these formations is not yet solved. In some regions they have been ascribed to the action of the wind, which is known to have deposited immense quantities of dust after carrying it through great distances. In certain arid regions dust-storms have been known to fill the atmosphere with dust for days, even obscuring the sun. Wind-blown dust is probably one of the sources of loess deposit; another is thought to be rain-washed sediment from bare slopes. The loess of river-valleys generally was probably laid down in water during the periods of flooded lakes and rivers.

GUANO.—This substance is a mixture of organic matter, ammonium salts and phosphate, of lime. It is a brown, light, porous body with an ammoniacal odor. The deposits of guano occur in rainless regions and are the droppings of the immense flocks of sea-fowl that have for centuries frequented the regions. South America and the rainless islands off the western coast of that continent contain the most noted deposits. If the underlying rock is calcium carbonate it may be gradually converted into calcium phosphate. Similar deposits made by bats have been found in many caves.

VOLCANIC TUFA is a rock formed from the comminuted fragmentary material ejected from volcanoes. These materials are consolidated partly by pressure and partly by infiltrating waters. Vast quantities of fine matter are often ejected from volcanoes, the finest being termed ashes. There is a gradation from this through sand into the coarser varieties of ejected matter. The term "ash" is used because of its resemblance to the ash from wood or coal, but no result of combustion is implied. The tufas, or "tuffs" as the word is sometimes written, include the rocks formed from the consolidated ashes, sand, and finer material.

The ejected material may fall into bodies of water, thus giving aqueous as well as terrestrial tufas. The finer ejected material, especially that of a sandy nature, is sometimes called *peperino.* The erupted matter from volcanoes and fissures forms other extensive land deposits, but they cannot be included under the head of sedimentary rocks.

TALUS.—This is a term applied to the piles of earth and bowlders generally seen at the base of cliffs and mountain-slopes. Talus results from the unceasing action of gravity and meteoric agencies in dragging down the higher elevations. In the case of cliffs, if the débris is not removed from the base, the precipice will in time be converted into a slope.

DETRITUS.—Detritus is the general term for earth, sand, alluvium,* silt, gravel, and mud. The material is derived to

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*The alluvial material is constantly carried into lakes, bays, etc., at the mouths of the rivers and streams. It is not under such circumstances a terrestrial deposit. In bays and harbors these shore deposits are usually called silt. They tend to delta formation and may eventually give rich alluvial lands.

a great extent from the wear of rocks through disintegrating agencies, attrition and decomposition.

DRIFT.—Drift is the unstratified sand, gravel, and stones, with more or less clay, deposited by glaciers; it is also called TILL.

II. IGNEOUS OR UNSTRATIFIED ROCKS.

The first of these terms is applied to this class of rocks because heat has evidently been concerned in their origin, and the second because of the entire absence of true stratification. These rocks are believed to have consolidated from a fused or semi-fused condition. The term *eruptive* is sometimes used as synonymous with the above terms, but *eruptive* is also used as the equivalent of *volcanic*, and will be so understood in this text.

EVIDENCE OF ORIGIN.—The igneous origin of these rocks is primarily involved in the accepted theory of the earth's origin, and they are believed to have been the rocks first formed and to have resulted from the cooling and solidification of the molten globe; they are therefore the primitive rocks from which all others have been derived and must of necessity, at greater depths, underlie all superficial rocks. Subsequently and up to the present time all exposed igneous rocks have been produced from within the earth's crust, and there is the strongest ground for thinking that all have been in a molten or a pasty condition. The effects which the igneous rocks have frequently produced upon the sedimentary deposits with which they have come in contact, and the extreme similarity of these rocks, in many cases, to modern lavas, leave little doubt that heat has been an agent in their production.

CHARACTERISTICS OF IGNEOUS ROCKS.—The igneous rocks in general differ from the sedimentary by the absence of all lamination, due to the sorting of material; by the texture, which is more or less crystalline, glassy, or compact; by the absence of fossils, and by the marked difference in the manner of occurrence.

Besides the general terms of *coarse* and *fine* texture, descriptive of rocks, the igneous rocks display four distinct types of texture with gradations from one to the other. These types are designated as follows:

1st. Glassy, in which the rock is a glass mixture, not showing distinct minerals; is devoid of crystalline masses and has that texture which is best described by the term itself and thus universally recognized. The incipient stages of crystallization are often shown under the microscope in native glasses, by hair-like formations (trichites) and minute grains (spherulites). When the fused glass material is subjected to the action of escaping gases, there may be produced a fine cellular or vesicular mass, thus giving rise to pumiceous or scoriaceous texture.

2d. Compact,* in which the mass is made up of minute crystals too small to be seen by the eye alone. When the microscope reveals the crystals the rock is *microcrystalline*, and when they cannot thus be seen, *cryptocrystalline*. Compact rocks are homogeneous and stony, not glassy in appearance.

3d. Porphyritic, in which distinct crystals are interspersed throughout a ground mass which is glassy, minutely crystalline, or both. The large crystals are called *phenocrysts*. This texture is thought to indicate two periods of crystallization, the phenocrysts forming first and the magma solidifying later. In some cases, if not all, the phenocrysts were formed before the rock was erupted and hence are said to be *intratelluric*.

4th. Granitoid, in which the texture is wholly crystalline without any amorphous ground-mass.

CLASSIFICATION OF IGNEOUS ROCKS.

The igneous rocks for the purposes of the general student can be best and most significantly divided into two primary groups, *plutonic* and *volcanic*, with a less distinctly defined group forming an intermediate series. The typical members of the first two groups are distinctly different, but other members of the group approach each other by insensible gradations until they might with equal

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* *Felsitic* is often used synonymously with *compact*.

propriety be assigned to either; these form the *intermediate* series and are sometimes classed as *intrusive* rocks. These divisions of the igneous rocks involve distinctions both in mode of occurrence and in the texture of the kinds.

1. Plutonic Rocks.

The plutonic rocks occur in the greater masses and have cooled and solidified at greater depths than the other groups and consequently more slowly. They have never been erupted on the surface. This slow cooling has led to a more perfect and wholly crystalline texture. They have the granitoid texture; that is, the rocks are made up of an aggregate of crystals more or less perfect without any uncrystallized ground-mass between the crystals. They are coarsely crystalline (macrocrystalline) and granular. The constitutent minerals are mainly quartz, the feldspars, mica, and hornblende. The principal rocks of this group are:

GRANITE.—Common granite consists of quartz, feldspar, and mica. Massive, with no general appearance of layers in the arrangement of the mineral ingredients. The quartz usually transparent, bluish glassy, without cleavage; the feldspar (usually orthoclase) opaque white or reddish with glistening cleavage surface; the mica in glistening scales, either whitish or black. When the rock also contains hornblende or the mica is replaced by hornblende, it is called *hornblendic granite.* When the feldspar is in well-defined crystals in a finer but still crystalline ground-mass it is called *porphyritic granite.* Granite is generally plutonic, but sometimes metamorphic.

SYENITE is a rock composed essentially of orthoclase and hornblende. The hornblende may be replaced by biotite or augite, giving mica or augite syenite. Magnetite and apatite are very generally present in syenite and granite as accessory minerals.

DIORITE.—A dark, speckled, greenish or grayish black rock, generally consisting of a crystalline aggregate of triclinic feldspar (oligoclase) and hornblende, though some varieties contain pyroxene or biotite. Quartz frequently present; if in large quantity it makes quartz-diorite. Usually granitoid in texture, though much finer than granite. Generally plutonic, sometimes metamorphic.

DIABASE.—A dark, greenish, crystalline rock, similar in appearance to diorite, but containing augite in place of hornblende. Usually fine-grained. Often contains olivine.

GABBRO.—Is now a very comprehensive term applied to the more coarse-grained, granitoid basaltic rocks, which are typically made up of plagioclase and augite, but the proportions of these constituents vary until some of the rocks, as the anorthites, are nearly pure labradorite, and others, as the pyroxenites, contain little or no feldspar. Olivine, hornblende and the orthorhombic pyroxenes are also often present.

The above selections include the more typical rocks of the plutonic group, but they graduate into each other and give rise to many varieties.

Diorite and diabase are often intrusive, and accordingly fall also in the intermediate series of trappean rocks.

2. Eruptive or Volcanic Rocks.

The volcanic rocks have been brought to or near the surface by volcanic action and thus have been subjected to more rapid cooling than the plutonics. This has generally resulted in a wholly glassy or only a partially crystalline texture; when partially crystalline, the crystals are imbedded in an amorphous or glassy paste; they are usually micro- or cryptocrystalline, and have a minutely speckled appearance. While generally the characters are as stated above, some of the volcanics are holocrystalline, but even then the principal mass of the rock is likely to be of very minute crystals. The difference in texture between the volcanic and plutonic rocks is due to their modes of occurrence, which involves difference in the conditions of cooling.

OBSIDIAN.—Lava which has been completely fused and cooled rapidly. A volcanic glass. Gray to black. Breaks with a conchoidal fracture, the splinters often transparent. Most of the obsidians are essentially composed of orthoclase. Its dark color and opacity are due to vast numbers of incipient crystals.

Pitchstone has much the appearance of obsidian, but contains water.

PUMICE.—A finely vesicular, light-colored variety of scoria. It is so light that it will float upon water. A strikingly similar substance can be produced by injecting steam into certain iron slags. Pumice may result from different magmas, but the more common kind is composed essentially of orthoclase. It is often capillary or in thread-like masses, even silky.

RHYOLITE.—This is one of the most common kinds of lava erupted when the original igneous material is granitic in composition. The ground-mass is mainly orthoclase in minute crystals with more or less glass. It has the porphyritic texture, the isolated crystals (phenocrysts) being of quartz and sanidin. Rhyolites are exceedingly abundant in the western United States. When coarsely granular it is sometimes called *nevadite*. *Liparite* and *quartz trachyte* are also names applied to forms of rhyolite.

TRACHYTE.—A light-colored, ash-gray rock. It consists of a ground-mass which is mainly minute orthoclase crystals, with little or no glass, with phenocrysts of sanidin of glassy luster. Often contains amphibole, pyroxene, or biotite, and is slightly porphyritic in texture. It graduates into rhyolite.

PHONOLITE.—A compact, grayish-blue or brown feldspathic rock, somewhat slaty in structure. It *clinks* under the hammer. It differs in composition from trachyte in containing nepheline and sometimes leucite and hornblende. It is a rare rock in this country.

BASALT.—This term is applied to many varieties of the volcanic rocks, which differ considerably in appearance. As most commonly applied it is a dark, almost black, cryptocrystalline rock, breaking with a dull, slightly conchoidal fracture. It contains microscopic crystals of labradorite, augite, and usually olivine, in a ground-mass of the same. Magnetite is often an abundant constituent.

DOLERITE, has the same composition as basalt, except the olivine, and is more coarsely crystalline. Its color, is dark grayish. It is commonly called *trap-rock*, a term which is applied to several other granular volcanic rocks.

ANDESITE.—A dark-grayish rock, consisting essentially of triclinic feldspar (oligoclase or andesite), with hornblende (or augite).

3. Intermediate, Intrusive Rocks.

In the plutonic and volcanic groups we have described only the more typical varieties, but there are many other igneous rocks which cannot with more distinctness be assigned to one rather than to the other of these groups. Many of these ill-defined rocks, in their mode of occurrence as well as their texture, are intermediate between the plutonic and the volcanic. The volcanic are generally the superficial igneous rocks; the plutonic are the profound masses underlying the surface; the intermediate series form the connecting conduits and sheets between them. Sometimes they are driven like wedges between the strata which rest upon the plutonics and are overlaid by the volcanics. The most common of the intermediate rocks are intrusive forms of dolerite, diorite, and diabase. They differ from the plutonic varieties only in their modes of occurrence, which may also affect their texture. The terms *trap* and *greenstone* are often applied to the basaltic intrusive rocks.

FELSITE is a light-colored intrusive rock, usually reddish or gray. It is compact, fine-grained, and composed chiefly of feldspar and quartz without glass. It is often porphyritic in texture, the phenocrysts being of quartz or feldspar. The first is sometimes called *quartz-porphyry*, and the second *porphyrite*. The term *porphyry* is applicable to any rock which consists of a homogeneous base, with well-defined crystals of the same material or another mineral.

We thus often have *greenstone porphyry* as well as *felsitic porphyry.* The term *porphyry* is very generally employed by miners in our West for any rock that occurs in what they call veins.

OTHER MODES OF CLASSIFICATION OF IGNEOUS ROCKS.

No single common system for the classification of igneous rocks has been adopted. In addition to the divisions based upon their mode of occurrence, above given, other divisions, based upon chemical and mineralogical composition, are very generally recognized, and are more fundamental to the special student. This method of classifying gives the following groups for the rocks described:

Acid group, containing over 65 per cent of silica.	(1) Granite-rhyolite family.	Obsidian. Pitchstone. Pumice. Rhyolite. Felsites. Granites.	The principal minerals present are orthoclase and quartz, oligoclase in subordinate quantity, with some hornblende and mica.
Intermediate group, containing between 55 and 65 per cent of silica.	(2) Syenite-trachyte family.	Trachyte. Phonolite. Syenite.	Principal minerals present are orthoclase and hornblende, some oligoclase, pyroxene, and biotite. Quartz generally absent; orthoclase predominating mineral. Nephelite-syenite belongs to this family, nepheline and leucite largely replacing orthoclase.
	(3) Diorite-Andesite family.	Andesite. Diorite.	Plagioclase (soda-lime) feldspar is the predominating mineral, with hornblende in considerable quantity. Pyroxene and biotite may occur. Quartz in small quantity.
Basic group, containing between 45 and 55 per cent of silica.	(4) Basalt-Gabbro family.	Basalt. Dolorite. Diabase. Gabbro.	Principal minerals present, plagioclase feldspar (labradorite or anorthite) and pyroxene. Magnetite and olivine are often present.
Ultra-Basic, containing generally less than 45 per cent of silica.	(5) Rocks composed almost entirely of pyroxene or hornblende and olivine. Serpentine rocks.		

III. METAMORPHIC ROCKS.

The metamorphic rocks are those which have been produced by the transformation without disintegration of pre-existing rocks. This transformation generally involves one or more and often all the following changes—greater hardness, different and more crystalline texture, development of different minerals.*

One of the most important characteristics of many of the metamorphic rocks is a *foliated* structure. This term generally refers to that structure brought about by the presence of minute scales, such as produce the fissile character of schists, but the term is now often used in a more general sense and is made to include cleavage.

Until quite recently it was thought that metamorphic rocks were all originally sedimentary rocks, but it is now known that the original rocks often belonged to the igneous classes. Metamorphic rocks may be said to have had two dates, one of *formation* and one of *transformation.*

The metamorphic rocks have great extent and thickness at many places throughout the world. The more important kinds are the gneisses, schists, clay slate, marbles, quartzite, and serpentine. The gneisses, schists, and slates have the foliated structure, the other kinds have not. The foliation in slates is usually termed cleavage.

COMMON GNEISS.—This rock has the general appearance and mineral composition of granite, but the ingredients are arranged in layers. Gneiss grades insensibly on the one hand into granite and on the other through the schists into sandy clays or clayey sands. It is now thought that gneiss has frequently resulted from the metamorphism of granite.

If hornblende is also present as a constituent in the rock it becomes *hornblendic* gneiss.

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* The term *metamorphic* has recently been used to include rocks altered by decomposition and disintegration. Such use greatly enlarges this class of rocks, but also makes the use of the term very general and less definite.

THE SCHISTS.—More or less fissile rocks, made up largely of scales or thin crystals of the minerals from which they derive their names. The structure is called *schistose*, and differs entirely from that of slates.

The structure is included under the general term of foliation. It is now thought that schists may have been derived either from igneous or sedimentary rocks.

The varieties of schists are:

Mica Schist.—This is a grayish fissile rock consisting of mica, considerable quartz, and frequently some feldspar. It often contains garnets. Some varieties are used for flagstones.

Hydromica Schist.—Composed chiefly of hydrous mica or of this with some quartz. The surface nearly smooth, pearly to faintly glistening in luster, grayish in color.

Chlorite Schist.—Grayish green, smooth but not greasy to the feel. Consists of chlorite with usually some quartz and feldspar. Often contains crystals of magnetite.

Talcose Schist.—Composed essentially of talc. Has the appearance and feel of talc.

Hornblende Schist.—Schistose, dark-colored, rough to the feel, composed of hornblende.

CLAY SLATE (ARGILLITE).—An argillaceous rock, splitting into thin even slabs, the planes of cleavage running athwart the stratification planes. Many of the common slates contain considerable quantities of mica and hydromica in scales. They are generally derived from sedimentary argillaceous rocks, but it is believed that they may result through the transformation of volcanic tufas.

THE MARBLES.—The marbles were originally common limestone, but metamorphism has produced in them a crystalline-granular texture. They are either calcite, dolomite, or calcite-dolomite. They often contain mica, tremolite, talc, pyroxene or apatite. Some of the common marbles are:

Statuary Marble.—Pure white and fine grained.

Architectural Marble is coarse or fine grained, white and mottled of various colors.

Verd Antique, Ophiolite.—A marble containing serpentine.

QUARTZITE is a changed siliceous sandstone, usually firm and hard. The grains and the cement holding them together are both silica. It generally requires the microscope to recognize the fragmental nature of the rock, but sandstones and quartzites graduate into each other.

ITACOLUMITE is a schistose quartzite through which are distributed scales of mica, chlorite, and talc. The rock is often only slightly compacted and almost friable. It is sometimes the matrix in which diamonds are found in Brazil. It is slightly flexible, due to the schistose scales.

SERPENTINE ROCK is composed of serpentine. Fine granular, easily scratched with a knife. Generally of a dark oil-green color and slightly greasy on a smooth surface. The massive compact varieties which receive a good polish are termed *serpentine marbles.* The origin of serpentine is not well understood; in some cases it appears to be derived from magnesian clays, but perhaps more often by the alteration of chrysolitic, augitic, and hornblendic rock.

Metamorphism may be due to local or general causes. The first constitutes *local* and the second *general* metamorphism. The first is effected by igneous intrusions, dikes, laccolites, etc., and extends over a comparatively small area. The second involves the changes that are produced in rocks covering great areas, often many hundreds of square miles. Both general and local metamorphism are primarily due to the internal heat of the earth operating in conjunction with the mechanical pressure and the chemical agents of the earth's crust. The causes of metamorphism are discussed in Geology.

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GENERAL INDEX.