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

MINERAL DEPARTMENT.

AN INTRODUCTION
TO THE
STUDY OF MINERALS,

WITH A GUIDE TO THE MINERAL GALLERY.

FOURTEENTH EDITION.

LONDON:
PRINTED BY ORDER OF THE TRUSTEES.
1914.

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MINERAL DEPARTMENT.

AN INTRODUCTION
TO THE
STUDY OF MINERALS

WITH A GUIDE TO THE MINERAL GALLERY.

BY
L. FLETCHER, M.A., F.R.S.,
DIRECTOR OF THE NATURAL HISTORY DEPARTMENTS OF THE BRITISH MUSEUM;
FORMERLY FELLOW OF UNIVERSITY COLLEGE AND MILLARD LECTURER AT TRINITY COLLEGE, OXFORD.

FOURTEENTH EDITION.

[This Guide-book can be obtained at the Museum: written applications for it should be addressed to "The Director, Natural History Museum, Cromwell Road, London, S.W."]

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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 4 in the Pavilion at the end of the Gallery (see the special Guide).

VI. The Collection of Meteorites, in cases 1–3 in the Pavilion.

* * *

Index.—To find the position in the Gallery of any of the more common and interesting minerals, the Visitor should refer to the Index (page 119), where a reference is given to the table-case in which specimens of the mineral are placed, and to the page upon which the mineral is mentioned in this Guide.

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.

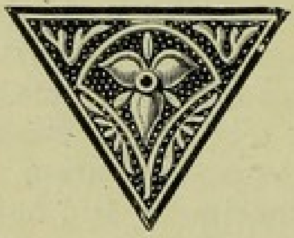
It may be added that in the description of the minerals of the General Collection the matter interesting or intelligible only to the student has been printed in smaller type, and thus need not perplex the general public.

June 18*th*, 1884. L. Fletcher,
Keeper of Minerals.

PREFACE TO THE FOURTEENTH EDITION.

The fourteenth edition is practically a reprint of the thirteenth, with only a few alterations.

March 19*th*, 1914. G. T. Prior,
Keeper of Minerals.



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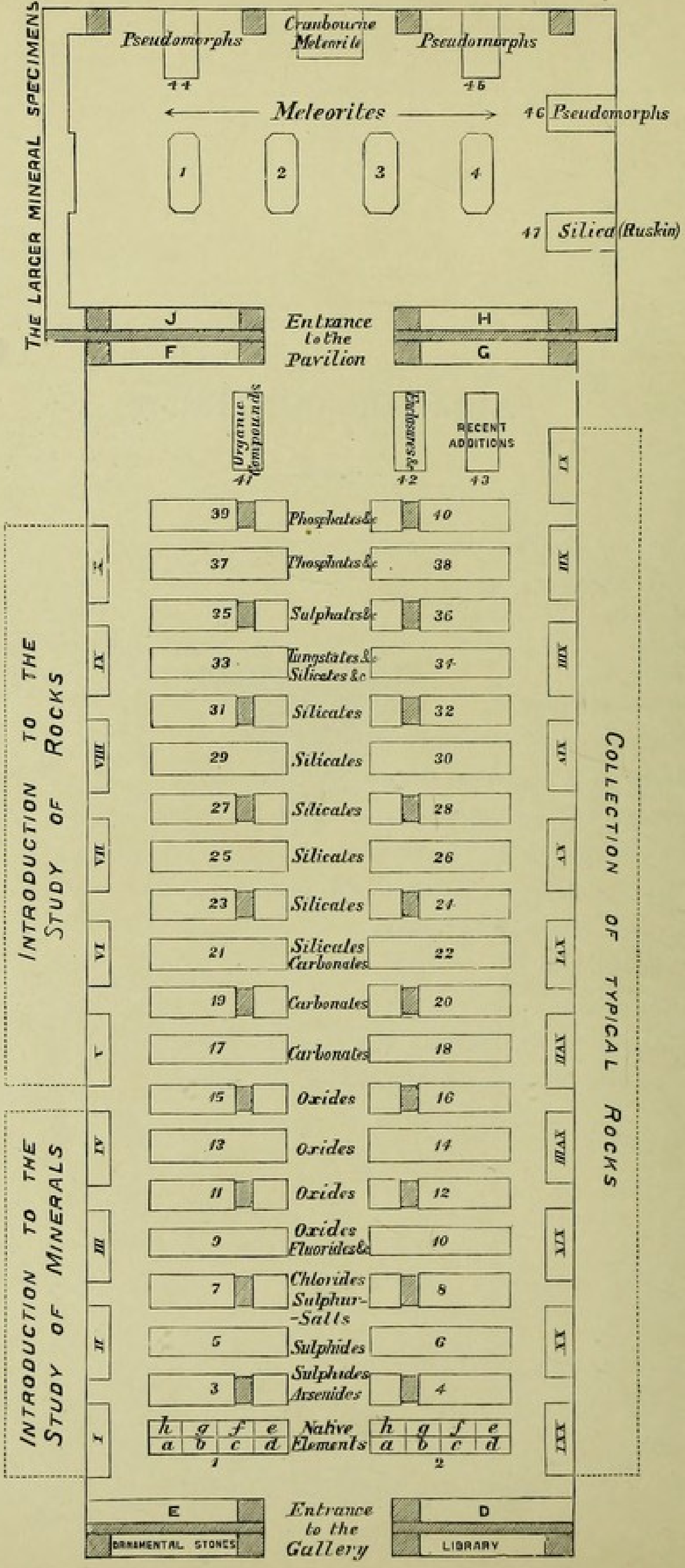
PLAN OF THE MINERAL GALLERY



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 4 in the Pavilion); the collection of meteorites (cases 1–3 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

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

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 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. A. Fleischmann; these include Pyrargyrites (Case 8a), Alexandrite (Case 9e), 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** (page 109).

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.** (page 100).

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 in 1914 by **F. N. A. Fleischmann, Esq., M.A.**

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 calcspar 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 Noble 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 and copper.

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 ineralogy

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.

Specimen.

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

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.

Specimens.

> For instance, from a side of the cavity of a specimen exhibited in the case springs a beautiful mineral (Scolecite), showing no evident likeness to any component of the enclosing rock (Dolerite); 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 of corundum.

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

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

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* *Introduction to the Study of Rocks.* 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.

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* 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

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* 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

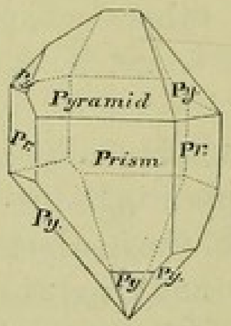

Fig. 1.

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.

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-

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* 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).

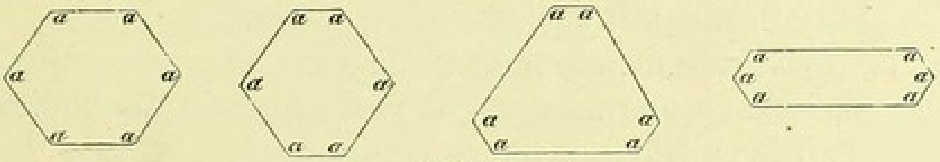

Fig. 2.

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):—

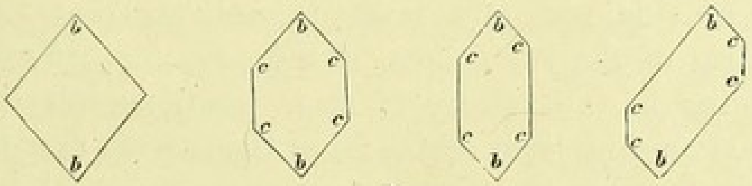

Fig. 3.

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.

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

Specimen.

Invention of a goniometer.

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* 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 :—

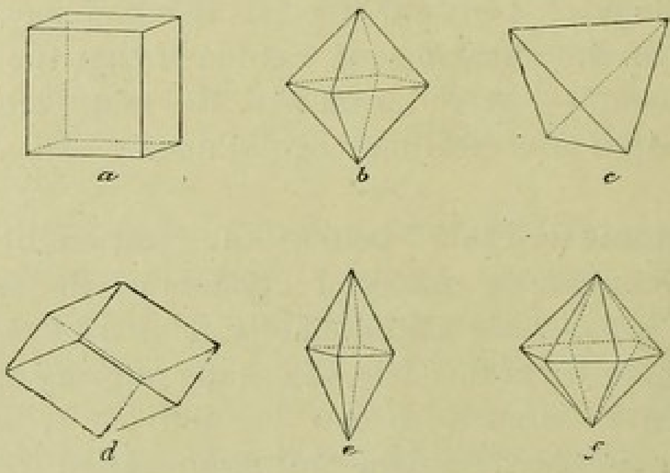

Fig. 4.

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.

Model and Specimen.

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).

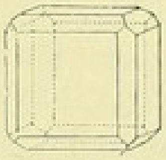
Fig. 5.

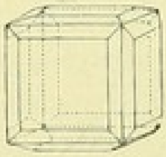
Fig. 6.

Model and Specimen.

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).

Models and Specimens.

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.

As these new faces increase and the faces of the original cube

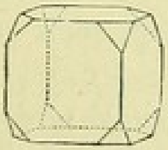
Fig. 7.

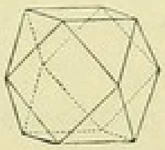
Fig. 8.

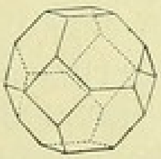
Fig. 9.

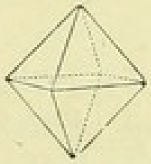
Fig. 10.

diminish in size, there is a gradual transition from the cube to the regular octahedron (as shown in Figs. 7, 8, 9, 10).

Model.

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).

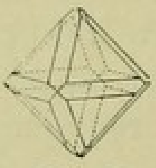
Fig. 11.

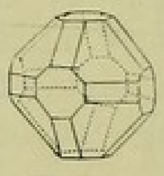
Fig. 12.

Model and Specimen.

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.

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).

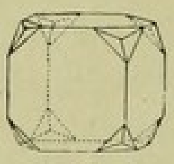
Fig. 13.

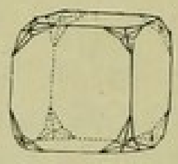
Fig. 14.

Model and Specimen.

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).

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*.

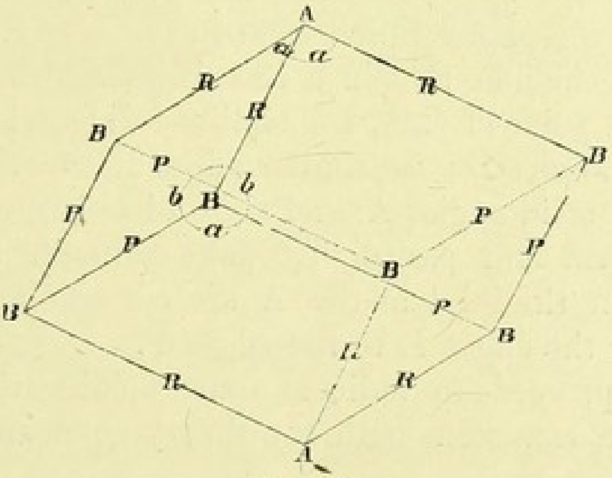

Fig. 15.

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.

Model and Specimen.

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).

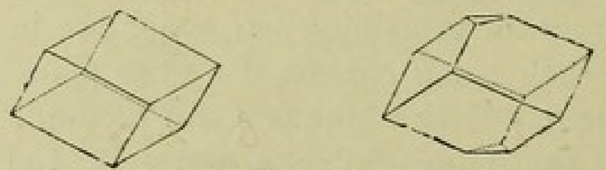

Fig. 16.

Models and Specimens.

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

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.

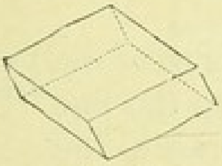
Fig. 17.

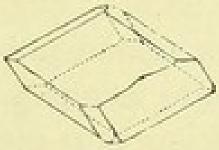
Fig. 18.

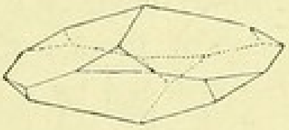
Fig. 19.

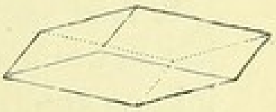
Fig. 20.


Fig. 21.

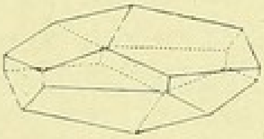
Fig. 22.

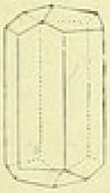
Fig. 23.


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.

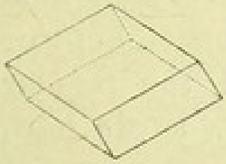
Fig. 25.

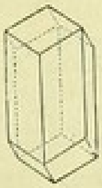
Fig. 26.

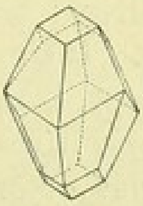
Fig. 27.

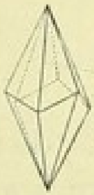
Fig. 28.

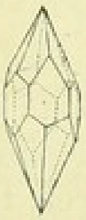
Fig. 29.

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.

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.

Model and Specimen.

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 an octahedron, 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 means 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.

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* 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:

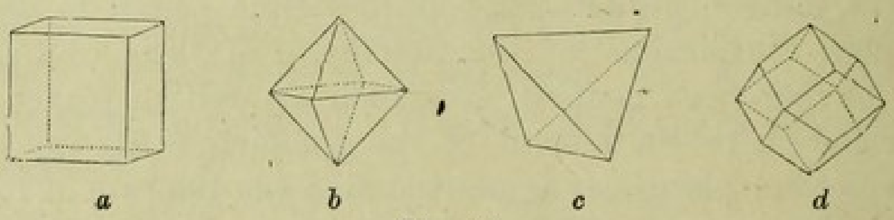

Fig. 30.

1. The cube,
2. The regular octahedron,

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

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

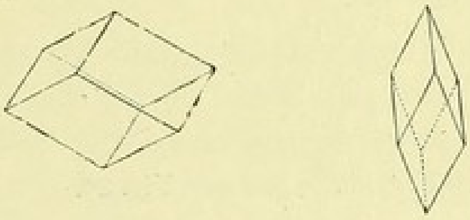

Fig. 31.

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

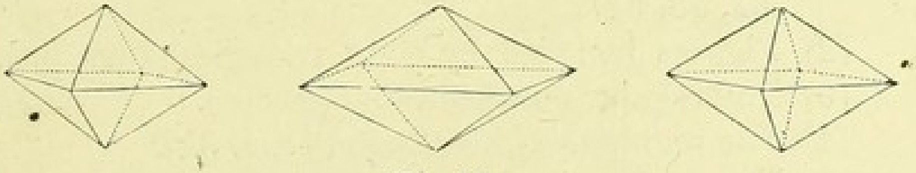

Fig. 32.

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

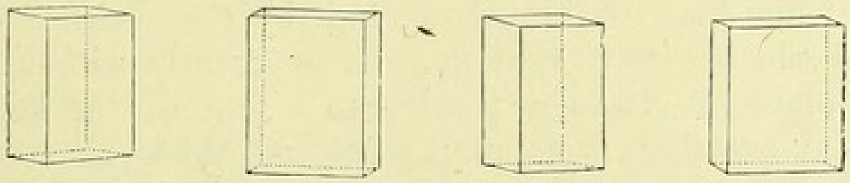

Fig. 33.

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 ;

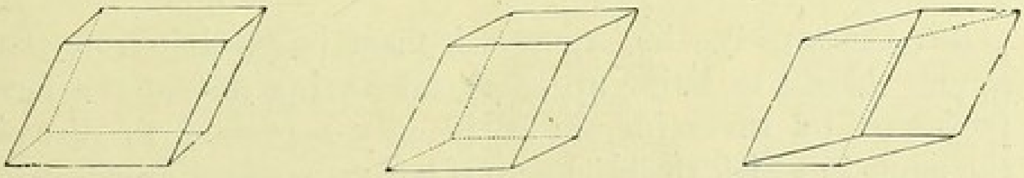

Fig. 34.

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).

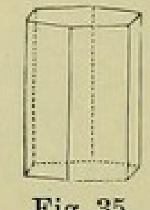

Fig. 35.

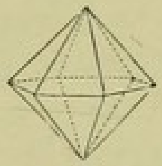

Fig. 36.

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.

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

Models.

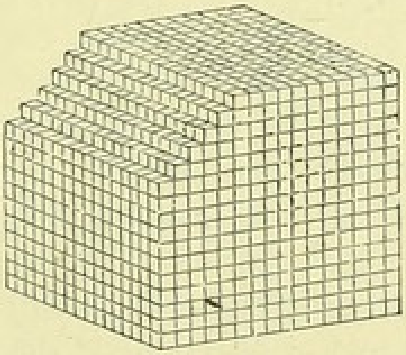

Fig. 37.

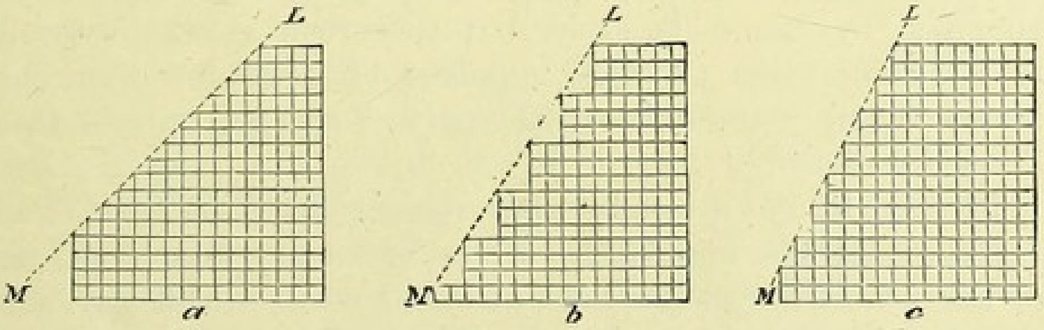

Fig. 38.

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**.

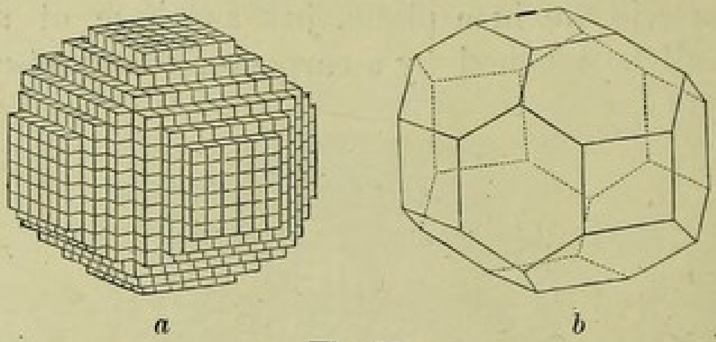
a *b*

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.

Objections 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.

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* De indagando formarum crystallinarum charactere geometrico principali dissertatio. Lipsiæ, 1809. Uebersichtliche Darstellung der verschiedenen natürlichen Abtheilungen der Krystallisations-systeme. (Denksch. d. Berl. Ak. 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

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* 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 not only be 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.

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

Specimen.

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* 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 Class A, its introduction between the two tourmalines produces absolutely no change, and the field of view remains dark. If the crystal belongs to Class 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 Class 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.

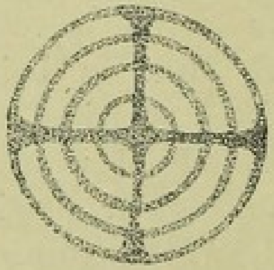

Fig. 40.

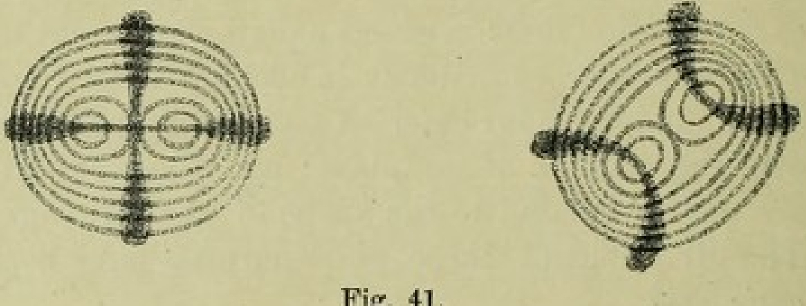

Fig. 41.

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

47. This division of crystals into classes 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.

There cannot be more than six systems.

49. The fundamental character of each of these six 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 of symmetry, and no others, each of them referable to one or other of the above six 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 six 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 and 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

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* 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 Bitterspar 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.

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* *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

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[*] Ueber das Verhältniss der Krystallform zu den chemischen Proportionen. Ueber die Körper welche in zwei verschiedenen Formen crystallisiren (Abhandl. d. Berl. Ak. 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.

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* 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," wherefrom 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.

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* 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 is virtually one published by Gustav Rose,* in 1852, as an

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* 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:—

(1) The Arsenic group:—arsenic, antimony and bismuth.

(2) The Sulphur group:—sulphur, selenium and tellurium.

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

(4) 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 will serve to give a clearer idea of this system: further detail will be given later in describing the General Collection:—

The System of Classification adopted in the Mineral Gallery.

SIMPLE MINERALS.	Div. I. **Native elements.**	Sec. (1). Metallic.	
		Sec. (2). Non-metallic.	
	Div. II. **The compounds of metals with elements of the arsenic and sulphur groups.**	Sec. (1). Arsenides, &c.	
		Sec. (2). Sulphides, &c.	
		Sec. (3). Arsenosulphides, &c.	
		Sec. (4). Sulphur-salts.	
	Div. III. **The compounds of metals with elements of the chlorine group.**	Sec. (1). Simple Chlorides, &c.	
		Sec. (2). Compound Chlorides, &c.	
	Div. IV. **The compounds of oxygen.**	Sec. (1). Oxides.	
		Sec. (2). Oxygen Salts.	Class *a.* Carbonates. *b.* Silicates, &c. *c.* Molybdates and Tungstates. *d.* Chromates and Sulphates. *e.* Borates. *f.* Nitrates. *g.* Phosphates, Arsenates and Vanadates.
	Supplement.	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.

Window-case II.

The Forms of Crystals.

The systems of crystallisation :—

The Cubic (or Tesseral) system: *fluor.*
The Tetragonal (or Pyramidal) system: *apophyllite.*
The Rhombohedral (or Hexagonal) system: *calcite, emerald.*
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 : *copper-pyrites.*
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 : *pearlspar.*
Ash-grey : *zoisite.*

Window-case III.

Black.

Greyish-black : *lydian-stone.*
Velvet-black : *tourmaline.*
Greenish-black : *augite.*
Brownish-black : *lievrite.*
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 : *cuprouranite.*
Pistachio-green : *epidote.*
Asparagus-green : *asparagus-stone.*
Blackish-green : *olivenite.*
Olive-green : *pyromorphite.*
Oil-green : *beryl.*
Siskin-green : *calcouranite.*

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* (*mountain-wood*).
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, copper-pyrites.*

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.*
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.*

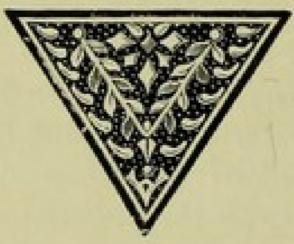
Taste :—

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.



DIVISION I.

THE NATIVE ELEMENTS.

Of the elementary bodies into which matter has been resolved by the chemist, the few which have been found in Nature in the uncombined state are shown in cases 1 and 2: they are arranged in two sections, Metallic and Non-Metallic elements. This division of the elements, though convenient, is quite arbitrary, for no sharp line of division can be drawn between the two sections.

Section i. — Metals.

Case 1ab.

With the native metals are placed the native alloys, or compounds and mixtures of metals which belong to the same chemical group.

Copper. This native metal, with silver and gold, has been known from the earliest times. A locality long ago known to the ancients was situated in the Island of Cyprus, and to the name of that island the word copper is itself related. The toughness of the metal, and the hardness of its alloys made it highly valued by the ancients as a material for tools and weapons.

In recent times the finest crystals and the largest masses have been furnished by the mines of Russia and of the neighbourhood of Lake Superior: in one of the mines of the latter locality there was found, in 1859, a mass estimated to weigh upwards of 400 tons; its length was 45 feet, and its greatest width and thickness 22 feet and 8 feet, respectively; 40 men were employed for 12 months in extracting it.

Though the crystals of native copper are rarely symmetrical in appearance, attention may be directed to the branch of cubes from the Lake Superior mining region (case 1b), and to the groups and tree-like growths of crystals from the Russian mines (case 1a). As instances of the variety of form of the native metal we may also mention:—the dendritic and the mossy growths from Cornwall (case 1a); the thin plate from Barrhead, Renfrewshire; the long branches of indistinct crystals from the Lake Superior district (case 1b), the largest of them, presented by Professor Ruskin, being shown in wall-case H in the Pavilion; the large irregular waterworn mass brought from near the Coppermine River in British North America by Mr. Hearne in the year 1771.

SILVER is found native in a large variety of forms and in many localities. Case 1cd.

Magnificent specimens have been obtained from the mines of Kongsberg in Norway: one of them, now in the Mineral Collection at Copenhagen, weighs upwards of 5 cwt.

Amongst the specimens here shown we may remark:— the wiry forms from several Cornish mines; the long branches and the groups of crystals from Kongsberg; the dendritic groups from Freiberg, Saxony, from Potosi, Bolivia, from Peru, and from Chañarcillo, Chili; crystals associated with native copper, from the Lake Superior district; native foil from Sultepec mine, Mexico; a nugget, weighing 37 oz., from Peru. Case 1c. Case 1d.

GOLD, one of the most widely occurring of minerals, is almost always found either in and about veins of quartz-rock or in alluvial deposits. Native gold always contains more or less silver, and when the proportion of the latter reaches about 20 per cent. is called *Electrum;* the crystalline forms of electrum are generally much more sharply defined than are those of the purer gold. Case 2a–d.

Special attention may be called to the following specimens:— gold associated with tetradymite, from Merionethshire, Wales; small nuggets from Cornwall, Scotland and County Wicklow. Gold associated with rock-crystal, from La Gardette, Isère, France; dendritic and leafy growths ("electrum"), from Transylvania; gold in calcite, from Ädelfors, Sweden. Case 2a.

Crystals from Beresovsk in the Urals; in association with galena, from the same locality; the "Latrobe" nugget, from Victoria, Australia, weighing 23 oz. troy, remarkable as showing crystalline structure; in calcite, from Queensland. Case 2b.

In calcite, from Solferino Reef, New South Wales; finely divided gold ("mustard-gold," "paint-gold"), a result of the alteration of tellurides of gold, from Kalgoorlie, Western Australia; deposited on the roots of plants, from Kanowna, Western Australia; nuggets and masses of crystallised gold, gold in quartz and in serpentine-conglomerate, from California. Case 2c.

Gold in quartz, from Mexico, presented by Mr. R. Simmons in 1836; a rich series of crystallised specimens, some of a pale colour, from Colombia; on barytes, from Chili; with galena, from Argentina. Case 2d.

A large mass of quartz from Costa Rica, estimated to contain above 50 oz. of finely divided gold, will be seen in the lower part of case 2.

Models of some of the most interesting gold nuggets are shown in the lower part of the case.

IRON, LEAD and TIN are of very restricted occurrence in the native state; almost all the iron thus met with is believed to have fallen from the sky, and many specimens of it are shown in the Collection of Meteorites in the Pavilion: the iron found at Ovifak by Baron Nordenskiöld is, however, now regarded by most mineralogists as having had a terrestrial origin. The iron of commerce is obtained from its "ores," among which we may especially mention magnetite, hæmatite, limonite, chalybite and clay-iron-stone: the lead of commerce is in great part extracted from galena, a compound of lead with sulphur; and the tin of commerce from cassiterite or tin-stone, a compound of tin with oxygen. Case 2e.

PLATINUM is another valuable native metal, generally found in small grains but occasionally in rather large nuggets; one in the case weighs upwards of forty ounces. The metal was first met with in South America. After its discovery in the Urals an attempt was made to introduce a platinum coinage in Russia, but without success, owing to the irregularity in the amount produced, though platinum to the value of £400,000 is Case 2e.

said to have been coined between 1826 and 1844. Platinum is one of the heaviest metals known: it weighs in the native state 17 or 18 times, and when purified, 21½ times as much as an equal volume of water. It is almost infusible, and is attacked by few substances, properties which render it of great value as a material for chemical apparatus.

Case 2e. Iridosmine is a rare mineral containing the metals iridium and osmium, and is generally found associated with platinum. It is used for the tips of the nibs of gold pens, on account of its hardness and the difficulty with which it is acted upon by acids.

Case 2e. Mercury, or Quicksilver, though found native, chiefly as small globules, is generally extracted from the mineral cinnabar, in which it exists in combination with sulphur. Though metallic in its general characters it is remarkable as being liquid at ordinary temperatures; it is by far the densest liquid known, being 13½ times as heavy as its own volume of water. It is much used for thermometers and barometers, the silvering of mirrors, the extraction of gold and silver from their ores, and the preparation of the artificial compound with sulphur, the *vermilion* of commerce.

Case 2e. Native Amalgam. The "mixtures" of mercury with other metals are called amalgams. That known as native amalgam is found almost wholly in the Landsberg mine in the canton of Ober-Moschel, Rhenish Bavaria; it contains from 25 to 35 per cent. of silver. Remarkably good crystals are shown in the case.

Case 2g. Arsenic, antimony and bismuth form a group of metals of which the crystals present the symmetry of the Rhombohedral system and have almost identical angles: with these is placed the much rarer element tellurium, of which the crystals present similar characters; its chemical properties, however, associate it rather with the element sulphur, which immediately follows it in the arrangement of the Collection.

Case 2f. Arsenic is rarely found in distinct crystals: it is often granular in structure and mamillary in shape: though initially tin-white it is soon altered to a dark grey by exposure. Simple metallic arsenic is not itself of much importance in the arts, but the alloy with lead has been found useful as a material for the manufacture of shot. The arsenic required for commerce is for the most part obtained from mispickel, a compound of arsenic with sulphur and iron.

Case 2f. **Antimony**, though found native, is chiefly obtained for commerce from the much more plentiful mineral stibnite, in which the metal is combined with sulphur. It is very valuable for the manufacture of type-metal, an alloy of antimony with lead and tin: this alloy, like water, presents the exceptional property of increasing in volume when passing from the liquid to the solid state; it thus, whilst solidifying, keeps in constant contact with the mould and takes a sharp impression. Britannia metal and pewter are alloys of antimony with tin.

Case 2f. **Allemontite** is remarkable as being a compound of the two similar elements antimony and arsenic: of the latter it contains 65 per cent.

Case 2f. **Bismuth** is chiefly found native: a fine mass from Bolivia, rich in gold, is shown in wall-case H in the Pavilion: the specimens in the table-case (2f) are chiefly from Cornwall and Saxony. Bismuth has the peculiar property of forming alloys with lead and tin which melt at a very low temperature, some of them far below the boiling point of water: these alloys are much used in the process of stereotyping. The metal is also employed in the manufacture of some kinds of solder.

Section ii. — Non-metallic elements.

In the second section of native elements is placed sulphur; and also diamond and graphite, the two native modifications of the element carbon.

Case 2gh. **Sulphur.** The specimens of this mineral are from their colour, transparency, size, and sharpness of crystalline form, among the most magnificent of natural products: very fine groups of crystals will be found in the upper and lower parts of the case and in the Pavilion. Sulphur generally occurs in the neighbourhood of volcanoes, active or extinct, and is often associated with gypsum. Most of the sulphur required for commerce is brought in the native state from Sicily: in France, Germany and Sweden it is also artificially prepared by distillation from pyrites. It is employed in medicine (the common brimstone); and also in the manufacture of gunpowder and of oil of vitriol.

Diamond and Graphite, though chemically only different Case 1e–h. states of the element carbon, are almost completely opposite in their general characters. The diamond is the hardest of all known minerals; graphite is one of the softest: diamond is found in more or less symmetrical transparent crystals, generally colourless or faintly yellow, but sometimes with blue, grey, or other tints; graphite, on the other hand, rarely occurs in well defined crystals; it is opaque, black in colour, and has a metallic lustre quite different from that of the diamond: diamond, too, is a very bad conductor of electricity, graphite an excellent one.

The diamond, from its rarity and hardness, has long been regarded as the most precious of the decorative stones; its superiority of lustre and brilliancy have been rendered even more conspicuous by the discovery, made not many centuries ago, that this, the hardest of stones, can be cut and polished by means of its own powder.

The diamond becomes strongly electric on being rubbed: when it is heated or exposed to a strong light it becomes luminous, and remains so for several hours: a diamond also becomes luminous if held near a particle of radium bromide.

The collection of mounted crystals is extremely remarkable Case 1f. as representing a great variety of crystalline form. A very symmetrical South African crystal, weighing 130 carats, presented by Professor Ruskin, is exhibited; the triangular markings on the octahedral faces, so characteristic of the diamond, are in this specimen extremely distinct.

Those specimens which are useless to the jeweller, owing to imperfect crystallisation (when the specimens are known as *Boart*) or to flaws, have considerable value for the lapidary, by Case 1e. whom they are reduced to powder and employed in cutting and grinding the precious stones.

There is found in Brazil a black compact aggregate of minute crystals of diamond, called *Carbonado*, which is in much Case 1e. request for the drilling of hard rocks. To this purpose isolated crystals of diamond are not suited, for, notwithstanding its great hardness, the diamond easily splits in certain directions related to the crystalline form; of this property the diamond-splitter avails himself for removing the parts containing flaws, and for shaping the specimens before the polishing is begun. Very few diamonds are now found in India, in the south of which the mines once famous under the name of the mart, Golconda, are situated: almost all those of commerce are brought from South Africa.

It is not known how the diamond has been produced in Nature, and it has rarely been found in the place where it was formed: specimens of the pebbles amongst which the diamond has been met with in Brazil and India and of the rocks, one of them an Eclogite, in which it occurs in South Africa, are shown in the case. Minute crystals of diamond have been made through the sudden cooling of the outer parts of a very hot mass of molten iron rich in carbon: the interior of the mass then solidifies under great pressure, and some of the carbon crystallises out as diamond.

Models of some famous diamonds, including the 'Cullinan' diamond, the largest ever found (weight before being cut, $3025\frac{3}{4}$ carats, or about $1\frac{1}{3}$ lb. avoir.), are exhibited. Case 1g.

GRAPHITE, also known as *Plumbago* or *Blacklead*, has many uses. In its purest form it is the material of blacklead pencils: excellent graphite for this purpose was long supplied by the mines of Borrowdale in Cumberland, now worked out. The less pure forms are employed for the polishing of stoves and for reducing the friction of machinery; large quantities from Ceylon are mixed with clay and made into crucibles at the Battersea works. Case 1gh.

The graphite from New Cumnock, in Ayrshire, shows a columnar structure, probably caused by the heat which came from a neighbouring dyke. A curious fibrous structure is also conspicuous in some of the specimens from Battugol and Ceylon.

DIVISION II.

THE COMPOUNDS OF METALS WITH ELEMENTS OF THE ARSENIC AND SULPHUR GROUPS.

In the first of the four sections of this division are placed those minerals in which arsenic, antimony or bismuth is combined with a metal of another group: the second section includes those compounds of metals with sulphur, selenium or tellurium, in which the latter are regarded as playing a part analogous to that of oxygen in the oxides: in the third section are arranged the minerals wherein certain arsenides of section i are combined with the sulphides of section ii, or which may otherwise be looked upon as the result of a replacement of half the arsenic of the minerals of section i by its equivalent of sulphur: the fourth and last section comprises those minerals in the chemical constitution of which sulphur is regarded as playing a part analogous to that of oxygen in the oxygen-salts, a class of compounds hence termed sulphur-salts.

Section i.—the arsenide

Dyscrasite is a compound of antimony and silver, and contains from 77 to 85 per cent. of the precious metal. Case 3a.

Niccolite is a compound of nickel and arsenic, and an important source of the nickel of commerce; an alloy of this metal with copper and zinc is the well-known German silver. The metal is at present chiefly used for electroplating with silver. Case 3a.

Smaltite, a compound of cobalt and arsenic, is the mineral from which blue enamel colours, particularly smalt, are prepared. Case 3b.

Chloanthite is the corresponding compound of nickel and arsenic, and is another source of the metal nickel. Case 3c.

Skutterudite is a compound of cobalt and arsenic, crystallising in forms analogous to those of pyrites. Case 3c.

Section ii.—the sulphide group. The mono-sulphide series.

Argentite is an important ore of silver, 100 parts containing 87 of that metal combined with 13 of sulphur: before exposure to the light it has a bright metallic lustre, but soon after exposure becomes coated with a dull dark powder: the mineral is remarkable as being perfectly sectile. Good specimens from Freiberg, Chili, and also Cornwall, will be found in the cases. Cases 3d, 4a.

Blende is an important ore of zinc: 100 parts of the mineral contain 67 of zinc and 33 of sulphur. Case 4b–d.

A particularly fine suite of specimens is shown in the case. A specimen of blende containing the rare element gallium, presented by the late Mr. W. G. Lettsom, is exhibited. Case 4d.

Occurring in many parts of the world and having been produced under many different conditions, the crystals of blende present a considerable variety in their forms, all of which can be referred to that section of the Cubic system of which the tetrahedron is a prominent type, and they thus afford material for the study of that kind of hemi-symmetry. It has been found that while all alternate faces of the octahedron are similar to each other, the adjacent ones differ in lustre, striation and smoothness, and also in the angles which the associated faces make with them. The crystals are rarely simple growths, being generally twinned upon the faces of the octahedron.

Galena is by far the most important ore of lead: 100 parts of the mineral contain 87 of lead and 13 of sulphur. The crystals from Rossie and from Neudorf are very sharply defined. A large crystallised specimen from the Great Laxey mine, Isle of Man, is shown on the adjacent table. Case 4e–h.

Alabandite is the corresponding compound of manganese and sulphur. Case 4h.

Pentlandite is a compound ot iron, nickel and sulphur, and is commercially important as a source of nickel. Case 4h.

Copper-glance, or Redruthite, is an important ore of copper: 100 parts contain 80 of copper and 20 of sulphur. The suite of specimens from Cornwall is unique for excellence and variety of crystalline form. The mineral is altered by exposure to light. Case 5e–g.

Cinnabar is the ore from which mercury (or quicksilver) is obtained by heating: 100 parts contain 86 of mercury and 14 of sulphur: the same compound artificially prepared is the *vermilion* of commerce. Almost the only localities known are those of Almāden in Spain, Idria in Austria, Moschel in Rhenish Bavaria, and New Almaden in California; extraordinarily fine twinned crystals from China are exhibited. Cases 3h, 5a.

Wurtzite is interesting as crystallising in the Rhombohedral system, though it has the same chemical composition as blende. Case 5a.

Greenockite is a very rare mineral found in association with prehnite and stilbite; it was first met with in cutting the Bishopton tunnel on the Glasgow and Greenock railway; it is a compound of sulphur and cadmium. The corresponding artificial compound is the pigment *cadmium yellow*. Case 5ab.

Millerite is another source of the metal nickel: the wool- Case 5b.

like form from St. Louis, Missouri, is worthy of notice. Considerable quantities of this mineral have been obtained from the Gap mine, Lancaster County, Pennsylvania.

CROOKESITE is remarkable as containing 17 per cent. of thallium: it is a selenide of copper and thallium with about 5 per cent. of silver. Case 5c.

NAGYAGITE is a telluride of gold and lead, in which some of the tellurium is replaced by sulphur. Case 5c.

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The disulphide series.

HAUERITE, beginning the series of disulphides, is the disulphide of manganese; its crystals present the same kind of hemi-symmetry as those of pyrites. Case 5d.

PYRITES, or Iron-pyrites, contains 47 of iron and 53 of sulphur in 100 parts. Though one of the most common of minerals, the difficulty of getting rid entirely of the sulphur prevents it from being employed for the manufacture of iron: it is, however, extensively used in the preparation of the green vitriol and oil of vitriol of commerce. Cases 5d, 6ab.

Just as blende is useful for the study of that hemi-symmetry of the Cubic system in which only the symmetral character of the cube-planes is in abeyance, so pyrites with its manifold forms is of the greatest value for the study of that kind of hemi-symmetry in which only the symmetry relative to the dodecahedron-planes is wanting. The specimens from Elba and Traversella are especially worthy of remark.

G. Rose sought to prove that the complementary semiforms of this mineral are associated with opposite thermo-electric characters: it has since been shown that similar differences are manifested by crystals of holo-symmetrical minerals.

MARCASITE, having the same chemical composition and the same commercial uses as the last named mineral, has from its lighter colour been called "White iron-pyrites"; but the differences in the crystalline form and other characters make it necessary to regard the two kinds as different species. The crystals of marcasite are far from being so distinctly formed as those of pyrites. They generally group themselves into peculiar shapes, thus giving rise to the fanciful terms, Spear-pyrites, Cockscomb-pyrites, &c. Case 6b.

MOLYBDENITE is the disulphide of molybdenum, and is the chief source of the molybdenum salts; it is very similar in Case 6c.

appearance to graphite, from which it was only distinguished in 1778.

Realgar is the disulphide of arsenic, and occurs in crystals of a beautiful aurora-red colour; as on exposure to light the mineral is soon altered to a yellow powder, the specimens are kept in the drawers. Case 6c.

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The sesqui-sulphide series.

Laurite is a sulphide of the rare element ruthenium, of which metal part is replaced by osmium: it has only been found in Borneo, where it occurs associated with platinum. Case 6d.

Sylvanite is a telluride of silver and gold. Case 6d.

Stibnite, or Antimonite, a compound of sulphur and antimony, is much used for the preparation of the metal and its salts, of which a large number have been employed in medicine: in the East the powdered mineral is used for painting the eyebrows. The specimens from Felsöbanya and Japan are especially worthy of notice; a magnificent specimen from the latter locality is shown on the adjacent table. Case 6ef.

Bismuthite is the corresponding sulphide of bismuth. Case 6f.

Orpiment is the corresponding compound of sulphur and arsenic: the artificial compound was one of the ingredients of the pigment *king's yellow*, now superseded by the harmless *chrome-yellow*. Case 6g.

Section iii.—the arseno-sulphide group.

Cobaltite, or Cobalt-glance, like smaltite, is highly valued as an ore of cobalt: it is a compound of that metal with arsenic and sulphur. The crystals are similar to those of pyrites in the development of their faces. Case 6g.

Gersdorffite, or Nickel-glance, is the corresponding compound of nickel; and Ullmannite is a similar compound of nickel in which the greater part of the arsenic is replaced by antimony. Case 6g.

Mispickel, a compound of arsenic, sulphur and iron, is the chief source of the arsenical compounds of commerce. Case 6h.

Danaite is a variety of mispickel containing cobalt. Case 6h.

Glaucodote is a similar compound, in which still more of the iron has given place to cobalt. Case 6h.

Section iv. —the sulphur-salts.

The first and somewhat ambiguous group of sulphur salts is regarded as containing Fe_2S_3 or FeS_2 as part of the "acid" component.

PYRRHOTITE, or Magnetic pyrites, is a compound of iron and sulphur. The specimen from Morro Velho, presented in 1883 by Mr. F. Tendron, is unusually fine; good specimens are also shown from the Miggiandone mine. Case 5e.

ERUBESCITE is a valuable ore of copper, and contains that metal in combination with sulphur and iron: the copper varies from 60 to 70 per cent. Case 5e.

COPPER-PYRITES, or Chalcopyrite, is the most important of copper ores, and contains the same elements as erubescite but in different proportions, the copper amounting to only 35 per cent. It is also used for the preparation of the "blue copper" (copper sulphate) of commerce. For general excellence the series of specimens in the case is unequalled. Case 5f–h.

The crystals of this mineral belong to the Tetragonal system, and are of great interest to the student as being almost the only representatives in that system of a hemi-symmetry corresponding to that of blende in the Cubic. The twin-growths, too, are especially important in their characters: remarkably good examples of a kind of growth almost, if not quite, peculiar to this mineral are shown from Cornwall and Freiberg (case 5g).

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The next and largest group of sulphur-salts is that consisting of sulph-arsenites, sulpho-bismuthites and sulph-antimonites.

STEPHANITE is a sulph-antimonite of silver, and is an important silver ore. Case 5h.

TETRAHEDRITE, or Grey copper-ore, a most valuable ore of copper, belongs to this class; it is a sulph-antimonite of that metal, part of which is frequently more or less replaced by silver, iron and zinc. The specimens from Cornwall, which are coated with copper-pyrites and tarnished, are very beautiful. Case 7ab.

TENNANTITE is the corresponding compound in which the antimony is replaced by arsenic. Case 7b.

Both the latter minerals crystallise in the Cubic system, and present a hemi-symmetry similar to that of blende.

BOURNONITE is a sulph-antimonite of lead and copper; the specimens from Herodsfoot mine are unique for size and splendent lustre. Case 7d.

PYRARGYRITE is a sulph-antimonite, and PROUSTITE a sulph-arsenite, of silver; before they are blackened by exposure to light they have a beautiful blood-red colour: Case 8a–c.

the two minerals may be distinguished by means of their streaks, the powder of pyrargyrite being purplish-red and that of proustite scarlet-vermilion. The pyrargyrites from Mexico and the Harz are particularly fine, while the mass of resplendent crystals of proustite from Chili, presented by Mr. H. Ludlam, is unique; unfortunately, for the above mentioned reason, it requires to be protected from the light. Pyrargyrite and proustite are important ores of silver.

Jordanite is a sulph-arsenite of lead: very good crystals from the Binnenthal are shown in the case. Case 8d.

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Xanthoconite has the same chemical composition as proustite but crystallises in the Monosymmetric system; of this rare mineral a specimen from Chili, associated with proustite itself, is probably unique for its excellence, but requires to be kept in the dark. Case 8e.

DIVISION III.

THE COMPOUNDS OF METALS WITH ELEMENTS OF THE CHLORINE GROUP.

Section i.—Simple chlorides, fluorides, &c.

Sylvite, of which fine specimens are exhibited, is a compound of the metal potassium with the element chlorine: it is very similar in its characters to common salt. Case 8f.

Salt, Common salt or Rock-salt, is a compound of sodium with chlorine. It occurs chiefly in beds, often of great thickness and extent, and is present in solution in salt-lakes and brine-springs. The Great Salt Lake of Utah, which has an area of 2000 square miles, contains 20 per cent. by weight of common salt in solution. The Dead Sea contains 20–26 per cent. of solid matter, and one-third of this is common salt. The waters of the ocean contain 4 per cent. of solid matter in solution, and about three-fourths of this is common salt. The most famous mines are those of Wieliczka, in Austria, which have been worked for the last 600 years; the beds of salt are there so thick that they have been excavated into houses, chapels and other ornamental forms, and the mines, when illuminated, are regarded as one of the sights of Europe. The salt mines of Cheshire are also well known. Case 8fg.

A beautiful crystallised specimen from Wieliczka, presented in 1862 by the Austrian Government, is in the case. Case 8f.

Some specimens are of a deep blue colour, which disappears when the salt is dissolved in water. Case 8fg.

SAL-AMMONIAC is the corresponding compound of ammonium and chlorine, and is found as a sublimation-product near to volcanoes and ignited coal-seams. That required for commerce is artificially prepared: it is valuable in medicine, and is also used by tinmen in soldering. Case 8g.

CHLORARGYRITE, Cerargyrite or Hornsilver, contains 75 per cent. of silver and 25 per cent. of chlorine, and is a valuable ore of the metal. Chlorargyrite is remarkable for its malleability and sectility; it is blackened by exposure to the light. Case 8h.

EMBOLITE contains about 65 per cent. of silver, the remainder consisting of variable proportions of chlorine and bromine: it is the principal silver ore furnished by the mines of Chañarcillo, in Chili. Case 8h.

FLUOR is a compound of calcium with fluorine: an extensive suite of specimens in the cases illustrates the varieties of colour and crystalline form presented by this beautiful mineral. Large quantities of the violet-blue variety (Blue John) have, until lately, been got from veins in the limestone of Derbyshire, and more especially in the large caves in the Castleton district. The Derbyshire fluor is wrought into various ornamental articles: it takes a good polish, but on account of its easy cleavage is difficult to work. With the exception of the pink variety found in the Alps, all the finest specimens of this mineral are of English origin. Fluor is also employed as a flux in the reduction of various ores; and the hydrofluoric acid prepared from it is used for etching glass. Cases 7e–h, 9ab. Case 7g. Case 7h.

CALOMEL is a chloride of mercury; the artificial salt is much used in medicine. Case 9b.

FLUELLITE is a very rare mineral of which minute crystals were found some years ago in Cornwall. It is a hydrated fluoride of aluminium. Case 9b.

Section ii. —Compound chlorides, &c.

CRYOLITE is a double fluoride of aluminium and sodium; it occurs forming a large bed or vein at Arksutfjord in Greenland. It is used for the preparation of commercial carbonate of soda, and also of opal-glass and enamelled iron. Case 9b.

DIVISION IV.

THE COMPOUNDS OF OXYGEN.

As the chemically energetic element, oxygen, forms a fifth part of the atmosphere by which our Earth is surrounded, and is by far the most important constituent of the water which is nearly everywhere present, the minerals having oxygen for one of their constituent elements are, as might be expected, very numerous. In fact, the minerals which by their aggregation form the rocks of the Earth's crust fall almost wholly within this chemical division.

Just as the compounds with sulphur are divided into sulphides and sulphur-salts, the compounds with oxygen are divided into oxides and oxygen-salts; the distinction, though difficult to define with logical precision, yet serves one important object of a system of classification in that it brings together compounds which, in their general characters, bear a close resemblance to each other.

Oxy-chlorides, &c.

At the beginning of the first section are placed the minerals in which oxides or hydrates are combined with the chemical compounds which fall under the last division.

Matlockite is an oxychloride of lead: very fine crystals of this mineral will be found in the case. Case 9c.

Mendipite is another oxychloride of lead, containing twice the proportion of lead oxide present in matlockite. Case 9c.

Atacamite is a hydrated oxychloride of copper; fine crystals from South Australia are exhibited. Case 9d.

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The oxides are so arranged that those containing the greater atomic proportion of oxygen follow after those containing less: commencing with the basic oxides, we thus pass through certain comparatively neutral oxides, among which we must look for those which possess the most equivocal claim to a place in the section, and we then come to the higher oxides which act the part of acids in combining with bases.

The first series is that of the monoxides.

Monoxides.

Cuprite, or Ruby-copper, is an important ore of copper, of which element it contains 89 per cent. It is found in beautiful transparent ruby-coloured crystals, which are rapidly blackened by exposure to light. Cuprite gives a very intense red colour to glass. Case 10a-c.

Case 10bc.

Chalcotrichite is a variety of cuprite in which the crystals are bright red and capillary, and are not so subject to alteration by light. Unequalled specimens both of cuprite and of chalcotrichite are in the collection.

Case 10b.

Tile-ore is an earthy variety of the same mineral.

Case 10c.

Periclase, the corresponding oxide of magnesium, has been found almost solely in the agglomerates of Monte Somma.

Case 10c.

Zincite, or Spartalite, is a very valuable ore of zinc found only in New Jersey: the red colour is probably due to a small proportion of an oxide of manganese. The corresponding artificial compound is used as a white paint.

Case 10cd.

Melaconite, or Black copper, is another compound of oxygen and copper, and contains 80 per cent. of the metal. In some mines it has been found in quantities sufficient to make it a very valuable ore.

Case 10d.

Brucite is a hydrate of magnesium: the specimens from Wood's mine are unusually fine.

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Epitritoxides.

The next series in the section of oxides is formed by minerals of which the chemical type is similar to that of magnetite; but while, regarded as oxides, they are represented by the same typical formula, they have also some claim to be regarded as oxygen-salts.

The first of this class is the Spinel group, which includes spinel, magnetite, chromite and franklinite, all of them crystallising in the Cubic system.

Case 10e.

Spinel in its transparent varieties is one of the precious stones: the deep-red is the *Spinel-Ruby* (less dense and less hard than the true Ruby), the rose-tinted is the *Balas-Ruby,* and the yellow or orange-red is the *Rubicelle* of the jewellers: sometimes, too, it has a dark blue colour. On account of their hardness the less valuable specimens are used for the jewelling of watches. Specially worthy of notice are a large polished octahedron, and a small growth in which the twinning is repeated in a peculiar way.

Case 10e.

Spinel may also be regarded as an aluminate of magnesia: different members of the spinel group, chiefly opaque, may be regarded as due to the replacement of the magnesia and of the alumina by other oxides; among these, *ceylonite* (or *pleonaste*) is an iron-magnesia-spinel, and *gahnite* a zinc-spinel.

Case 10ef.

Case 10fg.

Magnetite, or Magnetic iron-ore, is the richest and most valuable of the ores of iron, of which metal it contains 72 per cent. Magnetite is one of the most widely occurring of minerals: it is remarkable for its magnetic properties, and is found presenting polar characters: it is the natural *loadstone.* The crystals from Nordmark and the Binnenthal are very bright and sharply defined.

Chromite is the corresponding oxide of chromium and iron: it is the chief source of the salts of chromium, which are extensively used as dyes and pigments. Case 10gh.

Franklinite is another member of this group; it is first worked for zinc, and then the residue is treated as an iron ore. Case 10h.

Uraninite, or Pitchblende, consists almost entirely of oxygen and uranium; it contains also small quantities of helium and radium, of which latter it is the chief commercial source. From this mineral are obtained the uranium compounds used in porcelain painting and yielding yellow and black colours. Case 10h.

Hausmannite has the same type of formula as the members of the Spinel group, and is an oxide of manganese; it crystallises, however, in the Tetragonal system. Case 10h.

Chrysoberyl belongs to this series of oxides but is orthorhombic in crystallisation; it may also be regarded as an aluminate of beryllium. In its transparent varieties it is one of the precious stones: the beautiful greenish-yellow variety, almost equal in lustre and hardness to the sapphire, is the *Oriental Chrysolite* of the jewellers; another variety, with a peculiar play of light, is the *Cat's-eye;* while a third, green by sun-light but red by candle- or lamp-light, is the stone known as *Alexandrite.* Very fine twin-growths, and cut specimens of these varieties, are shown in the case. Case 9e.

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Sesquioxides.

The next series is that of the sesquioxides.

Braunite, though generally classified as sesquioxide of manganese, contains from 8 to 10 per cent. of combined silica: the specimens in the case from San Marcel are unusually fine. Case 9f.

Corundum is the sesquioxide of aluminium, and crystallises in the Rhombohedral system. Case 9f–h.

Ranking next in lustre and in hardness to the diamond, it is, after the diamond, the most precious of stones. When pure it is colourless, but with very minute traces of colouring ingredient it assumes the richest hues; when red it is the true Case 9f.

Ruby; when azure it is the *Sapphire;* the yellow, green and purple varieties were at one time known respectively as the *Oriental Topaz, Emerald* and *Amethyst;* the prefix *Oriental,* though at first used to suggest that the stones are not the ordinary topaz, emerald and amethyst, but other minerals of a similar colour coming from the East (India, Ceylon, Siam, Pegu, &c.), was afterwards understood to imply only the *excellence* of their characters. The *Asteriated Ruby* and *Sapphire* (*Star-stones*), when placed in a strong light, show a six-rayed star; its position bears a simple relation to the crystalline form. An extensive suite of faceted specimens of these varieties will be found in the case. Pointed crystals of corundum are mounted, like carbonado, in the crowns of rock-drills; owing to its hardness the mineral is also used for the supports of compass needles and of the pivots of watches.

Emery is an opaque and impure corundum, but is still, from **Case 9b.** its great hardness, very valuable as a grinding material.

HÆMATITE, though very different from corundum in its **Case 11a–c.** external characters, corresponds to it very closely both in chemical type and in the fundamental angles of the crystalline form; it is a sesquioxide of iron and a very important ore.

Of *Specular iron,* the crystallised variety of hæmatite, a **Case 11b.** fine suite of specimens, more especially from Elba and Switzerland, is shown in the case; some of them have a characteristic tarnish which produces an effect of great beauty.

The massive variety known as *Red Hæmatite* is found in **Case 11c.** large deposits both in Lancashire and Cumberland; a large mamillary mass of it will be seen on an adjacent pedestal. *Red Ochre* is in some cases an earthy variety of this mineral, in others a variety of the hydrated oxide. Red Ochre, and also massive hæmatite when reduced to powder, are used as polishing materials.

ILMENITE is one of the ambiguous species of this series, and **Case 11d.** may be regarded either as an oxide of titanium and iron analogous to hæmatite, or as a titanate of iron. Its crystals have almost exactly the same angles as those of hæmatite; the proportions of the sesquioxides of iron and titanium in ilmenite are very variable. It is the mineral in which the element titanium was first discovered. Fine crystals, chiefly from Russia and Norway, are exhibited.

With this series are arranged the hydrated sesquioxides.

Case 12a.

> Göthite is a hydrated sesquioxide of iron; unusually fine crystals of this mineral are shown from the Restormel and Botallack mines, Cornwall.

Case 12bc.

> Diaspore is the corresponding compound of aluminium, and Manganite, that of manganese.
>
> The last three minerals are very similar in their crystallographic as well as in their chemical type.

Case 12ef.

Limonite is one of the most important ores of iron, and when pure yields iron of superior quality; it contains about 15 per cent. of water. Reduced to powder it is, like hæmatite, used as a polishing material.

Case 12f.

Beauxite, or Bauxite, a hydrated oxide of aluminium and iron, is used for the manufacture of metallic aluminium on a large scale.

Case 12fg.

Psilomelane is a common ore of manganese, and generally contains from 70 to 80 per cent. of the oxides of that metal: the oxide of barium present sometimes reaches 17 per cent.

Case 12h.

Wad is a very similar mineral, but contains more water.

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Dioxides.

Case 11e.

Pyrolusite, beginning the series of dioxides, is the most important ore of manganese. It is much used in the manufacture of glass, for getting rid of the brown and green tints; also for bleaching purposes, and for the preparation of oxygen. The sulphate and chloride of manganese made from it are used in calico printing. Large and fine dendritic growths of pyrolusite are met with in the limestone of Solenhofen, in Bavaria; a good specimen is placed in the first pane of wall-case K in the Pavilion.

Cases 11f–13b.

Cassiterite, or Tin-stone, is the ore of tin, of which metal it contains 79 per cent. The mines of Cornwall supplied the ancients with much of their tin. An extensive suite of crystals from Cornwall and Schlaggenwald, and from La Villeder in Brittany, will be found in the case.

Case 13a.

Wood-tin is a fibrous form of the mineral and is somewhat like dry wood in general appearance.

Stream-tin is the ore in the form of sand, as obtained from the beds of streams and from alluvial deposits. Case 13ab

ZIRCON contains the dioxides of both zirconium and silicon : its crystals belong to the same system as those of cassiterite, and the two minerals have almost identical angles. Twin-growths are, however, as rare in zircon as they are common in cassiterite : the specimens from Renfrew in Canada are remarkably fine. When clear and without flaws it is one of the precious stones : one variety with peculiar red tints is the *Hyacinth* or *Jacynth,* while the colourless, yellowish and dull green are termed *Jargoon :* the colourless variety, owing to its high refractive power, approaches even the diamond in brilliancy : zircon is the densest of the precious stones. Fine cut specimens, and an almost unrivalled suite of Russian crystals, are shown in the case. Case 13bc. Case 13c. Case 13b.

THORITE has a similar composition to zircon, the zirconium being here replaced by the rare metal thorium ; it contains from six to nine per cent. of water, and is probably a result of alteration. *Orangite* is a yellow variety of this mineral. Case 13c.

RUTILE, ANATASE and BROOKITE are chemically identical, and are various forms of the dioxide of titanium. Cases 13c–14b.

Fine specimens of rutile from Georgia, U.S.A., and Brazil, of anatase from Switzerland, and of brookite from North Wales and the Tyrol, will be found in the cases.

We now come to a large group of specimens illustrating the manifold forms with which silica, the dioxide of silicon, presents itself in the Mineral Kingdom. The group begins with the crystallised varieties, tridymite and quartz, and ends with the amorphous variety, opal. Between these are arranged varieties regarded as mixtures of the crystalline and amorphous with each other, or also with oxide of iron, clay, or other impurities.

TRIDYMITE is a form of silica remarkable as crystallising in the Anorthic system, though the crystals are often so twinned that the growths present Hexagonal symmetry. It has the specific gravity of opal, which is less than that of quartz. Case 14b.

QUARTZ in its clear and transparent variety is the *Crystal* of the ancients, and the *Rock-crystal* of modern times ; it is the Case 14b-d.

Brazilian Pebble of the spectacle-makers. The simple rhombohedra from Bristol and Siberia, and the rare specimens Case 14b. showing a basal plane, are worthy of notice. Several of the specimens from La Gardette are remarkable not only for their clearness, but also as fine examples of a rare kind of twin-growth. A large ball, brought from Japan, illustrates this Case 14c. species in its purest form. The largest crystals are shown on separate stands at the end of the case: one of them, a doubly terminated crystal, was presented in 1882 by Mr. C. S. Bement, of Philadelphia, U.S.A.

The history of the formation of rock-crystal is illustrated by some most interesting specimens enclosing other minerals: they are shown in case 42 illustrating enclosures in general.

Next follow the less clear varieties of quartz, beginning Case 14e. with the white. The ***Potato-stone*** from Clifton, near Bristol, in outer aspect is like its namesake, but when broken is found to be hollow and lined with crystals. ***Cotterite***, an Irish quartz, Case 14f. has a peculiar pearly lustre.

To this succeed the smoky varieties, including the ***Scotch*** Case 14fg. ***Cairngorm*** and ***Occidental Topaz.*** Next comes the ***Amethyst***, some- Case 14gh. times yellow, sometimes purple; as a precious stone the purple amethyst lacks brilliancy, but still is beautiful in colour. The amethyst is distinguished from the other varieties of quartz by its rippled fracture and optical characters. Next follow the ***Milky quartz***, ***Rose-coloured quartz***, and the ***Prase*** of a leek- Case 13e. green colour. ***Avanturine quartz*** is the name given to a variety spangled in general with mica. The ***Quartz-Cat's-eye*** is a Case 13f. variety presenting the opalescence, but not the hardness or the brilliancy of the chrysoberyl Cat's-eye; the opalescence is due to fibres of an asbestos-like mineral in the specimens from Ceylon, and to fibres of crocidolite in the blue, and of altered crocidolite in the brownish-yellow specimens from South Africa.

These are followed by a series of specimens illustrating peculiarities of form: cellular, hacked, spongy, fibrous (both parallel and radiated), and capped.

The so-called ***Eisenkiesel***, or iron-flint, encloses and is coloured Case 13g. by the yellow or red oxide of iron.

Jasper is not a truly simple mineral, but a coloured mixture Case 13gh. of silica and clay, distinguished in aspect from ordinary

quartz by its opacity and dull 'earthy' fracture. It is of various
colours, chiefly red, brown, yellow and green; and the colours are
arranged sometimes in a nodular form as in the Egyptian Case 13h.
jasper, at other times in stripes, as in the Riband-jasper. Case 13g.

Hornstone is a variety of silica without evident crystallisation, Case 15a.
and generally presents a more or less splintery fracture; but in
one kind, *Flint*, the fracture is conchoidal, sometimes conical, Case 15b
as is well shown by the specimens in the case; in *Silicified Wood* Case 15a.
the particles of woody matter have been replaced by silica
in such a way that the details of the original structure have
been well preserved.

Chalcedony has a lustre nearly that of wax, and is either Case 15b–d.
transparent or translucent: specimens from the Trevascus and
Pednandrea mines, Cornwall, and from the Färöer Islands and
Iceland, are worthy of special notice. Some of the specimens
from Uruguay enclose water. Case 15d.

The *Heliotrope*, or *Bloodstone*, is a green stone with red Case 16a.
blood-like spots.

Next follow the *Plasma* and *Chrysoprase*, green stones: and the *Sard*, generally a brownish-red; as also the *Sardonyx*, its banded variety: all of them much prized by the ancients because, though hard and tough enough to resist ordinary wear and tear, they are more suited to the display of the engraver's skill than are the harder and more precious stones.

Then come the *Agates*, chiefly formed of thin layers of chalcedonic Case 16b-e.
and opaline silica, differing in colour and porosity. Most of
the specimens are now brought from Uruguay, in South America,
and are cut and polished at Oberstein, where, in former times,
agates were largely got from the mountains of the district.
Sometimes the layers are plane and parallel, and the stone is
then an *Onyx*, useful as a material for cameos: or the bands of Case 16c.
a section are arranged in zig-zag lines, and the stone is then
called a *Fortification-agate:* but in the ordinary agate the
layers are variously curved: many examples of the variety of
curve and colour will be seen in the case. The *Brecciated
agate* from Kunnersdorf is especially worthy of notice.

The *Moss-agates*, or *Mocha-stones*, are varieties of chalcedony, Case 16e.
enclosing moss-like forms of oxides of manganese and iron and
green earthy chlorite.

The *Carnelian* is a beautiful stone mucn valued by the engraver: its fracture has a peculiar waxy lustre, and is distinct from that of the sard, which is dull and hornlike. Case 16e.

We now come to the varieties of OPAL, the first being *Hyalite,* its purest form, generally clear and transparent as glass. Cases 16f–h, 15e.

Next follows the *Precious* or *Noble Opal,* conspicuous for its fascinating play of colours: by the side of those from the old Hungarian locality will be seen splendid examples from Queensland, most of them presented by Professor N. S. Maskelyne, F.R.S. Case 16f.

Hydrophane is remarkable as only being transparent and opalescent when its pores are filled with water.

The *Fire-opal,* from Mexico, varies from hyacinth-red to honey-yellow in colour. Case 16g.

Next to these are arranged other varieties, the green *Prase-opal, Rose-opal, Wood-opal, Menilite* or *Liver-opal, Semi-opal, Cacholong,* and also *Fiorite* with its beautiful pearly lustre. Cases 16h, 15e.

A series of specimens illustrating some of the forms of native silica, arranged and described by Professor Ruskin,[1] is shown in table-case 47 in the Pavilion.

Acid-forming oxides.

To quartz and opal, which terminate the series of the dioxides, succeed some other acid-forming oxides.

ARSENOLITE is the native sesquioxide of arsenic, crystallising in the Cubic system; the same compound, artificially prepared, is known in commerce as white arsenic or arsenious acid, and is obtained on a large scale by roasting arsenical ores. Case 15f.

SENARMONTITE, the isomorphous sesquioxide of antimony, is represented by fine specimens from Algeria. Case 15f.

VALENTINITE has the same chemical composition as senarmontite, but its crystals belong to the Orthorhombic system. Case 15g.

SASSOLITE is the hydrated sesquioxide of boron (native boracic acid), found in the crater of Vulcano, one of the Lipari Islands. Case 15g.

CERVANTITE is a peroxide of antimony, and is a product of the decomposition of stibnite. Case 15h.

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[1] *Catalogue of a series of specimens illustrative of the more common forms of Native Silica. By John Ruskin, F.G.S.* 1884. *Price* 1s.

Section ii. —Oxygen-salts. Carbonates.

We next begin the section of oxygen-salts, the first class under which is formed by the carbonates. The long series of specimens of the anhydrous carbonates begins with those of which the crystals belong to the Orthorhombic system.

Case 17a–d. ARAGONITE is the calcium carbonate or carbonate of lime, and is identical in chemical composition with the mineral calcite, which crystallises in the Rhombohedral system. The coralloidal variety from Eisenerz is well represented in the case, and a large specimen of that variety will be found on a table at the end of the Gallery. The twin-growths from Girgenti, Hungary and Bohemia, are unusually fine. Case 17bc.

Case 18a. WITHERITE is the barium carbonate; it is much used in the manufacture of plate glass, and, in France, in that of beet-sugar: the specimens from Fallowfield mine are remarkable twin-growths.

Case 18b. STRONTIANITE, the strontium carbonate, is one of the two minerals from which strontium nitrate is made for use in the manufacture of fireworks; the salt gives a fine crimson colour to the flame. The strontium minerals are at present much employed in connection with the process of sugar refining.

Case 18b–d. CERUSSITE is the corresponding lead carbonate: when abundant it is a valuable ore of the metal. The suite of crystallised specimens is a very fine one, but the specimens from Cardiganshire and Poullaouen, presented by Mr. J. Taylor and Mr. R. Simmons respectively, are worthy of special mention. Case 18c.

The isomorphism of calcium, barium, strontium and lead, is well shown by the above minerals, which are almost identical in their fundamental angles.

Next follow the Rhombohedral carbonates: on account of the isomorphism there is in several cases a gradual transition from one species to another.

Cases 18e–20c. First of the Rhombohedral carbonates is CALCITE, carbonate of calcium. The clearest and purest variety is that from Iceland, thence termed *Iceland-spar*. In this variety, owing to its clearness, was first remarked the fact that there are two images of an object seen through a cleavage-plate of calcite: whence it is sometimes called *Doubly-refracting spar*. It is largely used in optical instruments for affording polarised light.

The extraordinarily fine suite of specimens of calcite exhibited in the cases illustrates the almost endless variety of its crystalline form, and at the same time shows that the variation is subject to a definite law of symmetry. The specimens from Cumberland, Derbyshire and Cornwall are particularly worthy of attention. Two very large crystals from Iceland are shown in the Pavilion.

Specimens of twin-growths are shown in cases 19d and 20a.

The so-called *Crystallised sandstone of Fontainebleau* is a curious variety of calcite enclosing a large quantity of grains of sand. Case 19c.

In case 20b, are shown stalactites and stalagmites, formed respectively on the roofs and on the floors or sides of caverns: they owe their origin to the slow dropping and evaporation of water, which has become charged with carbonic acid, and afterwards with calcium carbonate, in its course through limestone rocks.

These are followed by a group of specimens illustrating the varieties of colour presented by this mineral. Case 20c.

Calcium carbonate occurs on a large scale as limestone and marble, specimens of which will be found among the Rocks.

MAGNESITE is the corresponding carbonate of magnesium. Case 20d.

DOLOMITE is a carbonate of magnesium and calcium. The rock is used as an ornamental marble; when burnt it yields a durable cement. Both dolomite and magnesite were formerly largely used for the preparation of artificial Epsom-salts. Case 20d–f.

ANKERITE contains the carbonates of calcium, magnesium and iron. Case 20g.

MESITITE is the corresponding carbonate of magnesium and iron. Case 20h.

CHALYBITE, or Spathic iron-ore, is the carbonate of iron, and is a most valuable ore of the metal. The series of crystallised specimens from Cornwall is very fine. Mixed with clay it is the most important English iron ore, *Clay-iron-stone*. Cases 20h, 19e–g.

RHODOCHROSITE is the carbonate of manganese: it is affected by the action of light. Case 19gh.

CALAMINE, the carbonate of zinc, is an important ore. The specimen with bright green rhombohedral crystals, presented by Mr. R. Simmons in 1836, is unique for excellence (case 19h). Cases 19h, 21a.

BARYTOCALCITE is a carbonate of barium and calcium, remarkable as crystallising in the Monosymmetric system: a fine series of specimens is exhibited. Case 21b.

Hydrated carbonates.

Cases 21d, 22a-d.

CHESSYLITE and MALACHITE are respectively the blue and green hydrated carbonates of copper, and are ores of that metal. An excellent suite of specimens of chessylite will be found in the case. Malachite is found in large masses; and, by reason of the high polish which it takes and its beautiful markings, is much used for ornamental work of various kinds.

Carbonates combined with chlorides, &c.

Case 22d. CROMFORDITE, or Phosgenite, a compound of carbonate and chloride of lead, is represented by remarkable specimens from Matlock, and from Monte Poni in Sardinia.

Case 22d. PARISITE is a compound of the carbonates and fluorides of cerium, lanthanum and didymium; the suite of crystals from the Emerald mines of Muso is an extremely fine one for this rare mineral.

Silicates.

The next class of oxygen-salts is that of the silicates, occupying no less than twelve cases. The minerals comprised in this large, varied and important class, are arranged in series distinguished by the type of oxide that characterises the bases of the silicate; in the first series are placed the silicates corresponding to monoxide-bases (ferrous oxide, magnesia, &c.); in the second, those of which the bases are sesquioxides; and in the third, the silicates of which the bases are of both kinds.

The anhydrous section of the first series begins with the orthosilicates.

Series i.—Monoxide bases.

Case 22e. A group of Rhombohedral minerals includes WILLEMITE, a zinc silicate, and PHENAKITE, a di-beryllium silicate: extremely fine specimens of the latter mineral from the Emerald mines of the Urals and from Norway are shown in the case. Here also is arranged DIOPTASE, fine crystals of which are now rarely met with; it is a hydrogen-copper silicate.

Case 22f. Passing to the next group which consists of Orthorhombic minerals, we find TEPHROITE a manganese silicate, and OLIVINE a magnesio-ferrous silicate of the series.

Case 22f. OLIVINE in its more transparent forms is one of the less hard and least valued of the precious stones; when of a yellow colour it is known as the *Chrysolite*, while the pistachio-green variety is the *Peridot* of jewellery. Fine crystals and faceted specimens are shown.

Case 22g. CHONDRODITE (Humite), a highly basic fluo-silicate of magnesium, is arranged here: the specimens are numerous and fine.

GADOLINITE, also one of the more basic silicates, chiefly of yttrium, iron and beryllium, is represented by fine crystallised specimens, more especially from Hitterö. Case 22gh.

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The minerals ENSTATITE, BRONZITE and HYPERSTHENE, crystallising in the Orthorhombic system, begin the metasilicates; they are silicates of magnesium and iron, the relative proportions of the metals varying in the different minerals. Case 22h.

The extensive AUGITE and HORNBLENDE groups now follow; though the chemical type is the same for all the members of these groups, the bases vary much both in nature and relative proportion, and thus give rise to so many varieties that we must refer the visitor to the text-books of Mineralogy for their discussion. Cases 21e-24d.

SPODUMENE, essentially a silicate of aluminium and lithium, is represented by very fine large specimens, one of the best being shown in the third pane of wall-case E; a rare emerald-green variety from North Carolina, *Hiddenite*, and a pinkish variety from California, *Kunzite*, have been introduced into jewellery as precious stones. Case 23a.

CROCIDOLITE is a silicate of iron and sodium; it is an asbestos-like mineral, interesting as being the fibrous substance enclosed in the South African blue quartz-cat's-eyes. Case 24b.

ASBESTOS is the only variety of hornblende used in the arts: it is found in long fibres, and in some of its varieties is so flexible that it can be used for spinning purposes. The term asbestos, *unquenched* or *unquenchable*, was applied to the mineral by the ancient Greeks because, owing to its being unaltered by heat, wicks made of it were used in maintaining the sacred perpetual fires of their temples. Napkins of asbestos were cleaned by being thrown into the fire; asbestos cloth was also used in the process of cremation to keep the ashes of the body distinct from those of the fuel. It is now much employed, for lining iron-safes, as a packing for steam-pipes and boilers, and in gas-stoves; short-fibred asbestos is used for the manufacture of paper, cardboard, etc. Case 24c.

JADE, or Nephrite, is a mineral assigned to this group, and is essentially a silicate of magnesium and calcium. This mineral has few known localities, and it has been difficult to find an answer to the question as to whence the older workers of jade can have obtained their material. Case 24d.

The various shades of colour, and the beautiful polish which this tough mineral will take, are illustrated by specimens in the case. The worked specimens from New Zealand, of which there are several in the collection, are now rare.

An immense waterworn mass found some years ago near the graphite mines of M. Alibert, to the west of Lake Baikal, in Asiatic Russia, is shown on the pedestal at the end of the case.

One of the characters useful for the recognition of jade is its specific gravity: this is generally about 3·0 in the green, and about 2·9 in the cream-coloured varieties.

Wollastonite is the calcium metasilicate. Case 24e.

Rhodonite, the manganese metasilicate, crystallises in the Anorthic system; the specimens of richer colour are in Russia used for ornamental work. Case 24ef.

Babingtonite belongs to the same chemical type and crystallises in the same system as rhodonite, but is a silicate of calcium, iron and manganese. Case 24f.

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Apophyllite belongs to the hydrated section of this series; it is a hydrated silicate of calcium and potassium. Extraordinarily fine specimens, got in blasting the rocks during the construction of the Bombay and Poonah railway, were presented by Mr. J. J. Berkley, in 1860–1; most of them are shown in a wall-case of the Pavilion. Cases 24f-h, 23e.

Meerschaum is the light soft porous mineral used for tobacco-pipes: it is a hydrated silicate of magnesium. Case 23g.

Talc is another hydrated silicate of magnesium, and was formerly used in the manufacture of porcelain. The amorphous variety, *steatite* or *soapstone*, is worked by the Chinese into ornaments, of which examples are shown in the case; it is also used for gas-burners, electric insulators, linings for stoves, &c. Case 23g. Case 23gh.

Serpentine is another hydrated magnesium silicate: the ease with which it is worked and takes a good polish, its green colour and varied markings, render it much sought for as a Case 25a.

Case 25a.

material for fire-places, tables, and other indoor work: exposed to the weather it soon loses its polish. Occurring on a large scale, it is best considered among the Rocks; only specimens illustrating the simple mineral are shown in the case.

Case 25b.

Hemimorphite, a hydrated silicate of zinc, is an important ore.

Case 25c.

Chrysocolla is a hydrated silicate of copper.

* * *

Series ii.—Sesquioxide bases.

The second series, consisting of minerals in which the bases are sesquioxides, commences with topaz, a silicate of aluminium, containing also a considerable percentage of the element fluorine.

Cases 25c-26b. Case 25d. Case 25c.

Topaz in its clear varieties is one of the precious stones. A large series of specimens illustrating the varieties of crystalline form will be found in the case; those from the Urulga river in Siberia are remarkably fine examples of crystalline development; they are of a delicate brown colour, but are kept covered as the action of light speedily bleaches them. The yellow crystals from Brazil assume a peculiar pink colour when heated, and are then known to jewellers as *Burnt* or *Pink topaz;* some of these will be found in case 26a; crystals with the same tint are sometimes found in Nature. The crystals from Saxony are of a paler yellow colour, which they entirely lose on being heated. Topaz has a very easy cleavage, and readily becomes electric on being rubbed or heated. Fine orange-red crystals from the Walker Collection are exhibited.

Case 26b.

Andalusite is a silicate of aluminium. Some of its transparent crystals are very dichroic, as is well shown by faceted specimens in the case.

Case 26c.

Staurolite is a silicate of aluminium and iron, the latter element being now regarded as present in the ferrous state; it is remarkable for its twin-growths, and is found almost exclusively in clay-slates and mica-schists.

Case 26cd.

Kyanite has the same chemical composition as andalusite, but crystallises in the Anorthic instead of the Orthorhombic system. The specimen from Chesterfield, Massachusetts, is unusually fine.

FIBROLITE also has the same chemical composition. Being extremely tough and yet not difficult to work, it was manufactured into stone-implements in prehistoric times, particularly in parts of France. Case 26d.

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Series iii.—Monoxide and sesquioxide bases.

The third series of silicates is constituted of those in which monoxides and sesquioxides together act as bases.

First of these is the Garnet group, the members of which all crystallise in the Cubic system but vary indefinitely in chemical composition, though always in accordance with a simple typical formula.

GARNET belongs to the group of precious stones; when the red is tinged with violet the stone is the *Almandine* and the *Syrian garnet* (so called after Syriam in Pegu), and when cut *en cabochon*, the *Carbuncle* of jewellery (Case 26f); the *Cinnamon-stone* or *Hessonite* varies from hyacinth-red to honey-yellow (Case 26e); the *Pyrope,* including the "*Cape Ruby*" and the *Bohemian garnet,* is blood-red (Case 26e). *Uvarovite* is a green chrome-garnet (Case 26h). In the case will also be found some of the green garnets (*Demantoid*) from the gold washings of the river Bobrovka, in Russia (Case 26g). Case 26e-h.

IDOCRASE crystallises in the Tetragonal system; though essentially a silicate of calcium and aluminium, the percentages of iron and magnesium in its different varieties are sometimes very high. Case 25ef.

SARCOLITE also crystallises in this system, and is noticeable as representing a kind of hemihedry of which there are few examples. In addition to the elements of idocrase it contains sodium. Case 25g.

SCAPOLITE also is Tetragonal in its symmetry; like idocrase it is a silicate of calcium and aluminium. Case 25gh.

ILVAITE is a silicate of calcium and iron, the latter element being present both as monoxide and sesquioxide; a series of good crystals from Elba is exhibited. Case 27a.

JADEITE is essentially a silicate of sodium and aluminium. It is one of the green stones which, under the name of jade, are wrought into ornaments in China; from that mineral, however, it is distinguished by its chemical composition, structure and higher specific gravity, the latter ranging from 3·1 to 3·4. Case 27a.

Case 27cd. EPIDOTE is essentially a silicate of calcium, iron and aluminium. Fine specimens from the Untersulzbachthal are in the case.

MICA is the name given to a group of minerals differing much from each other in chemical composition and optical properties, but having as a common character an easy cleavage in a single direction, and thus affording plates remarkably thin, transparent, tough and elastic. One of these minerals, muscovite, has been used in Russia in place of glass for windows; it is now in common use for lanterns and stoves, not being so easily cracked as glass by change of temperature; ground mica is used for decorative purposes and in the manufacture of lubricants.

In the Micas the oxides of potassium and aluminium are almost invariably present; PHLOGOPITE contains a considerable proportion of magnesium; BIOTITE contains both magnesium and iron; LEPIDOMELANE much iron and little magnesium, much of the aluminium being replaced by iron; MUSCOVITE, much potassium and aluminium; LEPIDOLITE contains small proportions of lithium, rubidium and cæsium, and is an important source of lithium and rubidium salts. Case 28a. Case 28bc. Case 28c. Case 28c–e. Case 28e.

Case 28e. LEUCITE is a potassium-aluminium silicate: its crystals were long regarded as presenting typical forms of the Cubic system, but vom Rath, after minute examination, inferred that the symmetry is that of the Tetragonal system; Klein has since discovered that its optical characters indicate a sudden change to Cubic symmetry at a temperature probably below the melting-point of zinc. A very fine transparent crystal will be seen in the case. The mineral has only been found in volcanic rocks.

Case 28f. NEPHELITE is a silicate of sodium and aluminium with some potassium; its crystals present Hexagonal symmetry.

We now come to the group of FELSPARS, the most important of rock-forming minerals; for details of their characters we must refer the visitor once more to the text-books. Their crystals, though belonging to two different systems, the Monosymmetric and Anorthic, present a great similarity of form; they have two easy cleavages, at right angles in the Monosymmetric and nearly so in the Anorthic crystals; they are a little less hard than quartz. The metals of the monoxide bases are calcium, sodium, potassium, and in one species barium; the sesquioxide is that of aluminium.

Anorthite, represented by excellent crystals from Vesuvius and other localities, is a lime-felspar. Case 28f–h.

Labradorite is a lime-soda felspar; specimens from Labrador are remarkable for the change of colour of the light reflected from them in different directions. Case 28h.

Oligoclase is a soda-lime felspar; the *Sunstone* is a variety. Case 27e.

Albite is a soda-felspar: *Pericline*, one of its varieties, is represented by very fine specimens. Case 29ab.

Orthoclase is a Monosymmetric potash-felspar; the *Moonstone* (case 27h) is a variety used by the jeweller. Case 27e–h.

Microcline is an Anorthic potash-felspar, closely simulating orthoclase in crystalline form. *Amazon-stone* is a green variety; the green colour disappears when the mineral is heated. Case 29a.

Leaving the Felspar group we now come to BERYL, a silicate of aluminium and beryllium, presenting Hexagonal symmetry.

Emerald, its bright green variety, is one of the most valued of precious stones. It was in ancient times got from Egypt, as is proved by the rough specimens found in the old workings by Sir Gardner Wilkinson and presented by him to the Museum. Emeralds are found in the Urals; but the locality for the finest stones has for a long time been that of Muso, about seventy miles from Santa Fé de Bogotá, in S. America; excellent specimens are shown in case 29c and also in the Introductory cases (III b and VI a). A few emeralds, though not of a very good colour, have been discovered in the United States; some of the best of those found are here shown. Case 29c.

The remaining varieties of this species are illustrated by a large suite of crystals, those from Mursinsk, in the Urals, being particularly fine. Faceted specimens of the colourless beryl, of the bluish-green beryl, known in jewellery as *Aquamarine*, and of pink beryl from California and Madagascar, are exhibited. Cases 29c-30a. Case 30a.

Euclase is a silicate of aluminium, beryllium and hydrogen, and crystallises in the Monosymmetric system: an almost unique suite of crystals of this rare mineral is exhibited. Attempts have been made to introduce this mineral into jewellery on account of its lustre and hardness; but for this purpose its brittleness and easy cleavage make it unsuitable. Case 30b.

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We now come to the remaining hydrated silicates, the first series of which consists of those minerals in which the bases are sesquioxides.

In this series are the various hydrated silicates of aluminium, including kaolinite, halloysite, chloropal, pyrophyllite, &c.

Case 30b. Kaolinite is a result of decomposition of the felspar of granite, and, under the name of *China-clay*, the mixture of kaolinite and quartz is extensively used for the manufacture of porcelain.

As a first group in the series of hydrated silicates having both monoxides and sesquioxides for bases, we come to the Zeolites, so called because when fused they appear to *boil*, owing to the escape of the water. Attention may be called to the remarkable series of these minerals presented by Mr. F. N. A. Fleischmann.

Case 30ef. Prehnite, related chemically to the Zeolites, has for bases alumina and lime; the proportion of water is only about 4·4 per cent.

Case 30gh. Case 29ef. Natrolite has for bases alumina and soda; in Mesolite the soda is partly, and in Scolecite wholly, replaced by lime: fine specimens from India and Iceland are shown.

Case 29f. Edingtonite is a hydrated silicate of aluminium and barium; it is an exceedingly rare mineral, and until lately had only been found as small crystals in the Kilpatrick Hills, near Glasgow: it has now been discovered in Sweden.

Case 29gh. Analcite has for bases alumina and soda; the specimens of this mineral furnish very typical examples of the symmetry of the Cubic system.

Case 29h. Pollucite, related chemically to the Zeolites, is remarkable as being a hydrated silicate of aluminium and of the rare element cæsium; the water amounts to only 2·4 per cent.

Case 29h. Laumontite has for bases alumina and lime; exposed to dry air the specimens fall to powder, owing to loss of water.

Case 31bc. Chabazite has the same bases as laumontite; its crystals, though really belonging to the Rhombohedral system, are almost cubical in form.

Case 31d. Harmotome, a hydrated silicate of aluminium and barium, is represented by very fine specimens from Strontian and Andreasberg; the cruciform growths of this mineral are very characteristic.

Case 32a-d. Stilbite and Heulandite are also hydrated silicates, having for bases alumina and lime; an exceedingly fine suite of specimens from Iceland, Færoe Islands and India is shown in the case.

We now leave the Zeolites and come to the Chlorite group, the members of which are very similar to the Micas in their general characters, but have water in their composition.

Case 32e. Penninite, has for bases alumina and magnesia, with some oxide of iron. Its crystals are pseudo-Rhombohedral in symmetry.

Case 32ef. Clinochlore has a very similar composition to penninite; its crystals are proved by their optical characters to belong to the Monosymmetric system; a superb specimen from Achmatovsk is exhibited.

Ripidolite has the same components as penninite and clinochlore, but contains a large percentage of the monoxide of iron. Case 32fg.

Vermiculite is a name given to a series of minerals which possess the curious property of exfoliating when heated, the volume being thereby increased sometimes as much as tenfold. Case 32g.

Margarite is a hydrated silicate of alumina and lime. Case 32h.

Cronstedtite, a hydrated silicate having for bases the sesquioxide of iron, and the monoxides of iron and manganese: unusually well crystallised forms of this Rhombohedral mineral are in the case. Case 31e.

Cordierite is a silicate of magnesium, iron and aluminium; its transparent variety is the *Saphir d'eau* of jewellery, and is remarkable for the variation of its colour according to the direction in which it is looked through; the polished specimens in the case illustrate this character. Case 31f.

Silicates combined with sulphides, chlorides, &c.

Leaving the silicates proper, we next come to minerals containing silicates in combination with other compounds, the latter containing no oxygen.

Danalite and **Helvite** are compounds of silicates with sulphides. Case 31gh.

Sodalite is a sodium-aluminium silicate combined with sodium chloride; it crystallises in rhombic dodecahedra. Case 31h.

Pyrosmalite is a silicate of iron and manganese, containing also chlorine and water; a fine suite of specimens will be found in the case. Case 31h.

Silicates combined with borates.

These are succeeded by minerals in which silicates are associated with other compounds of oxygen.

First are arranged the minerals in which silicates are associated with boric-oxide or borates.

Tourmaline is a mineral of which the crystals belong to the Rhombohedral system, and are remarkable as presenting a difference in the development of the faces at the two ends of the prism. This difference in the crystalline development of the two ends is accompanied by a difference in electrical behaviour; for when a crystal of tourmaline is being warmed or cooled, not only does it become electric and first attract and then repel light bodies in the same way as amber does, but one end of the crystal is opposite in electrical character to the other. Tourmaline of certain colours is much valued for its property of acting as a polariser on common light, a plate of the proper thickness absorbing one of the two rays produced Case 33a-c.

by the double refraction. Tourmaline is very variable in colour and also in chemical composition.

Case 33a.

Some of its varieties when free from flaws are classed with the precious stones. Among these are the pink *Rubellite* and the blue *Indicolite.* Fine specimens of rubellite from Burma, the Urals, and Madagascar are shown in the case; one specimen from Burma, remarkable for its size and shape, was brought to England by Colonel Symes to whom it had been presented by the King of Ava in 1795; another, not so large but of a deeper colour, was presented in 1869 by Mr. C. S. J. L. Guthrie. In a wall-case of the Pavilion (K 12) will be found a specimen from Elba, showing many pink crystals on granite.

Case 33a.

The pink-and-green tourmalines from Paris in Maine, and the magnificent crystals from San Diego County, California, are among the more beautiful of the mineral products of the United States.

Case 33d.

AXINITE is a borosilicate, with alumina as the sesquioxide, and lime and ferrous oxide as the monoxide bases; the suite of specimens is unusually fine.

Case 34a.

DANBURITE and DATOLITE are borosilicates of calcium, the latter containing about 5·6 per cent. of water: worthy of special mention are the specimens of Danburite from Japan, and of Datolite from Toggiana and New Jersey.

Silicates combined with sulphates.

Case 34b.

HAÜYNITE is a compound silicate and sulphate having for monoxide bases soda and lime, and for sesquioxide base alumina. The rich blue mineral mixture, the *Lapis-lazuli* of jewellery, sometimes contains haüynite; it is brought from Persia, Siberia, Bokhara and Chili. A large crystal in the case is worthy of attention.

When powdered, lapis-lazuli furnished the once costly pigment *ultramarine;* through the discovery of a method of producing an artificial and cheap form of the same material, the use of the mineral as a pigment has almost ceased.

Titanates, &c.

We next come to a series of minerals not only themselves of rare occurrence, but having in several cases for constituents some of the rarest elements, namely the titanates, tantalates, niobates, zirconates, &c., both singly and in association with each other, and with silicates.

Among these we may call attention to the specimens of SPHENE (34bc), TSCHEFFKINITE (34d), EUDIALYTE (34d), PEROFSKITE (34e), PYRRHITE (34f), COLUMBITE (34f), ÆSCHYNITE (34g), SAMARSKITE (34g), and FERGUSONITE (34h), as being especially remarkable either for their excellence or their rarity. Case 34b-h.

Molybdates and tungstates.

The next class is that of molybdates and tungstates.

WULFENITE is the molybdate of lead, and is represented by fine specimens from the United States and Carinthia. Case 33ef.

SCHEELITE and STOLZITE are respectively the tungstates of calcium and lead; of scheelite a fine suite, including specimens from Cumberland and Devon, is shown. Case 33fg.

WOLFRAMITE is the tungstate of iron and manganese, and is the chief source of the tungstates of commerce. Case 33h.

Chromates and sulphates.

CROCOITE is a mineral belonging to the next class, and is a chromate of lead; it has the same chemical composition as the artificial pigment *chrome-yellow*. As this mineral is affected by the light, most of the specimens are kept in the drawers, but a fine series of specimens from Tasmania is exhibited in a special case on the wall. Case 35a.

ANHYDRITE is the anhydrous sulphate of calcium. The crystal from Hallein is an exceptionally good one. Case 35b.

CELESTITE is the corresponding sulphate of strontium; rare blue crystals from Hungary, and excellent specimens from Bristol and Sicily are in the case. Case 35cd.

BARYTES, or Heavy spar, is the sulphate of barium; it is a very dense mineral, being 4½ times as heavy as its own volume of water. The suite of specimens from British localities is very fine, and pre-eminently so are those from Frizington and Wheal Mary Ann. A remarkably clear specimen from Przibram will also be found in the case. The mineral is ground up and mixed with white lead for use as a paint; barium sulphate is also manufactured on a large scale for the same purpose and is then known as *permanent white*. Case 36a-d. Case 36c.

ANGLESITE, the sulphate of lead, is represented by fine specimens from Anglesey and Derbyshire, and also from Pennsylvania and Monte Poni. Case 36ef.

LANARKITE also is a sulphate of lead; the specimens in the case are amongst the finest known of the species. Case 36f.

We now pass on to the hydrated sulphates.

Hydrated sulphates.

GYPSUM, or Selenite, is the hydrated sulphate of calcium. Its crystals belong to the Monosymmetric system; by reason of the easy cleavage parallel to the plane of symmetry it may be obtained in very thin plates, which are much used in polarising apparatus. Case 36f-h.

Gypsum, when heated, gives up its water of crystallisation and falls to powder, which is known as 'Plaster of Paris'; when moistened the powder combines again with the water and yields a coherent solid. Fine specimens from Bex and Sicily are in the case, and a very large crystallised specimen from Reinhardsbrunn in Gotha, a gift from the late Prince Consort, will be found in the Pavilion. *Gypseous alabaster* is a massive variety of gypsum; owing to its whiteness, fine texture and softness, it is largely used as a material for statuettes and other ornaments; *Oriental alabaster* is a harder substance, stalagmitic calcite. Case 36h.

EPSOMITE is the hydrated sulphate of magnesium, and is known in commerce as Epsom-salts: it is largely used in medicine and in dyeing. Epsom-salts are now largely manufactured from Case 36h.

KIESERITE, another hydrated sulphate of magnesium, which occurs in beds at Stassfurth; it is only slightly soluble in water. Case 36h.

MELANTERITE is a hydrated sulphate of iron. The iron sulphate of commerce (green vitriol), largely used for dyeing and tanning, and for the manufacture of ink and Prussian blue, is chiefly prepared from pyrites and pyrrhotite. Case 35e.

CHALCANTHITE is a hydrated sulphate of copper. The 'Blue Copper,' or 'Blue Vitriol' of commerce is chiefly obtained by treatment of copper turnings and roasted copper ores; it is much used in dyeing and calico-printing. Case 35fg.

BROCHANTITE and LANGITE are also hydrated sulphates of copper. The crystals of langite from Botallack and Fowey Consols are twinned like those of aragonite. Case 35g.

LETTSOMITE, a beautiful velvet-like mineral, is a hydrated sulphate of copper and aluminium: remarkable specimens are shown. Case 35h.

KALINITE, or Alum, a hydrated sulphate of potassium and aluminium, has long been valuable for dyeing purposes. The greater part of the commercial alum is, however, obtained artificially from beauxite, alunite, and shale. Case 37a.

ALUNITE, or Alumstone, is another hydrated sulphate of these metals: it occurs at the famous mines of Tolfa, in the neighbourhood of Rome, and from it a very pure alum is prepared by repeated roasting and lixiviation. Case 37a.

LINARITE is a hydrated sulphate of lead and copper: splendid specimens from Roughten Gill are exhibited. Case 37b.

Sulphates combined with other salts.

Connellite is a compound of sulphate with chloride of copper. Case 37b.

Caledonite is a compound of sulphate of lead with the carbonates of copper and lead. Case 37b.

Leadhillite and **Susannite** are compounds of sulphate with carbonate of lead. Case 37c.

The specimens of the last five minerals shown in the case are amongst the finest known.

Borates.

Ludwigite is a borate of iron and magnesium, and is very similar in appearance to the dark-coloured fibrous tourmaline. Case 37c.

Rhodizite, an extremely rare mineral, is probably an alkaline boro-aluminate: it was found near Ekaterinburg as minute crystals on rubellite. Case 37d.

Hydrated borates.

Borax is a hydrated borate of sodium. It is much used, as a flux in the process of soldering, and in the preparation of easily fusible enamels; also as a mordant, as an antiseptic, and in the manufacture of soap. It was formerly carried over the Himalayas from a lake in Thibet, but is now obtained largely from borax lakes of the United States, and is extensively prepared from the boracic acid of the lagoons in Tuscany. Case 37c.

Borates combined with chlorides, &c.

Boracite is a borate of magnesium combined with chloride of magnesium, the proportion of the latter amounting to 11 per cent. On account of its remarkable electrical and optical properties, and the relation of these to the crystalline form, boracite has long been extremely interesting to the mineralogist. Case 37d.

Nitrates.

Nitre, or Saltpetre, nitrate of potassium, belongs to the class of nitrates. It is used in the manufacture of gunpowder and fireworks, and also of nitric acid. Case 37d.

Nitratine, or Soda-nitre, is the nitrate of sodium: in the Desert of Atacama it is found in deposits of large extent. It is used for the preparation of nitric acid and of saltpetre, and also by farmers as a fertiliser. Case 37d.

Phosphates, arsenates and vanadates.

We now come to the minerals which contain phosphates, arsenates and vanadates; nearly all are hydrated.

Haidingerite and **Pharmacolite** are hydrated arsenates of calcium; the specimen of the former mineral, from the Allan-Greg collection, was long unique. Case 38b.

Churchite is a hydrated phosphate of cerium (didymium) and calcium: of this rare mineral one of the specimens in the case is the finest known. Case 38b.

Rhabdophane, a blende-like mineral, to which attention was first called by Mr. W. G. Lettsom, is a hydrated phosphate of cerium, lanthanum, didymium and yttrium. Its precise Cornish locality is unknown; the same species has since been discovered at Salisbury, Conn., U.S.A., and described under the name Scovillite. Case 38a.

Vivianite is a hydrated phosphate of iron: a fine series of crystals is shown from Wheal Jane: it is sometimes found with fossil shells and bones, having been a result of the decomposition of the organic matter. Case 38bc.

Erythrite is a hydrated arsenate of cobalt, found in beautiful crystals. Case 38c.

Pharmacosiderite and **Scorodite** are hydrated arsenates of iron: an excellent suite of each of these minerals is shown. Case 38de.

Wavellite is a hydrated phosphate of aluminium. Case 38ef.

Andrewsite is a hydrated phosphate of iron and copper: those in the case are almost the only specimens known. Case 38g.

Calaite, or Turquoise, is a hydrated phosphate of aluminium and copper. It does not occur crystallised. Being as hard as felspar and taking a good polish, it has been much prized in jewellery under the name of *Oriental Turquoise;* that which comes into the market is chiefly brought from Nishapur in Persia and from New Mexico. Some specimens of the turquoise found by Major Macdonald in the neighbourhood of Mount Sinai are exhibited. Case 38g.

Libethenite is a hydrated phosphate, and **Olivenite** the corresponding arsenate of copper. Case 37ef.

Ludlamite is a hydrated phosphate of iron: an unrivalled suite of specimens from Wheal Jane, its only certain locality, is shown. Case 37g.

Clinoclase, a hydrated arsenate of copper, is represented by good specimens. Case 37h.

Erinite also is a hydrated arsenate of copper. Case 37h.

Chalcophyllite is another hydrated arsenate of copper; fine examples are in the case. Case 37h.

Lazulite is a hydrated phosphate of aluminium and magnesium: the specimens from Werfen and Graves Mt. are worthy of special notice. Case 39b.

Case 39bc. Calco-uranite is a hydrated phosphate of uranium and calcium, and is represented by very fine specimens from St. Symphorien.

Case 39c. Uranocircite is a similar compound in which the calcium is replaced by barium: the fine Falkenstein specimen in the case was presented by Sir A. H. Church, F.R.S., in 1881.

Case 39d. In Cupro-uranite the calcium is replaced by copper: the Cornish suite is an excellent one.

Case 40a. Childrenite is a hydrated phosphate of aluminium, iron and manganese: a remarkably fine suite, including the largest crystal known, is in the case.

Case 40a. Liroconite is a hydrated arsenate of aluminium and copper.

Phosphates, &c., combined with chlorides, &c.

The next group is composed of minerals in the constitution of which phosphates, arsenates and vanadates, are associated with chlorides or fluorides.

Apatite is a mineral in which phosphate of calcium is Case 40b-d
associated with chloride or fluoride of the same metal. Among
the remarkably fine crystals exhibited may be specially mentioned
those from Kiriabinsk, Knappenwand, Schwarzenstein Case 40c.
and Bovey Tracey; the best specimen from the latter locality
is in the long wall-case of the Pavilion (K 12). *Phosphorite* Case 40d.
and *Osteolite* are massive varieties of apatite. When abundant
it is valuable as an agricultural manure; when used for this
purpose it is first treated with sulphuric acid.

Pyromorphite is a corresponding compound in which the Case 40ef.
calcium is replaced by lead; and Mimetite has a similar Case 40gh.
constitution to that of pyromorphite, the phosphoric acid
being replaced by arsenic acid: excellent suites of both
these minerals are shown, but the specimen of mimetite Case 40g.
presented in 1836 by Mr. Simmons is an extraordinary one.

Case 39e. Vanadinite is the corresponding vanadate of lead, and is also represented by a remarkable series of specimens.

Case 39f. Wagnerite is a phosphate and fluoride of magnesium.

SUPPLEMENT.

Organic Compounds.

As a supplement to the collection of simple minerals, there is arranged, in table-case 41, a group of natural substances which either belong or are closely related to the Mineral Kingdom, although in the formation of most of them organised matter has played a very important part. Consisting as these substances do, either wholly or in part, of carbon and hydrogen, they form a group sometimes known as that of the Hydrocarbons.

The most important members are coal and amber.

Case 41a. COAL, in most of its varieties, gives structural evidence of its vegetable origin: its chemical composition depends on the more or less complete nature of the change which has taken place, and is thus not so definite as in the minerals of the preceding divisions. In the variety called *anthracite* all traces of the original organised structure have disappeared.

Case 41cd. AMBER, in ancient times regarded as one of the precious stones, is likewise of vegetable origin. Amber is a fossil resin, chiefly derived from trees allied to the existing pine: its originally viscous condition is sufficiently proved by the insects which are sometimes found enclosed in it. Some of the ambers from Sicily, when placed in the sun-light, present in a remarkable degree the peculiar optical character termed fluorescence.

WHEWELLITE, a hydrated oxalate of lime, is represented by a portion of a specimen which was long the only one known and had been found at some unknown locality; the crystals of whewellite are small and associated with crystallised calcite: it was presented by Mr. W. G. Lettsom in 1870. The mineral has since been found in Saxony and Bohemia, and several specimens from these localities are exhibited.

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THE LARGER MINERAL SPECIMENS.

Of the mineral specimens which are too large for exhibition in the upper parts of the table-cases of the Gallery, those which have the greatest interest for the visitor are collected together and arranged in the three wall-cases of the Pavilion.

In the first wall-case (H) are shown those minerals which belong to the native elements or are compounds of metals with elements of the arsenic and sulphur groups: attention may be specially directed to the long branch of native copper from the Lake Superior mining region, presented by Professor Ruskin, the mass of native bismuth associated with lamellar gold from Bolivia, the specimens of sulphur from Spain and Sicily, all in the first pane; and to the Cornish bournonite in the last pane.

In the second wall-case (J) are shown the compounds of metals with the elements of the chlorine group: the specimens belong almost wholly to the species fluor.

In the last wall-case (K) are exhibited the compounds containing oxygen. Of the oxides themselves may be mentioned the two large dendritic growths of pyrolusite (K1), the specimens of quartz and amethyst (K2 and K3), the large sard from India (K3). Then follow the carbonates (K4—K7), including splendid examples of aragonite, witherite and calcite. Among the silicates (K8—K12), special attention should be given to the series of magnificent specimens of apophyllite, stilbite and heulandite from the Syhadree Mountains, Bombay, and also to the harmotome (K10) from Argyleshire, almandine (garnet) from Russia (K11), the long prism of beryl (K11) from Adun-Tschilon, the black tourmaline with apatite (K12) from Devon, and the rubellite from Elba. Next follow the sulphates, including fine specimens of celestite (K12), barytes and selenite, and finally the phosphates, apatite and pyromorphite (K14).

In a special case are placed

1. A fine specimen of Selenite from Reinhardsbrunn: presented in 1847 by the late Prince Consort.

2. Two splendid crystals of Iceland spar: one of them has been cleaved to show the two images of a cross painted on the opposite side of the specimen.

THE PSEUDOMORPHS.

In three table-cases, 44, 45 and 46, in the Pavilion is shown an extensive and instructive series of pseudomorphs—that is to say, minerals presenting a form characteristic, not of their own, but of some other substance. Pseudomorphs illustrate the decomposing influences to which many minerals have been subjected, and they throw valuable light on the order of succession in which, and the conditions under which, particular minerals have been formed and deposited; and, in furnishing us with sure proofs of conversions which we can never hope to effect in the laboratory, they afford us a knowledge of facts which can be arrived at in no other way.

Paramorphs. Case 44a. The first specimens are of the kind known as *paramorphs*, in which there has been a re-arrangement of the molecules and a corresponding alteration in the mineral characters, the percentage chemical composition and the form, however, remaining unchanged; for instance, calcite with the form of aragonite (case 44a).

Other pseudomorphs. The arrangement of the remaining pseudomorphs is based on the mineral species to which each specimen *now* belongs; and the species have the same order as in the General Collection (page 60): namely:—

Native Elements (case 44a).
Sulphides, Arsenosulphides, Sulphur-salts, &c. (case 44a–b).
Chlorides, Fluorides, &c. (case 44b).
Oxides and Hydrates (cases 44c–45b).
Carbonates (case 45c–d).
Silicates (case 46a–c).
Molybdates, Sulphates, Phosphates, &c. (case 46cd).

Pseudomorphs after organic remains.

These are followed by some minerals which have the forms of various organic remains; they afford a very convincing proof of the possibility of a change of substance without alteration of form.

By encrustation.

Pseudomorphs are sometimes a result of encrustation and are then termed *epimorphs:* as an example the specimen of quartz having the form of chalybite (45a) may be cited.

The original substance may be partially or completely removed from within the crust and the epimorph is then hollow: examples are silver after calcite (44a), pyrites after barytes (44b), quartz after fluor (45a), chalybite after barytes (45d).

By alteration.

In other cases, a pseudomorph may have resulted through the loss of a chemical constituent by the material: examples are copper after cuprite (44a), galena after bournonite (44a).

Or again, through the gain of a chemical constituent: examples are malachite after cuprite (45d), anglesite after galena (46d).

Or again, the process may have been an exchange of constituents: examples are galena after pyromorphite (44a), limonite after marcasite, pyrites and chalybite (44d), cerussite after anglesite (45c), barytes after witherite (46c).

By replacement.

Or again, one material may be completely replaced by another having no evident chemical relationship to it: examples are copper after aragonite (44a), hæmatite after fluor and calcite (44c), kaolin after fluor (46b).

Among the specimens worthy of special notice, in addition to those already mentioned, are rutile after anatase (44a), pyrites after pyrrhotite (44b), copper-pyrites after copper-glance (44b), cervantite after stibnite (44c), cassiterite after orthoclase (44c), pyrolusite after calcite (44c), chalcedony after datolite (45a), cerussite after leadhillite (45c), dolomite after calcite (45c), chrysocolla after atacamite (46a), serpentine after olivine (46a), steatite after quartz, dolomite and topaz (46a–b), kaolin after leucite and orthoclase (46b), chlorite after idocrase 46c), wolfram after scheelite (46c).

BIBLE MINERALS.

In a table case in the Pavilion are exhibited examples of the more prominent of the precious stones mentioned in the Bible.

THE CRYSTALS AND CRYSTAL MODELS.

Wall-cases D, E.

In wall-cases D and E near the entrance of the Gallery are shown specimens and models illustrating variety of crystalline form. In addition to specimens of crystals met with in Nature, there is displayed a selection from a fine suite of so-called artificial crystals prepared by Carl von Hauer, and presented to the Trustees in 1862 by Her Majesty Queen Victoria. The term *artificial* is in such case intended to imply, not that the specimens have been cut, but merely that the conditions under which the crystals have been deposited from solution have been artificially induced (page 24).

Some of the artificial crystals in the third pane of wall-case E are instructive as examples of isomorphism; in many instances a crystal of one kind of substance has been transferred from the solution in which it has been formed to another which would deposit crystals of a different kind of substance but of the same shape; instead of being destroyed, as is generally the case when a soluble crystal is immersed in a solution of a different kind of substance, the specimen has continued to grow. In some of the examples the change has been repeated several times, as is particularly evident where the solutions have been of different colours.

ALPHABETICAL INDEX

TO THE MINERALS MENTIONED IN THE GUIDE.

THE END.

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,, 15 to end	,,	2	,,	5	,,
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