R. C. Scott Dow 1/29

BRITISH MUSEUM (NATURAL HISTORY)

CROMWELL ROAD, LONDON, S.W. 7.

MINERAL DEPARTMENT.

AN INTRODUCTION
TO THE
STUDY OF MINERALS.

SIXTEENTH EDITION.

LONDON:
PRINTED BY ORDER OF THE TRUSTEES.
1924.

[PRICE ONE SHILLING.]

BRITISH MUSEUM (NATURAL HISTORY).

GUIDE BOOKS AND INSTRUCTIONS FOR COLLECTORS.

Summary Guide. Pp. 16. 3*d.* (*postage* 1*d.*).
Guide to Anthropology. Pp. 35. Illustrated. 1*s.* (*postage* 1*d.*).
,, ,, **Mammals.** Pp. 123. Illustrated. 1*s.* 6*d.* (*postage* 1½*d.*).
,, ,, **Great Game Animals.** Pp. 93. Illustrated. 1*s.* (*postage* 2½*d.*).
,, ,, **Elephants** (Recent and Fossil). Pp. 48. Illustrated. 1*s.* (*postage* 1½*d.*).
,, ,, **Horse Family.** Pp. 44. Illustrated. 1*s.* (*postage* 1½*d.*).
,, ,, **Domesticated Animals** (other than Horses). Pp. 56. Illustrated. 1*s.* (*postage* 1½*d.*).
,, ,, **Whales, Porpoises and Dolphins.** Pp. 48. Illustrated. 1*s.* (*postage* 1*d.*).
,, ,, **Birds,** Part I, General Series. Pp. 163. 2*s.* 6*d.* (*postage* 3*d.*).
,, ,, **Birds,** Part II, Nesting Series of British Birds. Pp. 62. 4 Plates. 1*s.* (*postage* 2*d.*).
,, ,, **Birds.** Atlas of 24 Plates with Explanations. 1*s.* 6*d.* (*postage* 2*d.*).
,, ,, **Reptiles and Batrachians.** Pp. 56. Illustrated. 1*s.* (*postage* 1½*d.*).
,, ,, **British Freshwater Fishes.** Pp. 39. Illustrated. 6*d.* (*postage* 1*d.*).
,, ,, **British Vertebrates.** Pp. 122. Illustrated. 1*s.* (*postage* 3*d.*).
,, ,, **Insects.** Pp. 65. Illustrated. 2*s.* (*postage* 2*d.*).
,, ,, **Crustacea, Arachnida, Onychophora and Myriopoda.** Pp. 133. Illustrated. 1*s.* (*postage* 3*d.*).
,, ,, **Mollusca.** Pp. 55. Illustrated. 1*s.* (*postage* 1½*d.*).
,, ,, **Coral Gallery** (Protozoa, Porifera or Sponges, Hydrozoa and Anthozoa). Pp. 73. Illustrated. 1*s.* (*postage* 3½*d.*).
,, ,, **Galleries of Geology and Palaeontology.** Pp. 64. 2 Plates. 1*s.* (*postage* 1½*d.*).
,, ,, **Fossil Remains of Man.** Pp. 34. Illustrated. 6*d.* (*postage* 1*d.*).
,, ,, **Fossil Mammals and Birds.** Pp. 96. Illustrated. 1*s.* 6*d.* (*postage* 2*d.*).
,, ,, **Fossil Reptiles, Amphibians and Fishes.** Pp. 112. Illustrated. 2*s.* (*postage* 2½*d.*).
,, ,, **Mineral Gallery.** Pp. 32. 6*d.* (*postage* 1*d.*).
Student's Index to the Collection of Minerals. Pp. 33. 6*d.* (*postage* 1*d.*).
Introduction to the Study of Minerals. Pp. 72. 1*s.* (*postage* 2*d.*).
Introduction to the Study of Rocks. Pp. 142. 1*s.* 6*d.* (*postage* 2½*d.*).
Introduction to the Study of Meteorites. Pp. 125. 1*s.* (*postage* 3*d.*).
Guide to British Mycetozoa. Pp. 49. Illustrated. 1*s.* (*postage* 1*d.*).

SPECIAL GUIDES.

No. 6.—**Guide to the Exhibition illustrating the modification of the Structure of Animals in relation to Flight.** Pp. 80. Illustrated. 6*d.* (*postage* 1½*d.*).
No. 7.—**Guide to the Exhibition of Disease-carrying Insects and Arachnids.** Pp. 46. Illustrated. 6*d.* (*postage* 1*d.*).

INSTRUCTIONS FOR COLLECTORS.

Handbook of Instructions for Collectors. Pp. 222. Illustrated. 5*s.* (*postage* 3*d.*).

Instructions for Collectors:—

No. 1. **Mammals.** Pp. 8. Illustrated. 6*d.* (*postage* 1*d.*).
,, 1A. **Mammals** (Skeletons and Cetacea). Pp. 8. Illustrated. 3*d.* (*postage* 1*d.*).
,, 2. **Birds and their Eggs.** Pp. 14. Illustrated. 6*d.* (*postage* 1*d.*).
,, 3. **Reptiles, Batrachians and Fishes.** Pp. 12. 3*d.* (*postage* 1*d.*).
,, 4. **Insects.** Pp. 12. Illustrated. 6*d.* (*postage* 1*d.*).
,, 5. **Diptera.** Pp. 16. Illustrated. 6*d.* (*postage* 1*d.*).
,, 6. **Mosquitoes.** Pp. 8. Illustrated. 6*d.* (*postage* 1*d.*).
,, 7. **Bloodsucking Flies, Ticks, &c.** Pp. 24. Illustrated. 3*d.* (*postage* 1*d.*).
,, 8. **Spiders, Centipedes, Peripatus, &c.** Pp. 4. Illustrated. 3*d.* (*postage* 1*d.*).
,, 9. **Soft-bodied and other Invertebrate Animals.** Pp. 20. 6*d.* (*postage* 1*d.*).
,, 10. **Plants.** Pp. 10. Illustrated. 6*d.* (*postage* 1*d.*).
,, 11. **Fossils and Minerals.** Pp. 8. 3*d.* (*postage* 1*d.*).
,, 12. **Worms.** Pp. 23. Illustrated. 3*d.* (*postage* 1*d.*).
,, 13. **Alcohol and Alcoholometers.** Pp. 8. 3*d.* (*postage* 1*d.*).

The above publications can be purchased at the Natural History Museum, Cromwell Road, London, S.W. 7. Postal applications should be accompanied by a remittance, including postage.

BRITISH MUSEUM (NATURAL HISTORY)
CROMWELL ROAD, LONDON, S.W. 7.

MINERAL DEPARTMENT.

AN INTRODUCTION
TO THE
STUDY OF MINERALS

BY THE LATE

SIR L. FLETCHER, M.A., F.R.S.,
FORMERLY DIRECTOR OF THE NATURAL HISTORY DEPARTMENTS OF THE BRITISH MUSEUM.

SIXTEENTH EDITION.

LONDON:
PRINTED BY ORDER OF THE TRUSTEES OF THE BRITISH MUSEUM.
SOLD AT
THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD, S.W. 7.
AND BY
B. QUARITCH, LTD.; DULAU & CO., LTD.; THE OXFORD UNIVERSITY PRESS; AND WHELDON & WESLEY, LTD., LONDON; ALSO BY OLIVER & BOYD, EDINBURGH.
1924.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
DUKE STREET, STAMFORD STREET, S.E. 1, AND GREAT WINDMILL STREET, W. 1

THE MINERAL COLLECTIONS.

It is recommended that the Mineral Collections be studied in the following order:

I. The Introduction to the Study of Minerals, in the first four window-cases on the left-hand side of the Gallery.

II. The Species and Varieties of Minerals, in table-cases 1–41 in the Gallery.

III. The Introduction to the Study of Rocks, in window-cases V–X on the left-hand side of the Gallery (see the special Guide).

IV. The Collection of Typical Rocks, in the eleven window-cases on the right-hand side of the Gallery.

V. The Introduction to the Study of Meteorites, in case 47 in the Pavilion at the end of the Gallery (see the special Guide).

VI. The Collection of Meteorites, in cases 1–4 in the Pavilion.

Guide.—For the use of the visitor there is published a Guide to the Mineral Gallery in which descriptions are given of the more common and interesting minerals, with references to the cases in which specimens are placed.

Student's Index.—For the use of the Student there is published an Index to the names and synonyms of all the mineral species and varieties represented in the Mineral Collection.

Recent Additions.—For some time previous to their dispersion through the General Collection, the most interesting of the *Recent Additions* are arranged for inspection in table-case 43 at the end of the Gallery.

PREFACE TO THE FIRST EDITION.

EVERY visitor of a Natural History Museum can trace a likeness between the Animals and Plants shown there and those with which he is already familiar, and he is thus ready to derive pleasure and instruction from their examination.

But when he comes to the Minerals, and finds that with life and organised structure has apparently disappeared everything which gives separateness to the individual, and that hardly any distinctive character seems to be left save colour, he becomes impressed with the idea that, while their beauty is evident, minerals must fail of being discriminated unless we penetrate beyond their superficial aspects.

An attempt is made in the present Guide to facilitate the comprehension of the subject by "An Introduction to the Study of Minerals." It is there sought to give a statement of the more important discoveries upon which the Science of Mineralogy is based, in such a form as to be intelligible to those who have hitherto given no attention to the wonders of the Mineral Kingdom, and at the same time to be of service to the student by indicating relations between mineral characters which might otherwise escape attention.

In addition to the specimens and models selected to make clear the statements and the reasoning of the Introduction, others have been arranged in the window-cases of the Gallery to illustrate in detail the various characters of minerals.

June 18*th*, 1884.

L. FLETCHER,
Keeper of Minerals.

PREFACE TO THE SIXTEENTH EDITION.

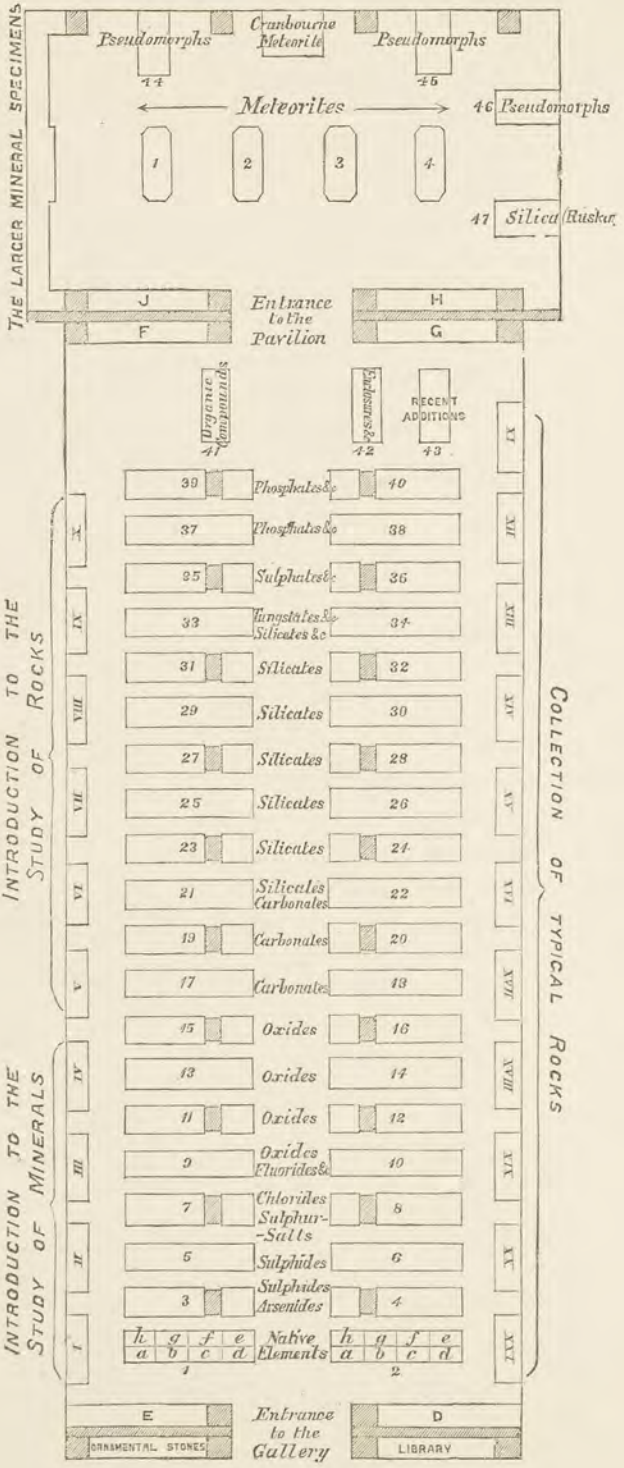
THE sixteenth edition is practically a reprint of the fifteenth, with only a few alterations.

August 16*th*, 1924.

G. T. PRIOR,
Keeper of Minerals.

TABLE OF CONTENTS.

PLAN OF THE MINERAL GALLERY



THE GENERAL ARRANGEMENT OF THE MINERAL COLLECTIONS.

By ascending the large staircase opposite to the Grand Entrance of the Museum and turning to the right, the visitor will reach a corridor leading to the Department of Minerals.

In a wall-case of the corridor, near the entrance to the Mineral Gallery, are shown polished specimens of some of the rocks and simple minerals used for decorative purposes.

Leaving the corridor the visitor will find the collections arranged in two rooms; the first of them, the Gallery, measuring 236 feet by 50 feet, the other, the Pavilion, 37 feet by 60 feet.

The mineral collections are arranged as follows:—

Minerals: A series illustrating the gradual development of the Science of Mineralogy, the characters of minerals, and the terms used in their description (window-cases I–IV); the collection of species and varieties (table-cases 1–41, the larger specimens being collected together in the wall-cases in the Pavilion); enclosures in minerals (table-case 42, in the Gallery); collection of isolated crystals with models (wall-cases D and E, also in the Gallery); pseudomorphs (table-cases 44–46, in the Pavilion).

Rocks: An introductory series illustrating the characters of rocks (window-cases V–X); the collection of typical rocks (window-cases XI – XXI): the larger rock-specimens are shown in wall-cases F and G at the eastern end of the Gallery.

Meteorites: An introductory series (case 47 in the Pavilion); the collection of meteorites (cases 1–4 in the Pavilion).

The most interesting of the *Recent Additions* are shown for a time in table-case 43 at the farther end of the Gallery.

THE HISTORY OF THE COLLECTIONS.*

THE Minerals formed a considerable part of Sir Hans Sloane's collections, of which the acquisition by the nation in 1753 led to the establishment of the British Museum; but however good they may have been for the early times in which they were collected, it was decided in 1799 that they failed to represent satisfactorily the variety, the natural forms, or the modes of occurrence of the products belonging to the Mineral Kingdom. Most of them have been replaced by better specimens; the rest consist chiefly of wrought articles of agate, jasper, and rock-crystal. Of these wrought articles, such as are interesting rather for the workmanship bestowed upon them than for the material of which they are made, are deposited at the British Museum (Bloomsbury); most of the remainder are shown in the table-cases of the Gallery.

Through the purchase in 1799 of the collection formed by Mr. Charles Hatchett, the bequest in the same year of the collection of very select minerals formed by the Rev. Clayton Mordaunt Cracherode, and the purchase in 1810 of the large collection made by the Right Honourable Charles Greville, including unique specimens of Rubellite and Cromfordite, the Mineral Collection of the British Museum was raised by 1810 to a very high, perhaps the highest, position among the mineral collections of the world.

In 1828–9 the Collection was increased by a series of specimens from the Harz district, presented by His Majesty King George IV, the silver-yielding minerals being particularly fine.

During the immediately succeeding years many specimens which had belonged to the collections of Mr. Heuland and Lady Aylesford were purchased for the Trustees; after the dispersion of the Aylesford collection the manuscript catalogue was obtained for the Museum.

In 1857 a Department of Minerals was instituted, and placed under the Keepership of Mr. Story-Maskelyne, Professor of Mineralogy in the University of Oxford. During his term of office, which lasted for twenty-three years, the Trustees were enabled by timely purchases to impart to the collection a perhaps unrivalled excellence, as well in its general completeness as in the perfection of individual specimens.

---

* The History of the Collections contained in the Natural History Departments of the British Museum; 1904, Vol. I., pp. 343–442.

The most important additions during this period were the Allan-Greg and the Koksharov Collections. The first of these had been begun and catalogued by Mr. Thomas Allan of Edinburgh, after whose death it was purchased by Mr. R. H. Greg; additions were made to it by his son, Mr. Robert P. Greg, through whom it was purchased by the Trustees in 1860. It supplied many species previously wanting, and was especially valuable for the authenticity of the localities assigned to the specimens, in which respect the Museum Collection had at that time fallen much in arrear. Its acquisition gave a new starting point for the Collection of Meteorites by the addition of a carefully formed series of those bodies; this has since become as complete a collection as can be made.

The other collection was purchased in 1865 from the eminent Russian crystallographer, General von Koksharov; it includes a very fine series of Russian and, in particular, of Siberian minerals, among which are specimens of Topaz and Euclase of the greatest rarity.

The collection formed by Mr. Richard Bright of Bristol, presented to the Trustees in 1873 by his grandson Mr. Benjamin Bright, furnished many additional good specimens.

In 1911 over 200 of the finest specimens belonging to the collection formed by Mr. Isaac Walker (1794–1853) were acquired, partly by purchase, and partly by presentation by Mr. F. N. Ashcroft; these include Pyrargyrite (Case 8a), Alexandrite (Case 9c), Olivine (Case 22f), Topaz (Case 26), Mimetite (Case 40g).

Of other remarkable specimens presented to the Trustees for the National Collection we may specially mention:—

The large mass of Meteoric Iron from Otumpa, presented in 1826 by **Sir Woodbine Parish, F.R.S.**

Several unusually fine specimens, presented in 1836 by **Richard Simmons, Esq., F.R.S.**, including specimens of Native Gold (Case 2d), Cerussite (Case 18c), Idocrase (Case 25e), Beryl (Case 30a), and Mimetite (Case 40g).

A large specimen of Selenite, presented in 1847 by **H.R.H. the late Prince Consort.**

A series of minerals from Greenland, including a fine specimen of Columbite (Case 34f), presented in 1855 by **Joseph Walter Tayler, Esq.**

A fine series of Apophyllites and Stilbites from India, presented in 1860–1 by **James J. Berkley, Esq.**

The Parnallee and Nellore Meteorites, presented in 1862 by **Sir William Denison, K.C.B., Governor of Madras.**

The Cranbourne Meteorite, presented in 1862 by **James Bruce, Esq.**

A beautiful specimen of Rubellite from Ava (Case 33a), presented in 1869 by **C. S. J. L. Guthrie, Esq.**

A magnificent specimen of Proustite (Case 8b), presented in 1876 by **Henry Ludlam, Esq.**

A large meteorite from Imilac, presented in 1879 by **George Hicks, Esq.** (separate stand).

A series of minerals, chiefly Cornish, selected from the collection of the late J. M. Williams, Esq.; presented in 1893 by **J. C. Williams, Esq., M.P.**

Four large crystals and a cleavage-slab of Selenite, presented in 1893 by **Professor J. E. Talmage.**

A polished slab of Antique Porphyry, presented in 1894 by **Henry Yates Thompson, Esq.**

Crystallised masses and groups of Chessylite and Malachite from Arizona (Case 22b and Wall-case K), presented in 1896 by **James Douglas, Esq.**

A collection of Gold Tellurides and other Gold ores from Western Australia, presented in 1902 by the **Government of Western Australia** and various **Western Australian Companies.**

The large and symmetrical crystal of Diamond, weighing 130 carats (Case 1f), the pink crystals of Fluor from Switzerland (Case 7h), a long branch of Native Copper (Wall-case H), and many specimens of Native Silica shown in a table-case of the Pavilion, presented at different times by **Professor John Ruskin.**

Various minerals, including fine specimens of Queensland Opal (Case 16f), presented at different times by **Professor N. S. Maskelyne, F.R.S.**

A series of minerals, including remarkable specimens of Zeolites from the Færoe Islands, Iceland, and Co. Antrim, selected from the collection of the late **Miss Caroline Birley**; by bequest in 1908.

An old collection of minerals of great historic interest, brought together by Mr. Thomas Pennant (1726–1798), presented in 1913 by the **Earl of Denbigh, C.V.O.**

A large series of fine specimens of Zeolites, presented at different times by **F. N. Ashcroft, Esq., M.A.**

A valuable collection of 203 faceted gem-stones, brought together by the late **Sir Arthur Herbert Church, K.C.V.O., F.R.S.**, presented in 1915 by **Lady Church.**

A fine series of Swiss minerals from the collection of the late **Rev. J. M. Gordon, M.A.**; by bequest in 1922.

THE SCOPE OF A COMPLETE MINERAL COLLECTION.

A Mineral collection, in order to be complete, must aim at representing all the definite varieties of chemical composition of the distinct mineral substances which occur in the Earth's crust, and at the same time must illustrate the often very extensive varieties of crystalline form assumed by the minerals of a species or group. But besides these chemical and morphological features other important characters have to be illustrated, among which are the various modes of occurrence of each particular mineral, including its associations with other minerals; and in a great National Collection that is to illustrate the mineralogy of the world, it is important that there be specimens from all localities where a mineral occurs under special and noteworthy circumstances; and it must be a special object that examples of each mineral species should show its most complete development, whether in magnitude or perfection of crystals, in the colour and limpid purity, or in any other important quality which may belong to it in its more exceptional occurrence.

In a mineral collection formed and arranged with these purposes in view, will be found materials of the greatest interest for science, and alike for the useful and ornamental arts: to the Crystallographer, it offers some of the best illustrations of a most beautiful geometrical science; to the Physicist, it provides the material on which some of the most refined and important investigations have been and may be made in connection with the theories of light, heat, magnetism, and electricity; and to the Geologist, its petrological department presents the means for discriminating those minerals, of which, though they are often only recognisable under the microscope, the largest portion of the Earth's crust is formed.

Here will be found, in all their variety, beauty, and association, the minerals which, under the name of *ores*, furnish the metals so essential to the needs and happiness of man; here also are specimens of the numerous minerals which, whether immediately or as the sources from which manufacturers derive important products, are employed in the multifarious purposes of daily life. The suggestion that materials for construction and architectural ornament, for pigments, mordants, and bleaching processes, that the phosphates for manures, the alkalies, and the materials for the manufacture of acids, are all largely dependent on the mineral resources of the world, will sufficiently show how intimately a complete mineral collection is connected with the arts and with commerce.

An illustration of the importance of a single mineral is afforded by Calcite or carbonate of lime. As the almost ubiquitous limestone, it supplies in some of its varieties the building materials of our cities; and when burnt gives quicklime, and in some of its impurer forms hydraulic cement; while in other varieties it presents itself as the white and spotless material used for statuary marble; or, again, beautifully and finely coloured, forms the infinitely varied ornamental marbles; sometimes it appears as calc-spar in a thousand crystalline forms, which it takes the skill of a crystallographer to reduce to a common symmetry; or, again, as in one locality in Iceland, it occurs in large masses of limpid crystal conspicuous for its double refraction, a character which rendered it invaluable in the hands of Bartholinus, Huygens, and Fresnel, for the investigation of the properties of light; or, again, in its softer form of chalk, it subserves many a domestic use.

Here also are to be found rough and cut specimens of the precious stones, among which may be mentioned the Diamond, a crystallised form of the element carbon; the Balas ruby and the Spinel ruby, a compound of alumina and magnesia; the Chrysoberyl and Alexandrite, a combination of alumina and beryllia; the Sapphire and Ruby, the sesquioxide of aluminium; the Hyacinth and Jargoon, a compound of silica and zirconia; the Amethyst, Sard, Plasma, Prase, Chalcedony, and Precious Opal, varieties of silica; the Chrysolite and Peridot, a silicate of magnesium and iron; the Garnet with a varied composition; the Beryl, Emerald, and Euclase, compound silicates of aluminium and beryllium; the Tourmaline and Rubellite, a borosilicate of several bases; the Lapis-lazuli, a compound silicate and sulphate; and the Turquoise, a hydrated phosphate of aluminium.

Petrology, so far as it is a classificatory science, it is essentially the function of a mineralogist to study and illustrate. The interest presented by a rock is not merely dependent upon its chemical composition, though that is one of its fundamental characters, nor upon its being a compact aggregation of the various minerals among which the chemical ingredients are distributed; but it is also historical, since the rock has assumed the form, in which we observe it, at some earlier period of geological time. To trace that history, and to collocate the various rocks of the globe in their relative positions and historical sequence, and to make each rock contribute its evidence towards the building up of that history, is the part of the geologist; but it falls entirely to the mineralogist to collect, describe, and classify the almost numberless varieties of rock with which the geologist has to deal.

And to describe a rock with accuracy is perhaps the most difficult task that the mineralogist has to perform. It is possible to make a complete chemical analysis of the whole of a rock-fragment, but the cases in which the individual minerals that compose the fragment can be isolated and separately analysed are extremely rare. The microscope, however, has been called in to raise the power of human introspection; by that instrument not only are the mineral ingredients of a thin slice of a rock—so thin as to be perfectly transparent—rendered visible, but the action of each separate ingredient upon the transmitted light can be easily ascertained. By combining the instruction gained from the chemical analysis of rock-fragments with the results of such a microscopic study, the mineralogist, after a long and intimate experience, is enabled to speak, with at least an approximate certainty, of the characters and even the chemical composition of the various constituent minerals of each kind of rock.

The great divisions of a petrological series are readily marked out, though their precise boundaries are not always so easy to define. We have, for instance, the sedimentary rocks, sometimes composed largely of a single ingredient, as the sandstones and limestones, at other times less simple in their nature, as the clays, shales, and slates. Again, we have the igneous rocks, comprising, on the one hand, lavas and beds of ash and pumice that have been poured out or ejected from orifices in the Earth's crust, and, on the other hand, the more compact forms which have cooled from a condition of fusion, or semi-fusion, under the pressure of superincumbent strata. Again, there are rocks of an intermediate character, in which a sedimentary deposit has become metamorphosed in the course of time under the combined influences of pressure and temperature.

Nor from the list of the interesting contributions of a mineral collection should be omitted the series of meteoric bodies which have come to this Earth from the regions of space. These strange masses of metallic iron, more or less rich in nickel, or of stone impregnated with the same metallic material, serve as witnesses that the same laws of chemical combination and of crystallographic symmetry, and the same elements of which our own world is built up, pervade the regions of space through which these masses of matter have wandered swiftly till, entangled in our atmosphere, they have been arrested in their career and have fallen to the Earth with startling accompaniments of explosion, fusion, and dissipation of their material, as a consequence of the enormous temperature for which they have exchanged an often more than planetary velocity.

◆

AN INTRODUCTION

TO THE

STUDY OF MINERALS.

The specimens and models illustrative of this Introduction are arranged in the first four window-cases on the left-hand side of the Gallery.

The Mineral Kingdom.

1. THE material products of Nature have been assigned to three Kingdoms,—the Animal, the Vegetable, and the Mineral; to the two former belong all those material products which are living or have lived, to the latter all those products which have not been endowed with life.

Specimen of fluor.

The products which are living or have lived can generally be most conveniently discriminated from those which have not been endowed with life by the presence of organs essential to the nutrition, growth, and reproduction of such products.

The distinction, however, is not always very obvious, for in some cases the outer form of a mineral product is so like that of a plant that it misleads the ordinary observer.

Specimens of pyrolusite and moss-agate.

Its extent.

2. The Mineral Kingdom includes not only the mineral products belonging to our own Earth, but also those which belong to outer space: some knowledge of the latter has been gained directly by examination of the bodies called METEORITES which have fallen from the sky; and also, indirectly, by a study of the light which reaches us from the sun, the stars, and the comets. These investigations have not yet indicated the existence of life outside our own planet.

Specimen.

The Science of Mineralogy

3. It is practically possible to obtain a direct knowledge of the mineral products of our own Earth within only a mile or so from its surface; but the detailed investigation of even this limited amount of matter is far too vast for one individual or one science.

The study of the present configuration of the Earth's crust is accordingly left to the Geographer, and the historical aspect of the materials to the Geologist; the Mineralogist deals, not with the Earth's configuration past or present, but with the characters, localities of occurrence, changes, and associations of the matter itself, and deduces principles on which to classify the various kinds.

Soil.

4. The first mineral product met with in the examination of the solid portion of the Earth is usually a loose *Soil*, which on inspection is found to be a mixture of fragments of substances of different kinds, and to be such as would result from the wearing away of the more compact matter in the neighbourhood.

Specimen.

Rock.

5. Beneath the loose soil is a firmer material, retaining much the same character generally over a considerable area of country and sometimes for a considerable depth; to such a material the term ROCK is applied.

Specimen of mica-schist.

Rocks are generally composite.

As in soil, so also in most kinds of rock the unaided eye is able to detect different kinds of matter.

Specimen.

> The illustrative specimen in the case is a fragment of a rock called Granite; mere inspection teaches us that in this specimen at least three different kinds of matter come together—first, a substance of a light brown colour, with some of its surfaces quite smooth and plane (Felspar); secondly, a substance of a glassy aspect, milky colour, and irregular shape (Quartz); and, thirdly, a dark-coloured substance apparently made up of thin leaves (Mica). By a process of mechanical division we can thus extract from this fragment of rock at least three kinds of substances; and these will prove to be distinct from each other, not only in outward appearance, but in all their manifold properties.

Simple minerals.

6. It will be found, however, that by no amount of *mechanical* division can any of these three substances be made to yield another having a different set of characters; they are SIMPLE MINERALS.

Specimens.

Other rocks.

7. The compositeness of some rocks is less evident to the naked eye, and requires the aid of a microscope for its demonstration.

Specimen of diabase.

Other rocks, as Marble, are of a simpler nature than the above, and consist wholly of matter of a single kind.*

Specimen.

Rock-forming minerals are not of many different kinds.

8. Up to the present we have had regard only to those minerals which are scattered more or less regularly throughout the whole mass of a rock; although such simple minerals compose the greater portion of the crust of the Earth, their kinds are extremely limited in number.

Modes of occurrence of other simple minerals.

9. But in addition to the above, rocks contain, either completely embedded or lining crevices and cavities, many other simple minerals, more or less irregular or local in their occurrence; and it is by these latter, which have had space for their free development, that the characters of minerals, more especially their forms, are best displayed.

> For instance, from a side of the cavity of a specimen exhibited in the case springs a beautiful mineral (Natrolite), showing no evident likeness to any component of the enclosing rock (Basalt); and a like remark may be made with respect to the simple substance (Wavellite) which lines the sides of the two parts of the adjacent specimen (Sandstone). It is from veins and lodes, sometimes of enormous size, that most of the mineral wealth of the world is derived.

Specimens.

Sometimes simple minerals are found as loose waterworn pebbles on a sea-shore or in the bed of a stream.

Specimens of corundum.

Fluid minerals.

10. In addition to the solid mineral products of Nature, there are others which are liquid or gaseous at the ordinary temperature; as they are few in number and generally mixtures, with the exception of the liquid Mercury, they will be left out of consideration in the following pages.

11. The existence of *simple minerals* is so striking a fact that it must have been more or less distinctly recognised from the earliest times. But to determine the properties of each kind of simple mineral so far as to be able to assert that one specimen is of the same kind or is different from another, and to classify the various kinds, are difficulties of a very serious character. A brief sketch of the gradual development of the

---

* *Introduction to the Study of Rocks.* 1s. 6*d.*

Science of Mineralogy will perhaps be the most instructive mode of explaining the nature of these difficulties and the ways in which they have been met.*

Distinction of minerals into kinds by the ancients.

12. The modern student relies so much on crystalline form and chemical composition as distinguishing characters, that he is at times almost inclined to believe that without a knowledge of these any distinction into kinds must have been impracticable; and yet, to give only a single instance, the diamond was recognised as a distinct mineral, and distinguished by a special name, very many centuries before its combustibility and its chemical identity with carbon had been discovered.

In the oldest existing treatise on Minerals † we are told how the subject was treated more than two thousand years ago.

Minerals were then classified as Metals, Stones, and Earths. The class of *Metals* included not only the metals proper, but all those minerals which are dense and have a metallic lustre; that of *Stones* contained those which are unacted upon by water; while the *Earths* were minerals which, when placed in water, either fall to pieces or are dissolved therein.

The following extract from the treatise referred to will show what were the properties then used for the distinction of "Stones" into kinds:—

> "There are in Stones of different kinds many peculiar qualities; of which colour, transparency, brightness, density, hardness, tenacity and the like are frequent, though other more remarkable properties are not so common. But beside these qualities there are others; such as their acting upon other bodies, or being subject or not subject to be acted upon by them. Some are fusible, others will never liquefy in the fire; some may be calcined, others are incombustible; to which it may be added that in the action of fire on them they show also many other differences. Some, as Amber, have an attractive quality. Others serve for the trial of Metals, as the Lydian stone.

---

* See also Whewell's History of the Inductive Sciences. London, 1857.

† History of Stones; written by Theophrastus shortly before 300 B.C. English version by John Hill. London, 1746.

> "But the most known and general properties of Stones are their several fitnesses for the various kinds of work. Some of them are proper for engraving on; others may be shaped by the turner's tools; others may be cut or sawn. Some also there are which no iron instruments will touch, and others which are very difficultly, or scarcely at all, to be cut by them."

Experiment necessary.

13. Among the characters mentioned above there is not a single important one, appealing directly to the sense of sight alone, which will serve for the distinction of minerals into kinds; for colour, transparency, and brightness are either too common or too inconstant to be of much avail. The fact that the most important distinguishing characters require experiment for their determination, and thus cannot be learned from a mere inspection of the specimens as they lie in a table-case, is the chief reason why a collection of Minerals is so much more difficult to understand than is one of Animals or Plants.

Origin of the term Crystal.

14. In the course of time another important and general but less obvious character came gradually into recognition.

Specimens.

To a certain mineral the ancients gave the name Crystal (i.e., clear ice), for, owing to its transparency, its freedom from colour, and the frequency with which it enclosed other bodies, the ancients imagined that it had been formed through the subjection of water to an intense cold. Even so lately as the year 1672 this idea as to the origin of Crystal is referred to by the learned experimenter, Robert Boyle,* in the following words:—

> "I found the weight of Crystal to be to that of water of equal bulk as two and almost two-thirds to one; which, by the way, shows us how groundlessly many learned men, as well ancient as modern, make Crystal to be but ice extraordinarily hardened by a long and vehement cold, whereas ice is, bulk for bulk, lighter than water (and therefore swims upon it), and (to add that objection

---

* An Essay about the Origine and Virtues of Gems; by Robert Boyle London, 1672.

against the vulgar error) Madagascar and other countries in the Torrid zone abound with Crystal."

"Crystal" is bounded by plane surfaces.

It was observed by the ancients that this mineral, wherever found, has a characteristic shape (Fig. 1). It is naturally bounded by flat surfaces (or planes) arranged in a definite way —six of them generally forming a column (or prism), at each end of which are arranged six other planes so inclined that they form a pyramid. The relative sizes and the shapes of these planes vary in different specimens; the prism may be comparatively short, or even be entirely absent.

Fig. 1.

Later meaning of the term Crystal.

Specimens.

15. This peculiarity of being naturally bounded by flat surfaces, and not by the curved ones which are so characteristic both of Plants and Animals, was afterwards found to belong not only to "Crystal" but to other minerals both transparent and opaque; so that by an extension of its meaning the term *Crystal* was eventually used to signify, not the particular kind of mineral still known as Rock-crystal, but any mineral naturally limited by plane faces.

Steno's discovery.

16. It was not till 1669 that any important addition to the knowledge of the properties of minerals was made. In that year **Nicolaus Steno**,[*] a Danish physician, announced that, amid all the variations in the sizes and shapes of the faces of the mineral termed Rock-crystal, there was something constant besides the number and the grouping of the faces. Cutting each of a series of specimens in a direction at right angles to the edges of the prism, he found that the edges of the six-

---

[*] De solido intra solidum naturaliter contento dissertationis prodromus. Florentiæ, 1669: English translation, London, 1671. Figs. 2 and 3 are reproductions of figures given by Steno.

sided sections thus obtained vary in length, and thus give figures apparently quite distinct from each other (Fig. 2).

Fig. 2.

On careful examination of these figures, Steno found that although the sides vary in length they do not vary in inclination to each other; that in fact the angles of any one figure are equal to each other and also to every angle of each of the remaining figures. Again, making sections of the specimens in another direction, namely, at right angles to the edge formed by a face of a pyramid with a face of the prism, he obtained such figures as the following (Fig. 3):—

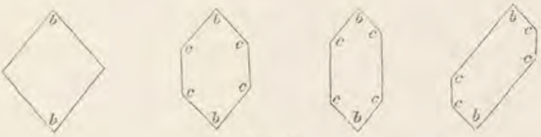


Fig. 3.

The angles of any one of these figures are not, as in the previous case, all equal to each other; two of them, the opposite and equal angles *b*, are different in size from the remaining four equal angles *c*, while both *b* and *c* are distinct in size from the angles *a* of the previous figures. And in the case of each of the specimens examined, Steno found that when the section was made in the stated direction he always obtained a figure having two angles equal to *b* and four angles equal to *c*, except when the absence of the prism led to a four-sided figure with two opposite angles equal to *b*, as shown in Fig. 3.

Hence he inferred that in all specimens of Rock-crystal corresponding pairs of faces have the same inclination.

17. A simpler method of procedure is to cut an angle in cardboard into which an angle of one of the specimens will just fit, and then to show that this is likewise the case with a corresponding angle of any other specimen.

Steno's explanation.

18. To account for this property Steno made the following suggestions:—

1. Rock-crystal has once been liquid; as is shown by the way in which it encloses other bodies. Specimens.
2. Rock-crystal may increase in size; as is proved by the fact that sometimes stages in the growth are indicated by the positions of the enclosures. Specimens.
3. The original nucleus, owing to the "nature of Rock-crystal," assumed the form of a regular six-sided prism, terminated at each end by a six-sided pyramid.
4. The increase is due to the deposit of layers of matter upon the faces of the nucleus.
5. The thickness of the layer deposited upon a given face is the same in all its parts; the outer surface will therefore still be plane and be parallel to the face upon which the layer is deposited; hence the angles between the faces will remain constant in size during the growth.
6. The thickness of a layer, though constant for various parts of the same face, is different for different faces, owing to the variety of their positions relative to the surrounding liquid; the faces themselves may thus vary considerably both in size and shape.

These suggestions, though on the whole satisfactory, fail to account for the presence of faces additional to the more prominent ones already referred to; and yet such additional faces are of common occurrence. Specimen.

Crystallisation.

19. The specimens of no other mineral being so similar to each other in form as those of Rock-crystal, a whole century passed away before any extension was given to the law announced by Steno. In the meantime it was found that a natural limitation by plane faces is to be met with, not only in the Mineral Kingdom, but whenever any dissolved substance reappears in the solid state through the evaporation of the solvent; and that when the evaporation is slow and the disturbance small, very perfect crystals are the result. Crystals thus obtained have been termed *artificial*. It was further remarked that to some extent the shape of a crystal depends Specimens.

on the kind of substance dissolved; common salt reappears as cubes, alum as octahedra, blue vitriol in rhomboidal forms, and nitre as prisms. It thus came to be imagined to be a general law of Nature that when the particles of a body are separated by a fluid and thus made free to move, they tend to arrange themselves into regular shapes, limited by plane faces, when the fluid disappears. Still, although it was recognised that the shape of a crystal depends in some way or other on the nature of the substance, it was found that the dependence was not a simple one, for, even with the same substance, very different shapes of crystal may be obtained.

Romé de l'Isle.

20. To **Romé de l'Isle** * belongs the great credit of discovering that these various shapes of crystals of the same natural or artificial product are all intimately related to each other.

Primitive form.

Invention of a goniometer.

Specimen.

According to Romé de l'Isle, the shape of every crystal of the same substance is such as can be derived by a particular process from a certain fundamental figure called the PRIMITIVE FORM, the shape and angles of which depend only on the nature of the substance itself. The process consists simply in the replacement of the edges or the solid angles (quoins) of the primitive form by single planes or by groups of planes, but always in such a way that the total alteration is similarly related to all those parts of the primitive form which are geometrically similar to each other; these planes of replacement he regarded as secondary and more or less accidental. To establish this as a general law, Romé de l'Isle proceeded to determine the shape of the primitive form of every kind of known substance, whether natural or artificial; and he was able to do this with a certain degree of precision by means of an instrument for the measurement of angles, devised by Carangeot, to whom he had entrusted the preparation of some of the clay-models intended to illustrate his theory. He thus demonstrated that the angles between the faces of a primitive form are always the same for the same kind of substance, and are characteristic of it; for example, he showed that while the primitive form of alum, nitre, and sugar is in each case an

---

* Essai de Cristallographie. Paris, 1772. Cristallographie, ou description des formes propres à tous les corps du règne minéral. Paris, 1783.

octahedron, the angles of these primitive forms are different, for that which in alum is always 110°, is 120° in nitre and 100° in sugar.

Kinds of primitive form.

Models.

21. The different kinds of primitive form met with by Romé de l'Isle in his examination of natural and artificial crystals were only six in number (Fig. 4), namely :—

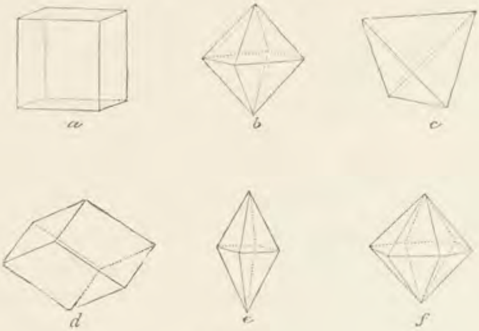


Fig. 4.

a. The cube,
b. The regular octahedron,
c. The regular tetrahedron,
d. The rhombohedron,
e. The octahedron with a rhombic base,
f. The double six-sided pyramid.

In the first three of these figures there can be no variety since they are by definition fixed in their angles, but in the latter three there may be any number of shapes due to difference in angle.

22. To make the theory of Romé de l'Isle more clear, it will be necessary to enter a little into detail; and in the first place we shall trace the varieties of crystalline form which his theory would lead one to expect to meet with in a mineral having the *cube* for primitive form. The illustrative specimens belong to the mineral Fluor.

Modifications of the cube.

Model and Specimen.

The faces of a cube being six equal squares, they are geometrically similar: all the twelve edges are likewise geometrically similar, for they are of equal length and are formed by faces meeting at the same inclination, namely, a right angle: all the eight solid angles are geometrically similar, for each of them is formed by the meeting of three similar edges all intersecting at the same inclination, a right angle. Any natural alteration of an edge of this primitive form we may expect to be similarly related to the two similar faces meeting in the edge, and any natural alteration of a solid angle to be similarly related to the three similar edges meeting in the solid angle; further, we may expect the same alterations to be repeated on all the similar edges and solid angles of the figure.

1. If an edge of the cube be replaced by a single face, the face must be equally inclined to the two similar faces meeting in the edge; and this alteration must be repeated on all the edges, since they are similar (Fig. 5). Model and Specimen.


Fig. 5.


Fig. 6.

2. If an edge be replaced by a face unequally inclined to the two faces meeting in that edge, a second face must also be present to make the total alteration similar with respect to the similar faces; and a similar pair of faces must replace each of the remaining edges (Fig. 6). Model and Specimen.

3. If a solid angle be replaced by a single face, the face must cut off equal lengths from the three similar edges forming that solid angle; and a similar face must replace each of the other solid angles. Models and Specimens.

As these new faces increase and the faces of the original cube diminish in size, there is a gradual transition from the cube to the regular octahedron (as shown in Figs. 7, 8, 9, 10).


Fig. 7.


Fig. 8.


Fig. 9.


Fig. 10.

4. Of the latter figure the faces, edges, and solid angles are respectively similar. Hence, just as in the cube, if an edge be replaced by a single face, the face must be equally inclined to the two similar faces meeting in the edge; and the alteration must be repeated on all the remaining edges (Fig. 11). Model.


Fig. 11.


Fig. 12.

5. And again, a solid angle of the last figure may be replaced by a single face cutting off equal lengths from the edges meeting in the solid angle; and the alteration must be repeated on the remaining solid angles (Fig. 12). Model and Specimen.

6. Returning to the cube, if a face replacing a solid angle cut off equal lengths from two of the edges, but a different length from the third edge, meeting in the solid angle, the total alteration will only be similarly related to the three similar edges if two additional faces come into existence; and a similar group of three faces must replace each of the remaining solid angles (Fig. 13). Model.


Fig. 13.


Fig. 14.

7. And, finally, if a face replacing a solid angle of the cube cut off unequal lengths from the three edges which meet in the solid angle, the total alteration will only be similarly related to the three similar edges if five other faces come into existence; and a similar group of six faces must replace each of the remaining solid angles (Fig. 14). Model and Specimen.

23. To make the theory still more clear we shall now apply it to the more difficult case where the primitive form is a *rhombohedron:* the relation between the derived forms will be more evident to the reader if he refer to the exhibited models, in which corresponding edges or faces are indicated by an identity of colour, rather than to the figures given in the text. The specimens illustrating the varieties of form are selected from the mineral Calcite.

The rhombohedron.

We must first ascertain which are the similar edges and similar solid angles of such a figure.

Model and Specimen.

Like the cube, the rhombohedron (Fig. 15) has six equal faces, each bounded by four equal edges; it differs from the cube in that the angles formed by these four edges instead of being all equal are only equal in pairs, one of which we may denote by *a* and the other by *b*.

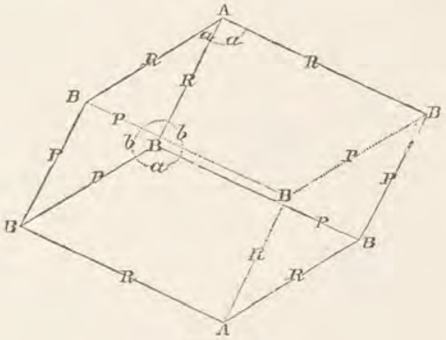


Fig. 15.

Its similar solid angles.

If now the rhombohedron be examined, it will be found that two opposite solid angles are geometrically similar to each other, each being contained by three plane angles *a*; but that these are different from the remaining six, which are in turn similar to each other, each being contained by two plane angles *b* and one plane angle *a*. Each of the first pair of similar solid angles is denoted in the figure by the letter A, and each of the remaining six by the letter B.

Its similar edges.

We have seen above that all the edges are equal in length; edges are, however, not *geometrically similar* unless they are formed by similar pairs of planes making the *same angle* with each other, or when they join similar pairs of solid angles. Thus the six edges denoted in the figure by the letter R are similar in that each of them joins a solid angle A to a solid angle B; but they are not similar to the six zig-zag edges denoted by the letter P, for these join only the solid angles B.

Or again, we have seen that each of the solid angles A is formed by three edges R having the same inclination to each other, namely, the angle *a*; whence it follows that the edges R are formed by planes having equal inclinations and are geometrically similar to each other. Also, since three edges which meet to form a solid angle B, are unequally inclined to each other, they cannot be all geometrically similar; the two edges P, however, make the same angle *b* with the edge R, and are so far similar to each other but not similar to R; it is further seen that the two edges P are contained by planes making the same angle, and that the angle is different from that between the planes which meet in the edge R.

Hence we conclude, that in a rhombohedron there are, from a geometrical point of view, two similar solid angles A, and six similar solid angles B; six similar edges R, meeting by threes in the pair of solid angles A, and six similar edges P, arranged in zig-zag form and passing by pairs through the six solid angles B; but the solid angles A are not similar to the solid angles B, nor the edges R to the edges P.

We now proceed to indicate some modifications of form which will be consistent with the theory enunciated by Romé de l'Isle.

Modifications of the rhombohedron.

1. Each of the similar solid angles A may be replaced by a single face cutting off equal lengths from the three similar edges R meeting in the solid angle (Fig. 16).

Model and Specimen.

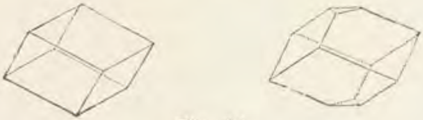


Fig. 16.

2. Each of the similar edges R of Fig. 17 (which represents a new position of the same rhombohedron) may be replaced by a single face equally inclined to the pair of faces meeting therein; as the new faces increase and the old faces diminish in size, there is a gradual transition to a more obtuse rhombohedron (Figs. 17, 18, 19, and 20).

Models and Specimens.

3. Each of the set of six similar solid angles B of this new rhombohedron (Fig. 21) may be replaced by a single face, cutting off

Models and Specimens.

equal lengths from the two similar edges and a different length from the third dissimilar edge meeting therein; if one of these new faces be parallel to the line joining the pair of similar solid angles A, the remaining five faces will also be parallel to it and the six faces will form a regular six-sided prism; in Fig. 22 the faces of the prism are small, and in Fig. 23 large.

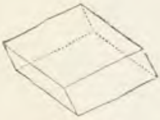


Fig. 17.

Fig. 18.

Fig. 19.

Fig. 20.

Fig. 21.

Fig. 22.

Fig. 23.

Fig. 24.

4. And again, each end of the last figure may be replaced by a single face cutting the six similar edges of the prism at the same inclination, a right angle (Fig. 24).

Model and Specimen.

5. Returning to the original rhombohedron (Fig. 25), each of the six zig-zag edges P may be replaced by a single face equally inclined to the pair of similar faces meeting therein (Fig. 26).

Model.

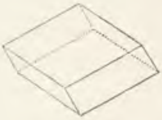


Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

6. If, on the other hand, a face replacing one of these edges P be unequally inclined to the two faces meeting in the edge, a second face must come into existence to make the total alteration similarly related to the similar faces; and a similar

Model and Specimen.

pair of faces must replace each of the remaining edges P (Fig. 27).

7. If the new faces increase until the old ones disappear, the resulting form is that shown in Fig. 28.

Model and Specimen.

8. And again, each of the set of six similar solid angles of the last figure may be replaced by a single face parallel to the line joining the pair of similar solid angles, thus giving rise to the shape shown in Fig. 29.

24. Such is the way in which Romé de l'Isle connected together the various crystalline forms met with in the same kind of substance. Some idea of the great advance in the knowledge of the forms of crystals which we owe to this mineralogist may be gained from an examination of the clay-models made for him by Lermina and Carangeot to illustrate the Treatise of 1783. One of these sets, which were the first ever made to illustrate a theory of crystals, is shown in the last pane of the adjacent wall-case E.

Difficulties of the theory.

25. Romé de l'Isle was very successful in proving that all the crystalline forms of the same substance belong to a series. The weak point of his theory was that the whole series could be derived in this way, not only from the primitive form itself, but from almost any one of the figures of the series, and that thus no hard and fast rule could be given for the determination of the true primitive; Romé de l'Isle himself was guided in his choice of the primitive by largeness of development and frequency of occurrence of particular faces, and by the simplicity of character of the figure formed by them; but in practice such a method presents great difficulties. It was owing to this mode of choice that he was led to adopt both the cube and the regular octahedron as distinct primitive forms, although, as we have seen, they are really terms of one series, and can be derived the one from the other by similar alteration of the similar solid angles.

26. Many of his contemporaries, however, went so far as to doubt not only the accuracy of his choice of the primitive form, but the very existence of the series; and, ten years after the publication of the Essay on Crystallography, we find the

Buffon. illustrious Buffon,* in his Natural History of Minerals, treating of the new science as follows:—

> "It has been claimed that crystallisation in rhombohedra is the specific character of Calcite; neglecting the fact that certain vitreous and metallic substances likewise crystallise in rhombohedra, and further, that although Calcite does seem to take by preference a rhomboidal figure, it takes also forms which are very different. Our crystallographers, in borrowing from the geometers the method by which a rhombohedron may be transformed to anocta hedron, a pyramid, and even a lens (for there is a lenticular spar), have only substituted ideal combinations for the real facts of Nature. No crystallisation will ever afford a specific character, for the variety is infinite; not only are there forms of crystallisation common to several substances of different nature, but, conversely, there are few substances of like nature which do not offer different forms of crystallisation. It would thus be more than precarious to establish differences or resemblances, real and essential, by mean of this variable and almost accidental character."

The truth is not obvious. **27.** That so distinguished a naturalist as Buffon could decline to recognise the correctness of the new theory is itself a testimony to the difficulty of the step which had just been taken. It was, indeed, not obvious on inspection that all the crystalline forms of a mineral belong to one series; and this is sufficiently evidenced by the discovery having been postponed to the time of Romé de l'Isle. The reasons are not far to seek: in the first place, as Romé de l'Isle himself remarks, mineralogists had not at that time begun to collect specimens conspicuous for the excellence of their crystalline form, having been content with such as well displayed the colour and lustre of a mineral, or the grouping of its crystals: in the second place, as was noticed above in the case of Rock-crystal, the symmetry of the arrangement of the angles may be almost hopelessly disguised by the differences in size of the corresponding faces.

---

* Histoire naturelle des Minéraux. Paris, 1783-8.

Haüy's discovery of the importance of cleavage.

28. The abbé **Haüy,**[*] however, soon broke down all opposition to the new science by discovering that a certain figure of the series of crystallisations has a distinct claim, if not an absolute right, to recognition as the true primitive form, and also that a wonderfully simple law controls the positions of the secondary faces.

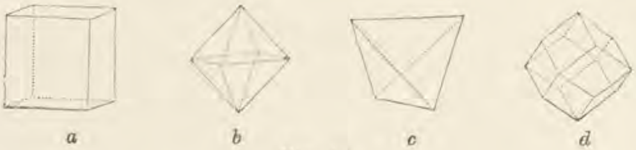
Specimen.

These important discoveries we now proceed to explain. A six-sided prism of Calcite had fallen from Haüy's table and had been broken in a way which attracted his attention: the fracture instead of being irregular like that of glass, presented a smooth plane face "with Nature's polish." On trial Haüy found that, with the help of a knife, further slices could be split off, not only parallel to the new face, but also in other directions similarly related to the alternate edges of the prism; and by carrying on the division to a certain point, he reduced (as indeed had been already done by Gahn, the pupil of Bergman) the six-sided prism to a rhombohedron. Repeating this experiment on other specimens of the same mineral, Haüy found that, whatever the outer form, the crystal could be reduced by cleavage to a kernel which always had exactly the same shape and the same angles; and that, treating this kernel as the primitive form, all the various crystallisations of Calcite could be derived from it by the process of Romé de l'Isle explained above. Extending the area of his experiments, Haüy found that this property was not peculiar to Calcite, but a general one; whence he inferred that the kernel obtained from a mineral by cleavage must be regarded as its true primitive form.

Haüy's primitive forms.

Models.

29. The various kinds of primitive form obtained by him during a long course of investigation were the following:



a *b* *c* *d*

Fig. 30.

1. The cube,
2. The regular octahedron,

---

[*] Essai d'une théorie sur la structure des crystaux. Paris, 1784.

3. The regular tetrahedron,
4. The rhombic dodecahedron (Fig. 30);

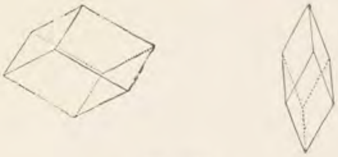


Fig. 31.

5. The rhombohedron, obtuse or acute (Fig. 31);

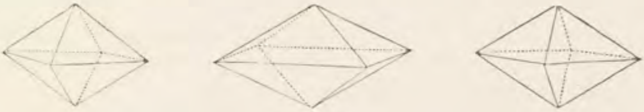


Fig. 32.

6. The octahedron, with square, rectangular, or rhombic base (Fig. 32);

Fig. 33.

7. The four-sided prism, with edges at right angles to the base, the base being either a square, a rectangle, a rhomb, or merely a parallelogram;

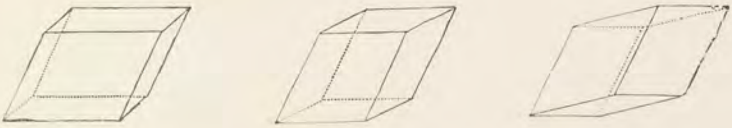


Fig. 34.

8. The four-sided prism, with edges inclined obliquely to the base, the base being either a rectangle, a rhomb, or merely a parallelogram (Fig. 34);

9. The regular six-sided prism (Fig. 35);
10. The double six-sided pyramid (Fig. 36).

Fig. 35.

Fig. 36.

30. Haüy further grouped these numerous figures into different kinds in another way:

(1) Figures bounded by parallelograms (Figs. 30*a*, 30*d*, 31, 33, 34).
(2) Figures bounded by eight triangles (Figs. 30*b*, 32).
(3) The regular tetrahedron (Fig. 30*c*).
(4) The regular six-sided prism (Fig. 35).
(5) The double six-sided pyramid (Fig. 36).

His theory of the structure of crystals.

31. By his study of cleavage Haüy was led to frame a theory of the *structure* of crystals, and to discover a law which connects the secondary faces with those of the primitive form.

He found that the kernel obtained by the cleavage of any crystal can be itself split up, and apparently without limit, for a plane of cleavage parallel to a face of the kernel is obtained, starting from any point at which the knife is placed.

Not believing in the infinite divisibility of crystals, Haüy was led to imagine that every crystal of the same substance can, theoretically at least, be reduced by cleavage to minute bricks of a definite size and shape, though too small to be separately visible.

32. Conversely—he argued—it must be possible from these minute bricks to build up a crystal having any of the forms presented by the mineral; it is only necessary to discover the mode in which the bricks must be arranged. For simplicity take the case where the little bricks are cubes.

In the first place, the resulting structure is to have the property of cleavage, and at all its parts the faces obtainable by cleavage are to have the same directions. Hence not only must the cubes be arranged parallel to each other in rows and layers, but they must not be interlocked, as are the bricks of an ordinary wall wherein cleavage is to be specially guarded against.

Models.

In the second place, the outer surface of the structure is to consist of a series of plane faces. A cube of any dimensions can be made still larger by adding to each of the faces layers of the proper size: but suppose that, starting from any edge of the cube, every new layer is just one row of bricks less in extent than the previous one; the layers will now be arranged in regular steps ascending from this edge, and all their edges will lie in a plane, just as those of a flight of stairs can all be touched by a carpenter's straight-edge (Figs. 37 and 38*a*). But the little bricks being really too small to be separately visible, the steps will appear to be wholly in this plane, and will thus form a secondary face equally inclined to two faces of the cube, for in each step the height is equal to the width. In the same way, a secondary face, having with respect to the faces of the cube an inclination

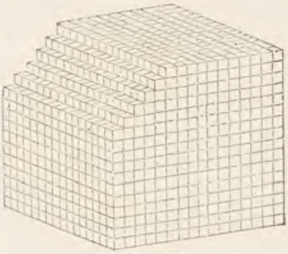


Fig. 37.

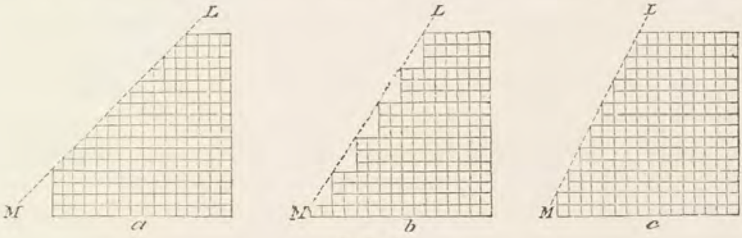


Fig. 38.

different from the above, but still determinable either by construction or by calculation, would be produced by the regular omission of two, three, or more rows, or by the deposition of layers two, three, or more bricks in thickness: in Fig. 38, LM shows the inclinations of the secondary face to those of the cube when each step is (*a*) one brick wide and one brick high, (*b*) two bricks wide and three bricks high, and (*c*) one brick wide and two bricks high.

If the arrangement of steps shown in Fig. 37 start from all the similar edges and be similarly disposed with regard to the similar faces of the primitive form, there will result such a group of steps as is shown in Fig. 39*a*, and, if the bricks be too small to be separately visible, such a group of faces as is shown in Fig. 39*b*: the same group can be derived from the cube by the process of Romé de l'Isle (Fig. 5), as indicated in § **22**.

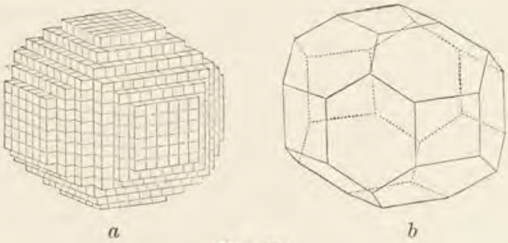


Fig. 39.

Haüy's law of whole numbers.

33. If the theory of Haüy be true, it follows that a secondary face has not an absolutely arbitrary position, as had been supposed by Romé de l'Isle, but only such as would result from the omission of whole numbers of rows, and from the layers having a thickness measured by some multiple of that of a single brick.

In fact, Haüy proved by measurement of a vast number of crystals that the inclinations of the secondary faces to those of the primitive form are such as would result in this way, and that the number of bricks in the width or height of a step is a very simple one, rarely exceeding six.

34. Such, briefly stated, is Haüy's theory of the structure of crystals. It is so simple, and moreover so completely consistent with the results of measurement, that the existence of series of crystallisations of the same mineral, all derivable according to simple laws from a primitive form characteristic of the mineral, was no longer questioned.

Objection to Haüy's theory of structure.

35. And yet the objections to the theory itself are very serious. It by no means follows that, because a crystal may be reduced by cleavage to certain fragments, the growth has taken place by the grouping together of the same fragments; and, indeed, we know that in slaty rocks the direction of cleavage is quite distinct from that of the planes of deposit. Again, some minerals have no distinct cleavage; others appear to be distinctly cleavable only in one or two directions: and as a solid figure cannot be bounded by faces having fewer than three directions, it is difficult to grant that in such minerals there is any cleavage-kernel at all. A more serious objection still is that when the cleavage-form is an octahedron, as in the case of Fluor, it is impossible to arrange the constituent bricks so as to completely fill up space; in fact, that the little octahedra may be parallel to each other and have their faces in directions parallel to the cleavages of the resulting crystal, they have to be arranged with only their edges in contact, and it is difficult to see that such a skeleton-like structure would not immediately collapse. Further, the two acknowledged facts, namely, the existence of series of crystallisations and the dependence of the positions of the secondary faces upon whole numbers, would still be explained in the same way if, instead of the cleavage-kernel, some other figure of the series were adopted as the primitive form.

Since the time of Haüy, the atomic theory of the constitution of matter has led to a more philosophical treatment of the facts which gave rise to his theory of crystal structure. In the mathematical investigations made by Bravais the idea of brick-like units in actual contact with each other gave place to that of atomic groups, the centres of mass of the latter being imagined to be arranged in the same way as the centres of the bricks of the original theory—namely, in straight lines and parallel planes. More general investigations by Sohncke and others have furnished results of great interest to the student.

Invention of axes and of systems of crystallisation by Weiss and Mohs independently.

36. Weiss,* the Professor of Mineralogy at Berlin, was the first to invent a mode of treatment which connected together the facts without requiring the assistance of any theory of structure at all.

In the first place, he arranged the primitive forms of Haüy into four classes, each distinguished by a purely geometrical character.

I. By joining the centres of the opposite faces of the cube, or the opposite solid angles of the regular octahedron, or the three pairs of similar solid angles of the rhombic dodecahedron, or the middle points of opposite edges of the regular tetrahedron, he obtained in each case three equal lines at right angles to each other.

II. Similarly, from the octahedron or the right prism with a square base, he again obtained three lines at right angles, but now only two of them were of equal length.

III. From a rhombohedron, or a regular six-sided prism, or a double six-sided pyramid, he obtained three lines in the same plane, all equal in length and equally inclined to each other, and a fourth line differing from the others in length and having a direction perpendicular to their plane.

IV. From an octahedron or a four-sided prism not having a square base, he obtained three lines at right angles but all of different lengths.

37. Conversely, starting from these four classes of sets of lines, Weiss deduced all the *primitive* forms of Haüy by constructing planes which passed :—

i.—through ends of three lines,

ii.—through ends of two of the lines and parallel to a third,

or iii.—through an end of one of the lines and parallel to two of them.

---

* De indagando formarum crystallinarum charactere geometrico principali dissertatio. Lipsiæ, 1809. Uebersichtliche Darstellung der verschiedenen natürlichen Abtheilungen der Krystallisations-systeme. (Denkschr. d. Berlin Akad. d. Wissensch. 1814–15.)

In other words, the planes either passed through an end of a line or else would not meet that line at all.

38. In the second place, he found that by taking points along each of these lines at twice, three times, and four times, &c., the original length, and constructing planes in the same way as before, he obtained a set which included all those *secondary* planes of which the actual existence on crystals had been demonstrated by Haüy.

These fundamental lines Weiss called *axes.*

39. A little later, but quite independently, **Mohs**,[*] the successor of Werner at Freiberg, arrived by a different process of reasoning at the same division into four classes, or, as Mohs now called them, *systems of crystallisation.*

The process was identical with that of Romé de l'Isle (§§ **22** & **23**), except that the positions of the derived planes were now limited by the law of whole numbers, in that the lengths cut off by these planes from each one of certain lines of the fundamental figure were in the ratio of whole numbers. The kinds of fundamental figure, each giving rise to a separate system of crystallisation, were as follows:

1.—The cube;
2.—The octahedron with a square base;
3.—The rhombohedron;
4.—The octahedron with a rhombic base;

and the systems of crystallisation derived from these were respectively called the Cubic, Pyramidal, Rhombohedral, and Prismatic; they correspond exactly with the groups I, II, III, IV of Weiss.

The notion of a primitive form disappears.

40. The notion of a primitive form thus disappeared wholly from the crystallography of Weiss, and almost from that of Mohs. The latter does, in truth, appear to take a primitive figure, but he employs it merely to *define* the series, and this

---

[*] The characters of the classes, orders, genera, and species; or, the characteristics of the Natural History System of Mineralogy. Edinburgh, 1820. Treatise on Mineralogy; or, the Natural History of the Mineral Kingdom; (translated from the German). Edinburgh, 1825.

might be done by means of any one of its figures: thus, exactly the same series of planes may be derived by his processes from the regular octahedron as from the cube.

The faces, which are predominant, or constantly occur, or are directions of cleavage, were regarded by neither Weiss nor Mohs as the *origin* of the series.

A simple form.

41. Since all similar edges and solid angles of each fundamental figure of Mohs were to be similarly altered, the existence of a single derived plane necessitated, as was the case in the theory of Romé de l'Isle, the simultaneous existence of a number of others having definite positions; such a set of faces was called by Mohs a *simple form* of crystallisation. Thus the regular octahedron, being derivable from the cube by a similar alteration of all the similar solid angles, is a simple form.

A combination.

If the faces of more than one simple form are present on a crystal (Figs. 5–9, 11–14), the resulting compound form is termed a *combination*.

As crystals generally exhibit combinations, and further (§§ **16** & **27**), the faces which are crystallographically similar usually vary considerably both in shape and size, such a series of large crystals as those of Fluor and Calcite shown in the case, presenting combinations, at once systematically developed and not too complex to be readily intelligible to the inexperienced, is one which it is difficult to get together; and indeed, the visitor will probably find that the specimens in the General Collection itself have usually forms which can only be interpreted after a most careful study.

Holohedry and hemihedry.

42. But there are sometimes found crystals presenting the faces of the regular tetrahedron; in other words, alternate faces of the regular octahedron are suppressed. Recognising this, both Romé de l'Isle and Haüy had regarded the regular tetrahedron as a distinct kind of primitive form.

To bring such modes of development within the limits of their systems, Weiss and Mohs found it necessary to imagine that simple forms may be not only complete, like the octahedron, but semi-complete, like the tetrahedron: the former kind was termed holohedral and the latter hemihedral. The half which presents itself is, however, not an arbitrary one, but can in every instance be geometrically derived in a systematic way from the complete simple form.

Discovery of two new systems of crystallisation.

43. Up to the present mention has been made of only four systems of crystallisation. In 1822 the precise measurement of certain crystals by means of a more accurate instrument, the reflective goniometer, invented in 1809 by Wollaston, led Mohs to assert the existence of two additional systems; for he found that the crystals presented forms which could not be referred to the kind of octahedron previously adopted, in which the lines joining the three pairs of opposite angles are perpendicular to each other, but must be referred to a kind of octahedron in which, in one class of cases, only two of these lines, and in the other class of cases, all three lines, are obliquely inclined to each other. Weiss, however, so strongly urged objections to the recognition of the new systems, still regarding those crystalline forms merely as developments of half-forms and quarter-forms from rectangular axes, that their independence can only be considered to have been fully established in 1833 by the discovery of the different actions of these crystals on light. The behaviour of minerals with regard to light is so important a character, that we must here make a short digression.

---

44. Up to the year 1819 no connection had been traced between the form and the physical properties of a crystal, but in that year **Brewster** discovered that the shape of the cleavage-form is intimately related to the action of the crystal upon light.

The optical characters of Iceland spar.

Specimens.

Since 1669 it had been known that a cleavage-plate of the clear transparent mineral, called Iceland-spar, has the strange property of giving a double image of an object seen through it; and that a beam of light, which, for simplicity, we may regard as entering the plate at right angles to its faces, is broken up into two distinct beams of *equal* brightness whatever the position of the plate. It was further found that though the properties of the two emergent beams are the same they are distinct from those of common light, for, if either of the beams be allowed to enter a second plate of Iceland-spar, in general two beams of *unequal* brightness emerge; when one of the

Polarised light.

plates is rotated round the beam this inequality varies in degree, and in four positions one or other of the beams quite disappears. The beam of light thus appears to have acquired "sides," and is said to be *polarised.*

Practically, however, it was difficult to isolate either of the emergent beams obtained in this way, for unless the original beam was very small, or the plate very thick, the two beams overlapped and together produced the effect of common light; hence, for a long time, very little progress was made in the study of the action of minerals on polarised light.

Other modes of obtaining it.

In 1808 Malus accidentally discovered that a beam of common light acquires by its reflection at a particular angle from a plate of glass exactly the same characters as are possessed by each of the beams emergent from a plate of Iceland-spar; and in 1813 it was discovered by Seebeck that although a beam of common light on entering a plate of the mineral tourmaline is resolved into two, one of them is completely absorbed if the plate is sufficiently thick, and there emerges an isolated beam of polarised light.

We have stated above that either of the beams, obtained by arranging a plate of Iceland-spar in the path of a beam of polarised light, can be extinguished by giving to the plate a particular position; if for the plate of Iceland-spar there be substituted a plate of tourmaline of the proper thickness, one of the beams will, in all positions of the plate, be destroyed by the absorption, and the single emergent beam, varying in brightness with the position of the plate, will itself, in two positions of the plate, be absolutely extinguished. Such a plate of tourmaline can thus be conveniently used to ascertain whether a given beam of light is common or polarised: if the light is polarised, then for certain positions of the plate the beam is completely extinguished; if, on the other hand, the light is common, the emergent beam is equally bright in all positions of the plate; if the light is only partially polarised, the brightness of the emergent beam varies, but does not become zero, when the plate is rotated round its normal. For the same purpose a plate of glass inclined to the beam at a particular angle may be used.

Hence a plate of glass or tourmaline can be used either as a

Polariser and analyser.

polariser—for polarising ordinary light, or as an *analyser*—for ascertaining whether or not the light is already polarised.

Brewster's discovery of a relation between the optical character and the form of a crystal.

45. The discovery made by Malus drew the attention of the scientific world to this subject, and for many years nearly all its energy was concentrated on the investigation of light and the alterations produced in it by minerals. At last, in 1819, Brewster * was able to announce the following general laws:—

A. All transparent crystals of which the cleavage-form is a cube, a regular octahedron or tetrahedron, or a rhombic dodecahedron, are alike in being without disturbing action on transmitted polarised light.

B. All transparent crystals of which the cleavage-form is a rhombohedron, a regular six-sided prism or a double six-sided pyramid, an octahedron or a prism with a square base, are such that there is one direction, and only one, in which a plate can be cut such that a beam of perpendicularly incident polarised light emerges completely polarised whatever the position of the plate and the colour of the light. This direction depends only on the shape of the primitive form; in the prisms the normal of the plate is parallel to their edges, and in the other figures to the line joining the pair of similar solid angles.

C. All transparent crystals of which the cleavage-form is other than the above are such that there are two, and only two, directions in which a plate can be cut such that a beam of perpendicularly incident polarised light of a given simple colour emerges completely polarised whatever the position of the plate; and these two directions are closely related to the shape of the cleavage-kernel. The directions of these plate-normals have been called *optic axes*.

The tourmaline pincette.

Specimen.

46. The simplest way of rendering evident these characters is the following:—Between two plates of tourmaline so disposed that no light can pass through the pair, is placed a slice of the crystal to be examined, and the whole apparatus arranged close

---

* On the connection between the Primitive Forms of Crystals and the Number of their Axes of Double Refraction: two memoirs. (Proceedings of the Wernerian Society. Edinburgh, 1821.)

to the eye, so that sky-light which has passed in various directions through the slice can be at the same time observed. If the slice is that of a crystal belonging to Group A, its introduction between the two tourmalines produces absolutely no change, and the field of view remains dark. If the crystal belongs to Group B and the slice has been cut in the right direction, there will be seen a series of coloured circular rings intersected by a black cross, and the appearance will be unchanged as the slice is turned round its normal (Fig. 40). If the crystal belongs to Group C, and the faces of the slice are at right angles to a line equally dividing one of the angles between the two directions which have been termed optic axes, the field of view remains dark at two points, around each of which is a set of coloured rings, as shown in Fig. 41. In four positions of the slice the rings are seen to be intersected by a dark cross, but in other positions the dark cross breaks up into two dark bands, termed brushes, each passing through the centre of one of the sets of rings, which, it may be added, appear to move with the crystal during its rotation.

Fig. 40.

Fig. 41.

Agreement of the optical and geometrical modes of classifying crystalline forms.

47. This division of crystals into groups according to their optical behaviour is in perfect agreement, as far as it goes, with that which had just before, on geometrical grounds, been suggested in Germany by Weiss and Mohs, and of which Brewster had not at that time heard; the only difference being that optically no distinction could be made between crystals belonging to the systems termed Pyramidal and Rhombohedral by Mohs. Still, Brewster's discovery was quite sufficient to prove that the grouping suggested by Weiss and Mohs is a *natural* one, depending on fundamental differences of structure.

Optical characters of the crystals which had been referred to the two new systems.

48. We have already stated (§ **43**) that Mohs afterwards (1822) recognised two additional systems, the crystals belonging to which both Weiss and Mohs had previously regarded as merely developments of half-forms and quarter-forms belonging to the Prismatic system. The independence of these systems was at length confirmed by the difference in the optical characters of the crystals assigned to them.

In those crystals, which both Weiss and Mohs regarded as undoubtedly belonging to the Prismatic system, the two lines which bisect the angles between the optic axes, and a third line at right angles to both of them, were proved to be identical in direction with the three lines which, on geometrical grounds, had been selected for crystallographic axes, and they were also found to be independent both of the colour of the light and the temperature of the crystal. On the other hand, in the fifth system of Mohs two of these lines, and in the sixth system all three, were found to be quite distinct from the rectangular crystallographic axes adopted by Weiss, and to vary in position in the crystal, not only with the colour of the light, but also with the temperature at which the observations were made.

[The third system of Mohs has later been split up into a Hexagonal system and a Rhombohedral or Trigonal system.]

There cannot be more than thirty two classes of crystals.

49. The fundamental character of each of these seven natural systems is now regarded as one of *symmetry;* in a holohedral crystal belonging to the Prismatic system of Mohs, for instance, every feature, whether geometrical or physical, is repeated in directions symmetrically disposed on opposite sides of three rectangular planes. And one of the most remarkable discoveries of the last half-century has been the mathematical demonstration, that if the law of whole numbers enunciated by Haüy be absolutely true, thirty-two types (classes) of symmetry, and no others, each of them referable to one or other of the above seven systems, are possible in crystals.

The distinction of minerals into kinds.

50. We have now indicated the steps by which it has been shown that substances of "the same kind" crystallise in forms which are intimately related to each other, and are capable of reference to one or other of seven natural systems.

In case an exception to this general law presents itself, it is necessary, in the first place, to ascertain whether the exception is not an apparent one, for it is possible that the substances may really not belong to the same kind. For instance, in the case of the specimens which had up to his time been called Heavy-spar, Haüy discovered that, although the crystals from England and Sicily are very similar in form, those of one locality differ in their fundamental angles from those of the other by amounts not large, but yet beyond the possible errors of measurement. This exception, which long puzzled Haüy, was to his delight removed by the discovery made by Vauquelin, that the crystals really belong to two distinct kinds of mineral (now called Barytes and Celestite respectively), one of them, the English, giving a green, and the other, the Sicilian, a crimson colour to a flame.

Specimens.

51. The difficulty as to when two specimens are to be regarded as being of the same kind has so far, for the sake of simplicity, been left out of sight; and we have assumed that, somehow or other, by help of the more obvious properties already mentioned (§ **12**), a discrimination into kinds can be made.

Before proceeding further it is necessary to treat with some detail of a very important class of properties, distinct from the rest in that their determination involves the destruction of the part actually tested; if any logical inference as to the concurrence of a group of properties in an individual is to be made, all the other properties must be first determined.

52. The action of fire upon a simple substance or on a mixture of substances, and the action of substances upon each other, must have been a subject of inquiry in the earliest times (§ **12**), one object of desire being the production of a substance more valuable than those destroyed in the process. It was thus discovered that lead can be got by roasting one kind of mineral (galena) with charcoal; a second mineral (tin-stone) yields tin; from a third (magnetite) iron can be obtained; a fourth (cinnabar or vermilion), when rubbed with vinegar in a brass vessel, according to Theophrastus yields quicksilver. Such properties are clearly of great importance for the distinction of minerals into kinds.

Different kinds of solvents prepared.

53. Several liquids similar to vinegar in having a sour taste and a power of dissolving many substances insoluble in water itself, were discovered by the old alchemists in their search for the philosopher's stone and the elixir of life; these liquids were called *acids.*

Thus, when a certain mineral (iron-pyrites) after being roasted or slowly acted upon by the air is treated with water, the resulting liquid yields, on evaporation, a solid termed "green vitriol"; from this, by heating in a retort, a very powerful acid, *oil of vitriol* (fuming sulphuric acid), was obtained.

By heating together a mixture of saltpetre and "blue vitriol," another acid, *aqua fortis* (nitric acid), useful for separating silver from gold, was produced.

In a similar way, from a mixture of nitre, sal-ammoniac, and green vitriol, the alchemists prepared *aqua regia,* a liquid capable of dissolving even gold itself.

And in the fifteenth century another acid, *spirits of salt* (hydrochloric acid), was obtained by heating common salt with oil of vitriol.

The difference of action of each of these liquids on the products belonging to the Mineral Kingdom supplied many tests by which substances very similar in their external characters could be distinguished from each other.

Alkalies.

54. By boiling in water the ashes of plants and evaporating the liquid thus obtained, a substance called *alkali,* having peculiar characters, was prepared; and a similar substance was derived from bones and other animal matters by dry distillation: it was found that the latter could be distinguished from the former, not only by its pungent smell, but by the action of heat, for it could be completely converted into vapour; hence the two kinds of alkali were termed fixed and volatile, respectively. Later, differences of character between the alkali of land-plants and that of sea-plants were observed, for the colour given to the flame of a spirit-lamp by the former was violet, whilst that given by the latter was yellow; the two kinds of fixed alkali were designated potash and soda.

By being boiled with quicklime, the alkalies acquire characters more pronounced than those they at first possess; the two states of the alkali were distinguished as caustic and mild, respectively.

Opposition of the alkalies and acids.

55. In properties the alkalies were found to be opposite to the acids: they destroy both the sour taste and the solvent power; and whereas the acids turn a certain blue vegetable colouring matter to red, the alkalies restore the original colour.

Salts.

56. When the solvent power of an acid was neutralised or destroyed by the action of a metal, an alkali, or an earth, another kind of substance called a *salt* was produced.

Alkaline earths.

57. About the middle of last century it was remarked that lime, a substance known to the ancients, had similar properties to those of the alkalies; owing to its being almost insoluble in water and to its remaining unaltered when exposed to a high temperature, it had been long regarded as one of the "earths"; it was now termed an *alkaline earth.* Other similar earths, magnesia, baryta, and strontia, were soon afterwards distinguished.

58. About this time it was discovered that gases, invisible but yet having very different properties, could be prepared.

Different kinds of gas recognised.

The gas evolved when limestone was acted upon by an acid was found to be distinct from common air, and was termed fixed air (carbonic acid); another gas (oxygen), given off when a certain substance was heated, was found to have very energetic properties; common air was found to be a mixture of the latter with still another gas (nitrogen): a fourth gas (hydrogen), light and inflammable, was obtained by treating iron filings with dilute oil of vitriol: water was shown to be composed of two of these gases (hydrogen and oxygen).

A new chemical theory.

59. A theory was now proposed which was to account for the peculiarities which had been discovered. The metals, long regarded as compounds and as capable of being changed one into another, are, according to the new theory, *elements* incapable of resolution into simpler substances; to this class were also assigned some non-metallic substances, such as sulphur, phosphorus, carbon, and some of the lately discovered gases (hydrogen, oxygen, and nitrogen): the number of elements then known was only twenty-three. All other kinds of matter were considered to be *compounds* of the elements with each other. By reason of the facility with which it enters into combination with the other elements, and its influence over the characters of the resulting compounds, oxygen was regarded as the most important of the simple substances. In general its compounds with non-metallic elements are acids, and its compounds with metals are *bases* or substances which have the property of neutralising acids: according to the same theory, a salt is produced by the union of an acid with a base.

The law of combination in definite proportions.

60. The next step was the discovery that every distinct chemical compound always contains exactly the same proportion of the elements of which it is composed; a fact first indicated by the experiments made by Cavendish with neutral salts, for he showed that in these compounds the proportion of base to acid obeys a distinct law; this view, however, was stoutly opposed by Berthollet, and it was not till 1808 that the fact was conclusively established by the researches of Proust.

The atomic theory.

61. About this time Dalton announced his atomic theory. According to this theory there are in Nature different kinds of minute indivisible particles, which Dalton called *atoms;* all atoms of the same kind are the same in figure and in weight; each elementary body consists of only one kind of atom; atoms of different kinds are capable of combining together in simple proportions to form small groups; a definite chemical compound consists of a collection of such atomic combinations, all of exactly the same kind.

The long series of investigations made by Berzelius (and more recently by Stas) to determine with accuracy the relative weights of the different kinds of atom, rendered it so clear that the proportions by weight in which the elements combine to form definite chemical compounds are fixed, that this constancy is now scarcely called in question.

Have minerals of the same kind an identical chemical composition?

62. But is a *mineral* a definite chemical compound? To Haüy,* in 1801, this question presented serious difficulties; and in his Treatise he refers to Felspar as an illustration.

Kirwan had brought together analyses of thirteen different specimens which had all been called Felspar, and to these Haüy adds an analysis made by Vauquelin of a fourteenth specimen. The results varied extremely, for not only were the proportions of the various constituents not constant, but one constituent present in considerable quantity in some of the specimens was entirely absent from the rest. Hence, Haüy was led to criticise the grounds upon which these specimens had been named Felspar; they were as follows:—(1) the specimens were so hard that they gave sparks when struck with steel; (2) they yielded rhomboidal fragments when broken; (3) they were about two and a half times as heavy as water; (4) they were fusible and gave a white bead.

Haüy contended that such properties were not sufficiently definite and precise to serve for the distinction of minerals into kinds (*species*); he therefore recommended that in the distribution of minerals into kinds attention should be paid to the crystalline form, and that specimens should not be regarded as belonging to the same kind of mineral unless their crystals presented the same primitive form. Haüy ventured to assert that when this limitation was introduced all minerals of the same kind would be found to have essentially the same chemical composition, for he could not believe that the little "bricks" could have exactly the same form without being of identical chemical constitution; except where the primitive form is a cube, regular octahedron, or tetrahedron, and has thus an absolutely definite shape.

63. Yet Haüy perceived that even where the primitive form is the same there is still much variation in the chemical composition of minerals; and this difficulty he sought to explain in the following ingenious but artificial way. At Fontainebleau are found crystals of Calcite, which have as much as from 50 to 60 per cent. by weight of sand-grains disseminated through them, and

---

* Traité de Minéralogie. Paris, 1801.

yet have the same shape of cleavage-kernel as the pure mineral; from the fact that this large proportion of mingled foreign matter has failed to influence the angles of the crystals built up from the little bricks of Calcite, Haüy argued that the variations of chemical composition of minerals, which otherwise appear to be of the same kind, are due to the interposition of foreign matter between those constituent particles to which the form of the crystal is really due.

64. The presence of this foreign matter would, according to Haüy, at the same time account for the variations of colour, and for the slight differences of hardness, fusibility, and other characters, met with in specimens regarded as belonging to the same kind of mineral. According to this hypothesis, Dolomite, Chalybite, and Bitter-spar are all varieties of Calcite, the large differences of composition being due to the interposition of carbonates of magnesium or iron between the particles of carbonate of lime, of which the extraordinary crystallising power was supposed to be demonstrated by the Fontainebleau crystals. Specimens.

Dimorphism and trimorphism.

65. Haüy thus acknowledged that, in the Mineral Kingdom, crystals having the same primitive form and a general similarity of character may have a very different chemical composition. On the other hand, he found that, in at least one case, crystals yielding a different primitive form have the same percentage chemical composition; for while one kind of carbonate of lime (calcite) can, as we have seen, be reduced by cleavage to a rhombohedron, a second kind (aragonite), when cleaved, yields an octahedron; this property has been termed *dimorphism.*[*] To those who thence argued that his belief in the association of a definite primitive form with a definite chemical composition must be founded on wrong premises, Haüy replied that at any rate he could not regard two specimens as belonging to the same kind of mineral merely because they had one single property in common, namely, identity of chemical composition; that the difference of primitive form was, in the case of calcite and aragonite, as also in that of diamond and graphite, associated with differences of hardness, density, and all the other properties, save chemical composition; and that there was Specimens.

---

[*] *Di-*, doubly, and *morphe*, form.

no exception to the more general law that a definite primitive form is allied with a definite set of properties.

To remove this exception to the generality of Haüy's theory, countless specimens of aragonite were analysed with the view of discovering some constituent other than carbonate of lime, and it was vainly hoped by some, though not by Haüy himself, that the presence of carbonate of strontium, small quantities of which had been found in some isolated specimens, might be held to account for the difference—an explanation which would require the traces of carbonate of strontium to have such a tremendous power of crystallisation as to completely overcome even that of the carbonate of lime.

In 1822-3 Mitscherlich announced another exception, and showed that while crystals of sulphur deposited from solution have one kind of primitive form, those obtained by allowing melted sulphur to quickly cool have a different one.

By the conversion of aragonite into calcite, and again by the production of both from the same solution, it was eventually made clear that the difference of form, to whatever due, can not be rightly attributed to slight difference in the chemical composition.

Later still (1845), it was shown that titanic acid is *trimorphous*, appearing in Nature with three distinct primitive forms, each connected with a definite, but different, set of properties.

Isomorphism.

66. To Mitscherlich* belongs the credit of establishing the existence, not only of artificial crystals having the same chemical composition and different primitive forms (dimorphism), but also of others having the same primitive form and essentially different chemical compositions, a relationship termed *isomorphism*.† This discovery followed from the examination of a series of phosphates and arsenates of the alkalies, artificial salts of which the purity could be secured. From his investigations Mitscherlich inferred that the chemical elements may be distributed into sets, the members of each of which are so far similar to each other that, in a chemical compound, one

---

* Ueber das Verhältniss der Krystallform zu den chemischen Proportionen. Ueber die Körper welche in zwei verschiedenen Formen crystallisiren (Abhandl. d. Berlin Akad. d. Wissensch, 1822-3).

† *Isos*, equal, and *morphe*, form.

atom can replace another atom of the same set without appreciably affecting the primitive form of the crystal. Potassium and sodium belong to one of these sets; phosphorus, arsenic, and antimony to another. He also inferred that the crystalline form of a chemical compound depends, not only on the percentage composition, but also on the configuration of the atomic groups.

67. The discovery of isomorphism in *artificial salts* removed the great difficulty presented by the fact that, in the Mineral Kingdom, crystals may be different in chemical composition, and yet so similar in form and general characters that they can scarcely be regarded as belonging to different kinds of mineral; for it indicated that although there is not in these crystals that absolute identity of matter which Haüy had been led to expect, still there is an identity of grouping of atoms and a law controlling the replacement of the members of the groups.

Systems of classification.

68. Having glanced at the more important properties, by help of which Minerals are distributed into kinds or species, we must next briefly consider how the kinds are to be classified, and thus how we are to ascertain readily whether or not a new specimen, of which the characters have been determined, is similar to some one of the many already described. The great discoveries made in crystallography and chemistry during the latter part of the eighteenth century render it unnecessary to discuss the classifications employed in earlier times.

Berzelius.

69. Berzelius* (1815) was the first to frame a system of classification depending only on chemical composition. The study of electricity had given rise to the idea that the act of chemical combination is an electrical phenomenon; and that every chemical compound consists of two parts, the one electropositive (the metal), the other electronegative (the acid). In his system, Berzelius brought together into one family all chemical compounds having the same electropositive part (the metal), and arranged the families among themselves according to the *degree* of the electropositivity of the metal: each family was distributed into orders arranged according to the degree of electronegativity of the acid part of the compound.

* Försök till ett rent kemiskt Mineralsystem. Stockholm, 1815.

The arbitrary nature of this system was made manifest by the discovery of isomorphism by Mitscherlich, according to which elements extremely different in electrochemical character can replace each other without appreciably affecting the characters of the compound. Berzelius thereupon acknowledged the completeness of his failure and reconstructed a chemical system (1824), depending now on the electronegative part (the acid): but to this, though more satisfactory in its results, the same objection may be urged, namely that the properties of a mineral have no manifest connection with the electrochemical character of its constituents.

Mohs. **70.** About the same time (1820), Mohs * framed a "Natural History system of classification," from which the chemical composition of a mineral was completely excluded as not being a "Natural History" property, since it could only be determined by destroying the part of the mineral experimented upon. As this system of classification was adopted, more especially in Germany, for many years, and has had great influence on the progress of mineralogical science, a brief statement of its leading features will not be out of place.

In framing the system, account was taken, not of a *single* character, but of *all* the more important of the external (or Natural History) characters, the most prominent in the definition of *species* being crystalline form (including cleavage), hardness, and specific gravity.

> The first of these has a definite geometrical significance, and the last has a definite numerical value: to give a similar precision to the character of hardness, Mohs constructed an arbitrary scale by means of ten minerals, of which experience had proved the suitability for the purpose; the minerals, in the order of increasing hardness, were:—

1. Talc.
2. Rock-salt.
3. Calcite.
4. Fluor.
5. Asparagus-stone.
6. Adularia.
7. Rock-crystal.
8. Topaz.
9. Corundum.
10. Diamond.

---

* The characters of the classes, orders, genera, and species; or, the characteristics of the Natural History System of Mineralogy. Edinburgh, 1820.

For the sake of brevity, the degree of hardness was expressed numerically; a specimen, for instance, which was estimated to be scratched as easily by Fluor as Calcite by the specimen itself, was said to have a hardness 3·5.

According to the system of Mohs, the number of classes of the Simple Minerals is three, of which the characters are as follows:—

Class I. Specific gravity under 3·8: no bituminous odour: if solid, a taste.

Class II. Specific gravity above 1·8: tasteless.

Class III. Specific gravity under 1·8: if fluid, a bituminous odour: if solid, tasteless.

As few minerals have so low a specific gravity as 1·8 or have a taste, the second class includes nearly the whole of the kingdom, the first consisting, almost solely, of the minerals which are soluble in water, and the last, of the organic products resin and coal.

In **Class II** are recognised thirteen orders, designated by the following names:—

1. Haloide.
2. Baryte.
3. Kerate.
4. Malachite.
5. Mica.
6. Spar.
7. Gem.
8. Ore.
9. Metal.
10. Pyrites.
11. Glance.
12. Blende.
13. Sulphur.

Each of the above orders is distinguished by a *combination* of characters: thus, the characters of the order Baryte are

Lustre: non-metallic.
Streak: uncoloured or orange-yellow.
Hardness: 2·5 to 5·0.
Specific gravity: 3·3 to 7·3.

Further, in this order, the characters are inter-related as follows:—

1. If the most distinct cleavage has only a single direction, the hardness does not lie between 4 and 5.

2. If the lustre is adamantine or imperfect-metallic, the specific gravity is not less than 5.

3. If the streak is orange-yellow, the specific gravity is at least 6.

4. If the hardness is 5, the specific gravity is under 4·5.

5. If the hardness is 5 and the specific gravity is under 4, the cleavage is diprismatic.

The orders are, in turn, distributed into genera, the number of the latter in the order BARYTE being six, termed respectively :—

1. Parachrose-baryte.
2. Zinc-baryte.
3. Scheelium-baryte.
4. Hal-baryte.
5. Lead-baryte.
6. Antimony-baryte.

The characters of the genus Hal-baryte, for example, are :—

System of crystallisation : orthorhombic.
Hardness : 3·0—3·5.
Specific gravity : 3·6—4·7.

Finally, the genera are subdivided into species: the genus Hal-baryte, for instance, contains four species, designated by Mohs as :—

1. *Peritomous hal-baryte,*
2. *Diprismatic hal-baryte,*
3. *Prismatic hal-baryte,*
4. *Prismatoidal hal-baryte ;*

they are the species known as *Strontianite, Witherite, Barytes,* and *Celestite,* respectively.

The above is perhaps sufficient both to render evident the difficulty of assigning a relative importance to the various external characters of minerals, and to illustrate the complicated and artificial character of the groups of properties defining the orders recognised in the system of Mohs: at the same time it serves to give an idea of the scientific nomenclature which Mohs sought to introduce for the mineral species.

Gustav Rose.

71. The system which was adopted by Professor Maskelyne for the classification of the British Museum Collection was virtually one published by Gustav Rose,* in 1852, as an

---

* Das Krystallo-chemische Mineralsystem. Leipzig, 1852.

improvement on the purely chemical system, and has been briefly described as a chemical system modified by the principle of isomorphism: it is therefore a mixed system, depending on two properties, chemical composition and crystalline form.

In this system minerals are arranged in four principal divisions, of which the first includes the native elements, and the remaining three, the compounds.

The chemical elements most useful in the classification of the compounds met with in the Mineral Kingdom are:—

The Arsenic group:—arsenic, antimony, and bismuth.

The Sulphur group:—sulphur, selenium, and tellurium.

The Chlorine group:—chlorine, bromine, iodine, and fluorine.

Oxygen.

The second division comprises those minerals in which metals are combined with elements of the Arsenic and Sulphur groups: the third division, those in which metals are combined with the elements of the Chlorine group; and the fourth, the compounds of Oxygen.

The divisions are subdivided into sections, and the sections into classes, the latter embracing the minerals which fall under the same chemical denomination; as, for instance, the salts of the same acid or of a group of acids chemically and crystallographically similar to each other.

Each class is further separated into distinct chemical series, the minerals included in any series being such as are designated by the same typical formula.

Finally, the chemical series are distributed into distinct crystallographic series, arranged according to the crystalline systems to which they belong; these are followed by the amorphous substances, which present either no crystalline forms at all, or only such as cannot be determined.

The table on p. 60 shows the classification based on that of Gustav Rose which is now adopted in the Mineral Gallery:—

The System of Classification adopted in the Mineral Gallery.

SIMPLE MINERALS.	Div. I. Native elements.	Metallic.	
		Non-metallic.	
	Div. II. The compounds of metals with elements of the arsenic and sulphur groups.	Arsenides, &c.	
		Sulphides, &c.	
		Arsenosulphides, &c.	
		Sulphur-salts.	
	Div. III. The compounds of metals with elements of the chlorine group.	Simple Chlorides, &c.	
		Compound Chlorides, &c.	
	Divs. IV.–XI. The compounds of oxygen.	Div. IV. Oxides.	
		Divs. V.–XI. Oxygen Salts.	Carbonates. Silicates. Titanates, Tantalates, Niobates, &c. Molybdates and Tungstates. Chromates and Sulphates. Borates and Nitrates. Phosphates, Arsenates, Vanadates, &c.
	Div. XII. Organic Products.		

THE CHARACTERS OF MINERALS.

In window-cases II, III, and IV is arranged a series of specimens illustrating at once the characters of minerals and the terms used in their description: with the view of reminding the student of their existence, characters are specified even when they require experiment for their determination, and are thus not evident from mere inspection of the minerals as they lie in the cases. The names of the illustrative minerals are given in *italics.*

The specimens in window-case II relate almost entirely to the *Forms* presented by minerals.

The Forms of Crystals.

Window case II.

THE SYSTEMS OF CRYSTALLISATION :—

The Cubic (or Tesseral) system: *fluor.*
The Tetragonal (or Pyramidal) system: *apophyllite.*
The Hexagonal system: *beryl.*
The Rhombohedral (or Trigonal) system: *calcite.*
The Orthorhombic (or Prismatic) system: *topaz.*
The Monosymmetric (or Monoclinic) system: *orthoclase.*
The Anorthic (or Triclinic) system: *axinite.*

DIMORPHISM :—*pyrites* and *marcasite.*
TRIMORPHISM :—*rutile, anatase,* and *brookite.*
ISOMORPHISM :—*chalybite* and *dolomite.*
PSEUDOMORPHISM :—
quartz, calcite, and *quartz* with the form of *calcite.*
galena, pyromorphite, and *galena* with the form of *pyromorphite.*

FORMS DEPENDING ON THE RELATIVE SIZES OF THE FACES :—

Prismatic: *epidote, stibnite, pyrosmalite, idocrase.*
Acicular: *cerussite.*
Capillary: *millerite.*
Tabular: *barytes, specular-iron.*
Stout: *apophyllite, topaz.*
Slender: *scolecite.*

Window-case II.

The Surface of Crystals :—

Smooth : *fluor.*
Drusy : *quartz.*
Rough : *calcite.*
Striated : *blende, magnetite.*
Curved : *calcite, dolomite.*

The Regular Growths of Crystals (twins) :—
Calcite, cassiterite, fluor, selenite.

Groups of Crystals :—

Parallel : *quartz.*
Radiating (or divergent) : *mesolite.*
Matted (reticulated or interlaced) : *chalcotrichite.*
Confused : *scapolite, beryl.*

Indeterminate forms :—

Globular : *blende, prehnite, calcite, marcasite.*
Branched (arborescent or dendritic) : *silver, copper, pyrolusite.*
Dentiform : *copper.*
Mossy : *copper.*
Leafy : *silver, gold.*
Wiry (or filiform) : *silver.*
Capillary : *millerite.*
Coralloidal : *aragonite.*
Mamillary : *arsenic, psilomelane.*
Warty : *menilite.*
Nodular : *blende, malachite.*
Botryoidal : *hydrodolomite.*
Reniform : *menilite.*
Amygdaloidal : *aragonite, agate.*
Geode : *quartz.*
Stalactitic : *calcite, marcasite, psilomelane, limonite, chalcedony, aragonite.*
Stalagmitic : *calcite.*

Window-case III.

In window-case III are collected together specimens illustrative of those characters of minerals which relate to Light.

The Scale of Colours (almost as suggested by Werner in 1774):—

METALLIC COLOURS.

Copper-red : *copper.*
Pinchbeck-red : *niccolite.*

Bronze-yellow : *pyrrhotite.*
Light-brass-yellow : *pyrites.*
Dark-brass-yellow : *chalcopyrite.*
Gold-yellow : *gold.*

Silver-white : *silver.*
Silver-white, passing into grey : *mispickel.*
Silver-white, passing into red : *cobaltite.*
Tin-white : *antimony.*

Whitish lead-grey : *stibnite.*
Pure lead-grey : *galena.*
Blackish lead-grey : *nagyagite.*
Steel-grey : *platinum.*

Iron-black : *franklinite.*

NON-METALLIC COLOURS.

WHITE.

Snow-white : *aragonite.*
Reddish-white : *margarite.*
Yellowish-white : *rock-milk.*
Greyish-white : *marble.*
Greenish-white : *tremolite.*
Milk-white : *opal.*

GREY.

Bluish-grey : *fluor (massive).*
Pearl-grey : *perlite.*
Smoke-grey : *flint.*
Greenish-grey : *hornstone.*
Yellowish-grey : *pearl-spar.*
Ash-grey : *zoisite.*

Window-case III.

Black.

Greyish-black : *lydian-stone.*
Velvet-black : *tourmaline.*
Greenish-black : *augite.*
Brownish-black : *ilvaite.*
Bluish-black : *cobalt-ochre.*

Blue.

Blackish-blue : *chessylite.*
Azure-blue : *lapis-lazuli.*
Violet-blue : *fluor.*
Lavender-blue : *teratolite.*
Plum-blue : *fluor.*
Prussian-blue : *salt.*
Smalt-blue : *chalcedony.*
Indigo-blue : *vivianite.*
Duck-blue : *anhydrite.*
Sky-blue : *liroconite.*

Green.

Verdigris-green : *noumeaite.*
Celandine-green : *jasper.*
Mountain-green : *beryl.*
Leek-green : *prase.*
Emerald-green : *emerald.*
Apple-green : *chrysoprase.*
Grass-green : *cupro-uranite.*
Pistachio-green : *epidote.*
Asparagus-green : *asparagus-stone.*
Blackish-green : *olivenite.*
Olive-green : *pyromorphite.*
Oil-green : *beryl.*
Siskin-green : *calco-uranite.*

Yellow.

Sulphur-yellow : *sulphur.*
Straw-yellow : *carpholite.*
Wax-yellow : *mimetite.*
Honey-yellow : *amber.*
Lemon-yellow : *orpiment.*

Window-case III.

YELLOW—*continued.*

Ochre-yellow : *ochre.*
Wine-yellow : *fluor.*
Cream-yellow : *halloysite.*
Orange-yellow : *wulfenite.*

RED.

Aurora-red : *realgar.*
Hyacinth-red : *hessonite.*
Brick-red : *polyhalite.*
Scarlet-red : *cinnabar (earthy).*
Blood-red : *pyrope.*
Flesh-red : *heulandite.*
Carmine-red : *chalcotrichite.*
Cochineal-red : *cinnabar (crystallised).*
Rose-red : *rose-quartz.*
Crimson-red : *ruby.*
Peachblossom-red : *lepidolite.*
Columbine-red : *almandine.*
Cherry-red : *kermesite.*
Brownish-red : *jasper.*

BROWN.

Reddish-brown : *tile-ore.*
Clove-brown : *axinite (massive).*
Hair-brown : *barytes (stalactitic).*
Chestnut-brown : *jasper (Egyptian).*
Yellowish-brown : *przibramite.*
Wood-brown : *asbestos.*
Liver-brown : *menilite.*
Blackish-brown : *limonite.*

A suite of colours of a single mineral :—*fluor.*

Play of colours :—*precious opal.*

Change of colours :—*labradorite.*

Tarnish :—*tetrahedrite.*

Iridescence :—*quartz.*

Window-case III.

Opalescence :—*moonstone.*

Pleochroism :—*cordierite.*

Fluorescence :—*fluor.*

Phosphorescence :—*calcite.*

Refraction and Polarisation :—

Single refraction : *salt.*

Double refraction (and plane polarisation) : *calcite.*

The Degrees of Transparency :—

Transparent :	*rock-crystal.*
Semi-transparent :	*calcite.*
Translucent :	*milky-quartz (massive).*
Semi- or sub-translucent :	*hornstone.*
Opaque :	*eisenkiesel.*

Lustre :—

THE KINDS OF LUSTRE—

Perfect metallic :	*pyrites.*
Imperfect (or sub-) metallic :	*pitchblende.*
Common adamantine :	*blende (transparent).*
Metallic adamantine :	*blende (black).*
Resinous :	*colophonite.*
Vitreous :	*celestite.*
Waxy :	*wax-opal.*
Common pearly :	*heulandite.*
Metallic pearly :	*bronzite.*
Silky :	*crocidolite.*

THE DEGREES OF INTENSITY OF LUSTRE—

Splendent :	*blende.*
Shining :	*calcite.*
Glistening :	*magnetite.*
Glimmering :	*galena.*
Dull :	*kaolinite.*

Streak :— Window-case III.

Shining : *argentite.*

Of the same colour as the mineral : *calcite, malachite.*

Of a different colour from the mineral : *crocoite, hæmatite, limonite, chalcopyrite.*

The specimens in window-case IV relate to the remaining characters of minerals. Window-case IV.

Cleavage :—

TRUE CLEAVAGE—*Salt, galena, fluor, blende, apophyllite, calcite, biotite, stibnite, topaz, barytes, selenite, hornblende, microcline.*

PLANES OF PARTING—*corundum, sahlite.*

Structure :—

CRYSTALLINE— *marble, coccolite.*

LAMINAR—

Flat : *slate-spar.*
Flat and divergent : *pyrophyllite.*
Curved : *specular-iron.*

FIBROUS TO COLUMNAR—

Parallel : *asbestos, gypsum, tremolite, satin-spar.*
Curved : *boschjesmanite.*
Radiating : *wavellite, natrolite.*
Matted : *pilolite.*
Columnar : *anthraconite.*

GRANULAR—

Coarsely : *magnetite, colophonite.*
Finely : *magnetite.*

Window-case IV.

COMPLICATED—

Layers: *agate, onyx, calcite, pisolite, varagonite.*
Curved layers made up of grains: *allemontite.*
Curved layers made up of fibres: *hæmatite.*

AMORPHOUS—*wad.*
Hyaline: *hyalite.*

The Kinds of Fracture:—

Conchoidal: *calcite, flint, barytes.*
Sub-conchoidal: *rock-crystal.*
Uneven: *semiopal.*
Even: *marble.*
Splintery: *jade.*
Hackly: *copper.*

Frangibility:—

Brittle: *sulphur.*
Tough: *fibrolite.*
Soft: *molybdenite.*
Friable: *sassolite.*

Sectility:—*chlorargyrite.*

Malleability:—*argentite.*

Ductility:—*silver.*

Flexibility:—*talc.*

Elasticity:—*muscovite.*

Hardness:—

The scale of hardness.

1. *Talc.*
2. *Rock-salt.*
3. *Calcite.*
4. *Fluor.*
5. *Apatite* (asparagus-stone).
6. *Adularia.*
7. *Rock-crystal.*
8. *Topaz.*
9. *Corundum.*
10. *Diamond.*

Differences of hardness on different faces of the same crystal: *calcite.*

Differences of hardness along different directions in the same face: *rock-salt.*

Window-case IV.

Specific gravity (relative to that of water):—

Between 1 and 2: *mellite.*
„ 2 and 3: *rock-crystal.*
„ 3 and 4: *topaz.*
„ 4 and 5: *zircon.*
„ 5 and 6: *bournonite.*
„ 6 and 7: *anglesite.*
„ 7 and 8: *galena.*
„ 8 and 9: *copper.*
„ 9 and 10: *bismuth.*
„ 10 and 19: *silver, amalgam, gold, platinum.*

Magnetic characters:—

PARAMAGNETIC—
Strong: *magnetite.*
Strong, without polarity: *magnetite.*
Weak: *dioptase.*

DIAMAGNETIC— *bismuth.*

Electrical characters:—

Due to pressure: *calcite.*

Due to friction: *amber, topaz.*

Due to changing temperature (pyro-electricity): *tourmaline, boracite.*

Due to difference of temperature at the points of contact with another substance (thermo-electricity): *bismuth, pyrites.*

CONDUCTIVITY—
Good: *graphite.*
Bad: *diamond.*

Thermal characters:—

DILATATION: *fluor, calcite.*
ACTION UPON RADIANT HEAT: *rock-salt.*
CONDUCTIVITY: *rock-crystal.*

Window-case IV.

Touch :—

Unctuous : *steatite.*
Meagre : *tripoli.*
Harsh : *trachyte.*
Porous and adhesive to the tongue : *hydrophane.*

Smell :—

Bituminous : *elaterite.*
Sulphurous (on friction) : *pyrites.*
Garlic-like (on friction) : *mispickel.*
Empyreumatic (on friction) : *anthraconite.*
Clayey (on breathing) : *kaolinite.*

Taste :—

Astringent : *chalcanthite, kalinite.*
Saline : *salt.*
Alkaline : *natron.*
Bitter : *epsomite.*

THE MINERAL SPECIES AND THEIR VARIETIES.

The Collection of Mineral Species and their Varieties is exhibited in the tops of the table-cases numbered 1 *to* 41 *: the eight upper panes of each case are severally distinguished by the letters* a *to* h. *The specimens are arranged as if each pair of cases formed a single large case extending across the Gallery.*

Many of those specimens which are too large for exhibition in the tops of the cases are shown in the glazed ends, and are placed as near as practicable to the smaller specimens belonging to the same species: others are mounted on separate stands, while a magnificent suite of large specimens is shown in the wall-cases of the Pavilion.

NATURAL HISTORY MUSEUM.

ECONOMIC PAMPHLETS.

No. 1.—**The House-Fly as a Danger to Health.** Its Life-history, and how to deal with it. By Major E. E. Austen, D.S.O. Third Edition. Pp. 20: 3 plates (containing 6 figures), and 5 figures in text. 1920, 8vo. 3*d.* (*postage* 1*d.*).

No. 1A.—**The House-Fly.** Its Life-history, and Practical Measures for its Suppression. By Major E. E. Austen, D.S.O. Pp. 52: 3 plates (containing 6 figures) and 5 text-figures. 1920, 8vo. 1*s.* 6*d.* (*postage* 1½*d.*).

No. 2.—**The Louse as a Menace to Man.** Its Life-history, and Methods for its Destruction. By James Waterston, B.D., D.Sc. Pp. 20: 1 plate (containing 2 figures), and 2 figures in text. 1921, 8vo. 6*d.* (*postage* 1*d.*).

No. 3.—**Fleas as a Menace to Man and Domestic Animals.** Their Life-history, Habits, and Control. By James Waterston, B.D., D.Sc. Second Edition. Pp. 21: 1 plate and 6 text-figures. 1920, 8vo. 4*d.* (*postage* 1*d.*).

No. 4.—**Mosquitoes and their Relation to Disease.** Their Life-history, Habits, and Control. By F. W. Edwards, B.A. Third Edition. Pp. 20: 6 text-figures. 1923, 8vo. 4*d.* (*postage* 1*d.*).

No. 5.—**The Bed Bug.** Its Habits and Life-history, and how to deal with it. By Bruce F. Cummings. Second Edition. Pp. 20: 7 text-figures. 1918, 8vo. 2*d.* (*postage* 1*d.*).

No. 6.—**Species of Arachnida and Myriopoda** (Scorpions, Spiders, Mites, Ticks, and Centipedes) **Injurious to Man.** By S. Hirst. Second Edition. Pp. 59: 26 text-figures and 3 plates. 1920, 8vo. 1*s.* (*postage* 1½*d.*).

No. 7.—**The Biology of Waterworks.** By R. Kirkpatrick. Third Edition. Pp. 58: 18 text-figures. 1924, 8vo. 1*s.* (*postage* 1½*d.*).

No. 8.—**Rats and Mice as Enemies of Mankind.** By M. A. C. Hinton. Second Edition. Pp. 67: 6 text-figures and 2 plates. 1920, 8vo. 1*s.* (*postage* 1½*d.*).

No. 9.—**Birds Beneficial to Agriculture.** By F. W. Frohawk. Pp. 47; 22 plates. 1919, 8vo. 2*s.* (*postage* 2*d.*).

No. 10.—**Marine Boring Animals Injurious to Submerged Structures.** By W. T. Calman, D.Sc. Pp. 35: 21 text-figures. [With Index.] 1919, 8vo. 1*s.* (*postage* 1*d.*).

No. 11.—**Furniture Beetles,** their Life-history and how to check or prevent the damage caused by the Worm. By C. J. Gahan, M.A., D.Sc. Pp. 23: 1 plate and 5 text-figures. 1920, 8vo. 6*d.* (*postage* 1*d.*).

No. 12.—**The Cockroach.** Its Life-history and how to deal with it. By Frederick Laing, M.A., B.Sc. Pp. 18: 1 plate and 2 text-figures. 1921, 8vo. 6*d.* (*postage* 1*d.*).

No. 13.—**Mites Injurious to Domestic Animals.** With an Appendix on the Acarine Disease of Hive Bees. By S. Hirst. Pp. 107: 85 text-figures. 1922, 8vo. 3*s.* (*postage* 2½*d.*).

ECONOMIC LEAFLETS.

No. 1.—**The Danger of Disease from Flies and Lice.** Second Edition. Pp. 4. 1918, 8vo. Price: 1*d.* for 3 copies (*postage* 1*d.*), 2*s.* 6*d.* for 100 (*postage* 6*d.*).

Applications to the Museum direct for any of these pamphlets should be accompanied by a remittance, including postage.

Written communications respecting them should be addressed to the DIRECTOR, British Museum (Natural History), Cromwell Road, London, S.W.7.

BRITISH MUSEUM

(NATURAL HISTORY)

SETS OF PICTURE POSTCARDS

Set A 1. Views of the Building. No. 1. 10 monochrome cards. 1*s*.
,, A 2. Ditto No. 2. 10 ,, ,, 1*s*.
,, B 1. Apes, Monkeys and Lemurs. 10 monochrome cards. 1*s*.
,, B 2. Carnivores. 10 monochrome cards. 1*s*.
,, B 3. Insectivores and Bats. 5 monochrome cards. 6*d*.
,, B 4. Rodents. 5 monochrome cards. 6*d*.
,, B 5. Large Ungulates. 10 monochrome cards. 1*s*.
,, B 6. Monotremes, Marsupials and Edentates. 10 monochrome cards. 1*s*.
,, B 7. Antelopes. 10 monochrome cards. 1*s*.
,, B 8. British Mammals. 5 monochrome cards. 6*d*.
,, B 9. British Dogs. 5 monochrome cards. 6*d*.
,, B 10. British Sporting Dogs. 5 monochrome cards. 6*d*.
,, B 11. Dogs: Foreign Breeds. No. 1. 5 monochrome cards. 6*d*.
,, B 12. Ditto No. 2. 5 ,, ,, 6*d*.
,, B 13. Toy Dogs. 5 monochrome cards. 6*d*.
,, C 1. Birds: British Series. No. 1. 10 monochrome cards. 1*s*.
,, C 2. Ditto No. 2. 10 ,, ,, 1*s*.
,, C 3. Birds: General Series. No. 1. 10 ,, ,, 1*s*.
,, C 4. Ditto No. 2. 5 coloured cards. 1*s*.
,, C 5. Ditto No. 3. 5 ,, ,, 1*s*.
,, C 6. Pigeons, Ducks and Fowls. 5 monochrome cards. 6*d*.
,, C 7–10. Eggs of British Birds. Nos. 1–4. Four sets each of 5 coloured cards. 1*s*. each
,, C 11. British Birds: Summer Visitors. 5 coloured cards. 1*s*.
,, C 12. Ditto Winter Visitors 5 ,, ,, 1*s*.
,, D 1. Meteorites. 10 monochrome cards. 1*s*.
,, D 2. British Meteorites. 5 monochrome cards. 6*d*.
,, E 1. Representative British Insects. 10 monochrome cards. 1*s*.
,, E 2. Remarkable Insect Types. 10 monochrome cards. 1*s*.
,, E 3. Noxious Insects. 10 monochrome cards. 1*s*.
,, E 4. Representative Foreign Insects. Series No. 1. 10 monochrome cards. 1*s*.
,, E 5. British Butterflies. Series No. 1. 5 coloured cards. 1*s*.
,, E 6. Exotic Butterflies. Series No. 1. 5 coloured cards. 1*s*.
,, E 7. British Moths. Series No. 1. 5 coloured cards. 1*s*.
,, E 8. Exotic Moths. Series No. 1. 5 coloured cards. 1*s*.
,, E 9. Exotic Butterflies. Series No. 2. 5 coloured cards. 1*s*.
,, E 10. Ditto ,, No. 3. 5 ,, ,, 1*s*.
,, E 11. Exotic Moths. Series No. 2. 5 coloured cards. 1*s*.
,, E 12. Ditto ,, No. 3. 5 ,, ,, 1*s*.
,, E 13. Exotic Beetles. Series No. 1. 5 coloured cards. 1*s*.
,, E 14. Exotic Dragonflies. 5 coloured cards. 1*s*.
,, E 15. Exotic Neuroptera. 5 coloured cards. 1*s*.
,, E 16. Exotic Grasshoppers and Praying Insects. 5 coloured cards. 1*s*.
,, E 17. Exotic Homoptera. Series No. 1. 5 coloured cards. 1*s*
,, E 18. Ditto ,, No. 2. 5 ,, ,, 1*s*.
,, E 19–24. British Butterflies. Nos. 2–7. Six sets each of 5 coloured cards. 1*s*. each.
,, E 25–27. Exotic Moths. Nos. 4–6. Three sets each of 5 coloured cards. 1*s*. each.
,, E 28. British Moths. No. 2. 5 coloured cards. 1*s*.
,, F 1. Remarkable Plant Structures. 5 monochrome cards. 6*d*.
,, F 2. Germination of Wheat. 5 monochrome cards. 6*d*.
,, F 3. Dispersal of Fruits and Seeds. 20 cards (15 in monochrome and 5 in colour). 2*s*. 6*d*.
,, F 4–7. British Flowering Plants. Nos. 1–4. Four sets each of 5 coloured cards. 1*s*. each.
,, G 1. Fossil Man. 10 monochrome cards. 1*s*.
,, G 2. British Pleistocene Mammals. 10 monochrome cards. 1*s*.
,, G 3. Fossil Fishes. 10 monochrome cards. 1*s*.
,, G 4. Fossil Reptiles. 10 monochrome cards. 1*s*.
,, G 5. Tertiary Fossil Plants. 10 monochrome cards. 1*s*.
,, G 6. Restorations of Extinct Mammals. Series No. 1. 10 monochrome cards. 1*s*.
,, H 1. Rare and Curious Books. No. 1. 10 monochrome cards. 1*s*.
,, K 1. Frogs and Toads. 5 coloured cards. 1*s*.
,, K 2. Reptiles and Batrachians. No. 2. 5 monochrome cards. 6*d*.
,, K 3. Ditto No. 3. 5 ,, ,, 6*d*.
,, K 4. Ditto No. 4. 5 ,, ,, 6*d*.
,, L 1. Sponges. 5 monochrome cards. 6*d*.
,, L 2. Stony Corals. 5 monochrome cards. 6*d*.
,, M 1. Life History of the Common Eel. 5 monochrome cards. 6*d*.

Each set is accompanied by a descriptive and informative leaflet. Individual monochrome cards may be obtained separately, price 1*d*.; and individual coloured ones, price 2*d*. A detailed list will be sent on application.

Orders for the above should be addressed, with the appropriate remittance, including postage, to—

THE DIRECTOR,
British Museum (Natural History),
Cromwell Road, London, S.W.7.

The postage on one set of five cards is 1*d*., on one set of 10 cards 1½*d*., and on one set of 20 cards 2½*d*. A halfpenny should be added for each additional set of 10 cards and for every two additional sets of 5 cards, and a penny for each additional set of 20 cards.

September, 1924.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LTD., DUKE STREET, STAMFORD STREET, S.E.1.