MINERAL SYSTEMS

CHAPMAN

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A REVIEW

WITH OUTLINE OF AN ATTEMPTED
CLASSIFICATION OF MINERALS
IN NATURAL GROUPS

BY

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PREFACE

APART from certain questions bearing more or less directly on the subject, the present Essay concerns itself entirely with the Classification of Minerals. It is not intended to serve in any way as an introduction to the actual study of Mineralogy: nor, indeed, can its argument be properly understood except by those who have already some knowledge of the subject to which it refers. It is published as a protest against the system of classification now so greatly in vogue, by which Mineralogy is practically dethroned as a natural science; and secondly, in the hope that it may induce some of our younger workers in this field of research to develop, sooner or later, a truly natural system that may be acceptable to all. The writer's own day has gone by for this. The inevitable "Thus far and no farther" that awaits the coming years of all, is, in his case wellnigh reached. In his discussion of past and present classifications, he is constrained, it will be seen, to differ somewhat widely from the views and opinions of others: but, in contesting these views, he has striven to do so without undue discourtesy.

POSTSCRIPT

On reading over the introductory sections to this Essay, it seemed to the writer to be hardly fair to criticise adversely the mineralogical classifications of others, without affording those who adopt these systems an opportunity of counter-criticism. An Appendix has therefore been added, containing an Outline of a Distribution of Minerals on an essentially mineralogical basis, as proposed by the author—so far, at least, as ingrained prejudices would admit of a departure from the beaten track.

In this Classification, the "Groups," only, are to be regarded as forming part of the Classification proper. The "Series," into which the Groups are collected, are merely given to convey to Readers accustomed to chemical systems a more ready conception of the Classification generally. The Groups, it is maintained, are natural collocations: whilst the Series, as in the Classes and Orders of ordinary Systems, are unavoidably more or less artificial groupings—resembling, in this respect, the commonly adopted subdivisions of Simple Bodies, Sulphides, Oxides, Oxygen Salts, etc., in which minerals the most dissimilar in character and conditions of occurrence find places side by side—such as the *Diamond* and *Native Sulphur*; *Cinnabar* and *Zinc Blende*; *Minium* and *Hausmannite* (as oxides of the same formula); *Chlorargyite* ("Horn Silver") and *Rock Salt*; with a host of other incongruous associations: whilst, in these systems also, the enforced separation of many naturally allied minerals, as *Hausmannite* and *Braunite* (often placed, far apart, in different sections), *Hauerite* and *Alabandite*, etc., etc., is equally conspicuous. Critics who may be inclined to regard in too hostile a spirit the author's attempted classification, are asked to answer honestly the following question. Are not the unions and separations, as recorded above—the union, for example, of *Minium* and *Hausmannite* in one and the same subdivision, and the wide separation of *Hausmannite* and *Braunite*—simply indefensible (to use no stronger term) in a classification of *minerals?* And scores of similar cases are involved, unavoidably, in all chemical or chemico-crystallographic classifications hitherto applied to Mineralogy. See the remarks in Sections I. and II. of the present Essay; and those, also, prefixed to the various classification-groups, in Appendix A.

In a *classification of Minerals*, the following points cannot be legitimately ignored:

(1) Two minerals may possess the same molecular constitution (as now understood), and yet, *as minerals*, may have absolutely nothing in common: *e.g.*, to give but one example, *Minium* and *Hausmannite*, placed together, in modern chemical classifications of minerals, as compounds of R_3O_4.

(2) Two minerals may be alike crystallographically,

and yet, *as minerals*, may be totally distinct in composition and all other characters: *e.g.*, *Augite* and *Borax*, *Anatase* and *Mercury Chloride.*

(3) Two minerals may be alike both in constitution and crystallization, and yet *as minerals*, if viewed in their entirety, may lie far apart: *e.g.*, *Hauerite* and *Pyrite; Laurite* and *Pyrite; Wollastonite* and *Pyroxene; Euclase* and *Gadolinite*, etc., etc.

(4) Many elements and their compounds are known to occur under different conditions as regards crystallization and other characters. It is more than probable, therefore, that every chemical body is capable of crystallizing in distinct systems, and of assuming other distinct conditions.

(5) The condition of an element, or elementary body, in composition with other matters, is evidently in many cases, and probably in all, totally unlike the ordinary conditions which the substance presents in its free or uncombined state. Hence, in classification, a mineral cannot properly be regarded as only the natural embodiment of a chemical conception, but should be viewed as regards itself, alone—*i.e.*, as a natural inorganic body—apart from all abstract considerations.

(6) In many chemical subdivisions—perhaps, it may eventually be found, in all—certain recurrent types occur: identical in crystallization, but quite distinct in general character and actual composition; and hence, *as minerals*, not properly referable to the

same natural group. Many examples are given in Sections I. and II., and in Appendix A.

Among the questions involved directly or indirectly in the classification of minerals, although commonly ignored, two have been considered somewhat prominently in this Essay. These comprise: the condition of the silica in many silicates, and the degree of oxidation of the iron in many of these and other related bodies.

In the classification now attempted, the names only of the minerals cited as examples under the different Groups have been given: this part of the Essay being limited practically to a brief exposition of the System which these Groups embody.

A French author has said—"C'est qu'en aucune chose, peut-être, il n'est donné à l'homme d'arriver au but: son devoir est d'y marcher." Let this be the writer's apology for the present publication.

E. J. C.

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CLASSIFICATION IN MINERALOGY

§ I

A BRIEF REVIEW OF SOME OF THE MORE IMPORTANT MINERAL SYSTEMS

1. *Prefatory Remarks.*—Being recently in a large city, and having a couple of idle hours to dispose of, the writer wandered into one of its great museums, in which, with other collections of natural objects, a large and very comprehensive mineralogical collection is admirably displayed. Practically, all known minerals and their varieties, including many that can hardly be obtained without great expense and difficulty, are contained in this magnificent collection.

As an almost life-long student of Mineralogy, the writer was naturally much interested in all he saw; but, in passing slowly from case to case, one thing struck him very forcibly. This was the close association, in many of the cases, of mineral substances of a totally dissimilar aspect and character. In one of the table-cases, for example, crystals of the hard, vitriform, infusible *Diamond* are seen almost side by side with examples of *Native Sulphur*; a very soft and highly inflammable substance, totally distinct from and unlike the *Diamond* in all its characters and conditions of occurrence.

In another table-case, natural examples of *Minium*, the soft, soiling, heavy, and highly-coloured "Red Lead" are placed with the manganese oxide *Hausmannite*: a black or dark-brown sub-metallic and comparatively hard mineral occurring in Nature under very different conditions. On the other hand, another manganese oxide, *Braunite*, closely related to *Hausmannite* in all its characters—so closely, indeed, as not readily to be distinguished from it by inexperienced observers—is placed in a different compartment.

These apparently anomalous unions, and no less anomalous separations, are of course explained by the chemical system of classification adopted in the arrangement of the collection: a system now almost universally in vogue. The *Diamond* and *Native Sulphur*—although as minerals totally unrelated—are thus placed together as being "Elements" or supposed "Simple Substances"; and, in like manner, *Minium* is placed with *Hausmannite*, although so strikingly dissimilar as a natural body, because both are regarded as oxides of the formula R_3O_4—the base or metal, however, being in one case *lead* and in the other *manganese*, metals that have hardly anything in common. *Hausmannite*, again, is separated from *Braunite* in this system of classification, because—although both are oxides of manganese, and closely alike in crystallization and general characters—the latter mineral is designated by the formula Mn_2O_3 in place of Mn_3O_4. But, *viewed as minerals*, it would be the height of absurdity to assert that *Hausmannite* is more closely related to *Minium* than to *Braunite*!

2. *Chemical Classifications.*—A system of chemical classification, as applied to minerals, presents at first sight an apparent simplicity; inasmuch as when once a mineral has been analyzed its position in the System is practically determined. It must necessarily, for example, be either: (1) A *Simple Elementary Body*; or (2) a *Sulphide* or related compound; or (3) a *Chloride* or other so-called *Haloid Body*; or (4) an *Oxide*; or (5) an *Oxygen-salt*, as a *Carbonate*, *Sulphate*, *Silicate*, etc.; or (6) a so-called *Organico-Chemical* body, as *asphalt*, *coal*, and certain *resins* and *organic salts*. Naturally, therefore, a system of this kind will present certain facilities to students who may not care to go closely into the subject, taking it merely as an adjunct to their studies in Chemistry, but, rightly considered, it is little more than a convenient list or register; and being founded essentially or mainly on the single character of composition, it is of necessity essentially artificial, as all classifications must be that are founded on a single character. It affords no true conception of the special nature and conditions of occurrence of a mineral, but is rather a classification of chemical formulæ, as presented (with more or less of probability) by minerals, than a classification of minerals proper.

As already shown, it places in the same Class or Order, and often in close contiguity, minerals which may agree in chemical constitution, but which, in all other respects, as natural bodies, are very widely separated. And this defect is exaggerated by the fact that some of these minerals are far more closely related to certain types of other classes than to those, or most of those, of their own class—as regards of course this system of classification.[1] Whilst the sulphide *Orpiment* (As_2S_3), for instance, has very remote, if any, relations to *Iron Pyrites*, or to *Chalcopyrite*, or *Galena*, or *Sphalerite*, or to most of the other representatives of the class of Sulphides (*Realgar* and, to some extent, *Stibnite*, of course excepted), it is very closely related to *Native Sulphur*, not only by its aspect, crystal-system, softness, and other physical properties, but also by its inflammability, and by many of its geological conditions of occurrence. But, it may be urged, *Native Sulphur* consists essentially of sulphur only, whilst *Orpiment* consists of sulphur and arsenic. That, of course, is true; but in what condition is the arsenic? Certainly not in the condition known to us in its ordinary state, but in some unknown allotropic or cryptomorphic condition in which it has become more or less akin to sulphur. The assumption that bodies in combination retain the conditions which they present in their known free state is manifestly untenable, al-

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[1] Certain *Carbonates* and *Sulphates* present a good illustration of this fact. *Aragonite* and *Malachite*, for instance, although placed chemically, as carbonates, in the same class or subdivision, have literally no natural relations to each other: whilst *Aragonite* is far more nearly related, as a mineral, to the representatives of the group of *Prismatic Sulphates*. In this, as in many other cases, it is the "basic" principle that controls the type.

though tacitly inferred in most, if not in all, of our mineralogical classifications.[1]

At any rate, taking the three minerals—*Diamond*, *Native Sulphur*, *Orpiment*—it can hardly be maintained that, *as minerals*, the Diamond and Native Sulphur are more closely related than Native Sulphur and Orpiment; and yet in chemical classifications the first two are placed together in the same subdivision, whilst Orpiment is placed, widely apart, in another class.

In the class of OXIDES (as adopted in chemical classifications) we have already seen how bodies as dissimilar as *Minium* and *Hausmannite* are placed in juxtaposition; whilst the latter mineral is separated by a wide interval from the very closely allied manganese oxide *Braunite*. In the group of MONOXIDES again, we have *Litharge* or *Lead Ochre* (PbO) and *Periclase* (MgO), minerals as distinct as it is possible to be when viewed as minerals. And under the SESQUI-

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[1] The physical condition of elements or compounds, which occur normally in a liquid or gaseous condition, must in solid mineral bodies be necessarily in the solid state; and the degree of condensation or atomic compression must in most of these cases be enormous. Alumina, for instance, which consists (in percentage values) of Al 53·2, and O46·8, has actually a higher density (3·9) than that of pure aluminium (2·6). Most combinations, indeed, possess a higher density than the mean density of their components. A curious contrast as regards molecular condensation or compression is presented by the two sulphides *Pyrite* and *Chalcopyrite* or *Copper Pyrites*. The former consists normally of sulphur 53·33 per cent., iron 46·67; and its average density equals 5. *Copper Pyrites* with a lower percentage of the light body, sulphur (34·9 p.c.), and with heavier metallic base (Cu 34·6, Fe 30·5) shows a maximum density of only 4·3.

OXIDES are included minerals as totally dissimilar as *Corundum*, *Braunite*, *Senarmontite*, and the soluble *Sassoline* or *Boracic Acid*, not to mention others. As BIOXIDES, furthermore, *Quartz* and *Pyrolusite* (or *Polianite*), and other unrelated species, become thus associated.

Incongruous associations of this kind present themselves throughout the entire classification, and are, indeed, inseparable from it. To the chemist, this, of course, is of little moment. It is not the actual mineral that he is classifying, but the abstract chemical conception that this seems to him to represent. But surely in a *classification of minerals*, apart from all theoretical considerations that may or may not be well founded, and which are always liable to change, it is the mineral itself, in its entirety as a mineral, and in its mineral relations, that is chiefly to be considered. If this be done, *Minium* and *Hausmannite*, though both may have the same general formula, cannot be properly placed in the same group; nor can *Hausmannite* be properly separated from *Braunite* except, of course, as a species. The System is essentially a classification of formulæ opposed to a classification of minerals in their mineral affinities.

Among other works in which a chemical or chemico-crystallographic classification of minerals after this principle is essentially followed, may be cited more especially: (1) the *Elemente de Mineralogie* of Zirkel (the so-called Naumann-Zirkel Elemente, 1877); (2) Klockmann's *Lehrbuch* (1900); (3) Dana's *System of Mineralogy* (1876-82); (4). Edward Dana's *Handbook*; (5) the French treatises of Beudant, Dufrénoy, Des Cloiseaux and others; (6) the recently published *Mineralogy* of Prof. H. A.

Miers (1902); and (7) the very copious *Handbuch* (now under publication) of Dr. Carl Hintze. This last-named work, as regards the crystallization and other descriptive characters, the history and geographical distribution of species, can hardly be surpassed. It is by far the most important work on Mineralogy that has yet appeared; but its publication may very probably retard the development of a truly natural system in the classification of minerals.

3. *Chemical Classifications founded on the Base or Metal.*—If a chemical arrangement of minerals be founded on the so-called Base or Metal, as opposed to the Electro-Negative Element or Compound, a very useful list for practical or technical purposes is obtained: all argentiferous minerals being thus placed together under SILVER; all cupreous minerals under COPPER; all ferruginous minerals under IRON; and so forth. But, as regards showing the real affinities and relations of these bodies, an arrangement of this kind is absolutely valueless. Minerals as closely related as those of the group of RHOMBOHEDRAL CARBONATES—*i.e.*, *Calcite*, *Magnesite*, *Siderite*, *Rhodochrosite*, etc.—come unavoidably under different classes. *Zinc-Sulphate*, *Epsomite*, *Nickel-Sulphate*, *Ferrous-Sulphate*, are equally separated, although so closely connected by their general characters and conditions of occurrence; and a host of similar examples might be cited. Furthermore, by the adoption of this system, minerals in which two or more bases are present, as in *Chalcopyrite*, *Aikinite*, etc., can only be referred arbitrarily to one class rather than to another.

The chemical classification of minerals after this method is adopted in Blum's *Lehrbuch* (4 Aufl.), 1874; in the *Mineralogie* of von Kobell (5 Aufl.), 1878, and in many other works.

4. *Classification of Möhs.*—The so-called "Natural-Historical System" of Möhs (and its subsequent modifications by Haidinger, Breithaupt and others) first published in 1822-24, and issued again in 1836, is founded essentially on the physical characters of minerals, and it asserts its entire independence of Chemistry. In this it reveals its artificial character, as the true conception of a mineral properly includes the entire nature of the substance—and to ignore composition as a classification-character is manifestly inadmissible. But while the System affects to have cast off the bonds and trammels of Chemistry, its author, it is evident, was influenced in many respects, and influenced in some cases detrimentally, by chemical considerations. His System, for example, adopts three Classes, named subsequently by Haidinger, *Acrogenide*, *Geogenide* and *Phyllogenide*. The first class is subdivided into four Orders: *Gases*, *Water*, *Acids*, *Salts*. Under the third Order, that of *Acids*, we find "Carbonic Acid," "Hydrochloric Acid," "Gaseous Sulphuric Acid," "Liquid Sulphuric Acid," "Boracic Acid" and "Arsenic Acid." The last two are solid bodies, more or less akin to some of the soluble minerals referred by Möhs to the next Order (Salts). They are, certainly, without any direct relations, either physical or chemical, to Carbonic Acid or Sulphuric Acid; but being known as "Acids," they were relegated to this Order, notwithstanding their dissimilar character and conditions of occurrence. Another instance of this unacknowledged chemical influence is seen in the separation of *Calcite* and *Siderite*.

These minerals are placed in different Orders obviously, if tacitly, on the plea that the latter is a metallic compound, commonly so called; although the two minerals are crystallographically and in other respects most closely allied. It is, indeed, well-nigh impossible to find an example of one that does not contain vicariously a certain amount of the other. *Apatite* and *Pyromorphite* are also placed, manifestly on the same principle, in distinct Orders; and many similar examples might be adduced.

The following examples of unrelated genera, selected from some of the Orders of this System, may serve furthermore to show how little claim it has to be considered a "Natural System" in the proper sense of the term.

Order HALOID (8 genera—including among others, *Gypsum*, *Scorodite*, *Wavellite*, *Fluorite*).

Order BARYTE (8 genera—comprising with others, *Siderite*, *Yttrocerite*, *Calamine* (zinc silicate), *Baryte*.

Order GRAPHITE (comprising chiefly *Graphite* and *Wad*) (!).

Order SPATHE (16 genera—including with others: *Schiller Spar*, *Datolite*, *Analcime*, *Orthoclase*, *Turquoise*) (!).

Order ERZE (9 genera including *Rutile*, *Cuprite*, *Hæmatite*, *Gadolinite*, etc.).

But apart from these and other manifestly unwarranted allocations, some of the Orders may fairly be admitted to constitute essentially natural subdivisions. The association in the same Order (SCHWEFEL) of *Native Sulphur* and *Orpiment*, although discarded by many of the followers of Möhs, is a case in point. See *ante*, pages 4, 5.

5. *Classification of Naumann.*—This classification appeared in 1828, a few years after the publication of that of Möhs, but was more or less modified by its author in subsequent treatises, the latest of which (issued by Naumann) appeared in 1871.[1] In this edition fifteen Classes are adopted, most of these being subdivided into two Orders, and the Orders for the greater part into Groups and Sections. Apart therefore from genera, the actual subdivisions exceed 160—the classification thus becoming, to say the least, somewhat complicated.

Under most of the Classes the most incongruous genera are brought into close association, as shown below.

Class METALLOIDE OXYDE (*Water*, *Sassoline*, Opal) (!).

Class ERDEN UND ANALOGE VERBINDUNGEN (*Corundum*, *Fluorite* (!), *Rock-Salt*, etc.).

Class HALOIDE (*Borax*!, *Wavellite*, *Baryte*, *Calcite*, etc.).

Class CHALCITE (*Siderite*, *Anglesite*, *Wolfram* (!), *Triphylline*, *Malachite*, etc.).

Class GEOLITHE (*Talc*, *Apophyllite*, *Datolite*, etc.).

Class AMPHOTEROLITE (*Cordierite*, *Chrysolite*, *Spinel*, *Gadolinite*, *Amphibole*, *Mica*, etc.).

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[1] In the edition of Naumann's work brought out after his death by Zirkel, the original classification is entirely superseded: the ordinary chemical classification, now so generally adopted, taking its place.

Class METALLOLITHE (*Pinguite*, *Cerite*, *Dioptase*, *Tephroite*, etc.).

Class TANTALITOIDE (*Tantalite*, *Pyrochlore*, etc.).

Class METALLOXYDE UND ANALOGE VERBINDUNGEN (*Atacamite*, *Chlorargyrite*, *Gœthite*, *Minium* (!), *Pitchblende*(!) *Cuprite*, *Pyrolusite*, etc.).

Class METALLE (*Iron*, *Silver*, *Arsenic*, etc.).

Class GALENOIDE (*Sylvanite*, *Galena*, *Jamesonite*, *Chalcosite*, *Molybdenite*, etc.).

Class PYRITOIDE (*Antimonial Silver*, *Tetrahedrite*, *Pyrites*, etc.).

Class CINNABARITE (*Covelline*, *Hauerite*, *Zinc-Blende*, *Cinnabar*, *Orpiment*, etc.).

Class METALLOIDE (*Sulphur*, *Diamond*, *Graphite*).

Class ANTHRACIDE (*Anthracite*, *Amber*, *Hartite*, *Mellite*, etc.).

These examples, given here in Naumann's order, have been selected to show the curious and very unsatisfactory character of his distribution generally. When we see, for instance, the soft, soluble, readily fusible *Boracic Acid* (*Sassoline*), associated thus with the comparatively hard and infusible *Opal* in one and the same group; *Corundum* placed in close association with *Fluorite* and *Rock-Salt*; *Wolfram* and *Malachite* in different sections of the same class; *Atacamite*, *Pitchblende*, *Cuprite*, etc., also in one class; with other equally remarkable collocations, it is difficult to see how this System could have become so popular and widely followed in Germany, notwithstanding the deservedly high crystallographic reputation of its author. It is but fair to point out, however, that in Naumann's earlier (1828) classification, many of these strange groupings are not adopted. *Corundum* and *Quartz* are placed close together (as species 99 and 100) in one and the same class. These two minerals, view them as we will, are assuredly more closely related, *as minerals*, than *Opal* and *Sassoline*, placed, as we have seen, in close proximity in Naumann's later system, in which the description of one follows immediately that of the other.

6. *Classification of Weiss.*—This system—adopted by Quenstedt, Pfaff and other authors now practically out of date—is perhaps better suited from its simplicity to the requirements of general students, or those who merely desire to get a popular knowledge of minerals, than many of a more pretentious character. It comprises only seven classes (five of which, however, are subdivided into families) founded essentially, though not in all cases, on composition—and it thus comprises forty-nine subdivisions altogether. These Classes and Families are as follows:

I. OXYDIZED STONES:—Quartz, Feldspars, Micas, Hornblendes, Garnets, Gem-stones, Zeolites, Scapolites, Haloid Stones, Metallic Stones.

II. SALINE STONES:—Carbonates, Sulphates, Phosphates and Arseniates, Borates, Fluorides and Chlorides, Nitrates.

III. OXYDIZED ORES:—Iron Ores, Manganese Ores Tin Ores, Copper Ores, Zinc, Antimony and Arsenic Ores, Uran Ores, Titanic Ores and Titanates, Tantalic Niobic, Tungstic, and Molybdic Ores.

IV. SALINE ORES:—Iron Salts, Manganese, Cobalt and Nickel Salts, Copper Salts, Lead Salts, Zinc Salts Uranium Salts, Silver Salts, Quicksilver Salts.

V. NATIVE METALS:—One Family only.

VI. SULPHIDES, ARSENIDES, SELENIDES. A. *Sulphur Bases*:—Iron Ores, Manganese Ores, Cobalt Ores, Nickel Ores, Copper Ores, Lead Ores, Molybdic Ores, Zinc Ores, Quicksilver Ores, Silver and Gold Ores. B. *Sulphur Acids.* C. *Sulphur Salts*:—Silver Ores, Lead Ores, Copper Ores, Iron Ores.

VII. COMBUSTIBLES (not subdivided into Families).

This System, simple and convenient as in many respects it undoubtedly is, contains however many incongruous groupings, and certain forced or artificial separations. This is seen (as regards incongruous groupings) in the association of *Gypsum* and *Baryte*; *Apatite* and *Turquoise*; *Red Zinc Ore* and *Arsenite*, etc., etc.; and in the separation of the rhombohedral carbonates *Calcite* and *Dolomite*, from *Siderite* and *Smithsonite*, with other similar and equally unsatisfactory displacements. In it, moreover, *Molybdenite* is immediately followed by *Sphalerite* and this by *Cinnabar*, leading to the inference that these are closely related minerals; whereas, apart from the presence of sulphur, they have absolutely nothing in common. *Native Sulphur*, as of old, is in direct association with graphite and coal. Many of the Families, also, are likely to cause uncertainty by having the same designation in different Classes: as "Iron Ores," "Manganese Ores," etc., in Classes III., IV. and VI. The System, furthermore, does not lend itself readily to the determination of individual minerals, although in this respect it is no worse than other published Systems.

7. *Kengott's Classification.*—This (1853, 1859) is based essentially on the classification of Möhs and Haidinger, but in a modified and somewhat extended form. The same three Classes are adopted: and in Class I. we find the same four Orders, with the same representatives, as in the System of Möhs. But in the second class (*Geogenide*) the ten Orders of Möhs are increased to fifteen, whilst two of these Orders (BARYTE and KERATE) are united. The Orders thus become: HALOIDE, BARYTE, MALACHITE, OPALINE (= ALLOPHANE, in part, of Möhs), STEATITE, PHYLLITE, KUPHITE, FELSITE, SKLERITE, ERZE, METALLE, PYRITE, GALENITE, CINNABARITE, SCHWEFEL.

Without attempting a detailed analysis of these Orders, a few examples may be adduced to show how little claim the System possesses to be considered a "Natural Classification." The Order HALOIDE, for instance, is made to include among other representatives, the very dissimilar species: *Gypsum*, *Erythrite*, *Torbernite*, *Turquoise*, *Cryolite*, *Calcite*, etc. The Order BARYTE contains *Siderite*, *Triphylline Baryte*, *Crocoisite*, *Calomel*, etc. The Order ERZE is in part represented by minerals as dissimilar as *Rutile*, *Cuprite*, *Chromite*, *Lievrite*, *Pyrolusite*, etc. *Sulphur* forms an Order by itself—the inflammable *Orpiment*, as a supposed improvement upon the otherwise closely followed System of Möhs, being placed in another Order with *Sphalerite* or *Zinc Blende*: an infusible sulphide, distinct from it in aspect, crystallization, hardness, specific gravity, atomic constitution, and pretty well every other character.

8. *Classification of Tschermak.*—This (in the edition of 1884) comprises nine Classes and thirty-two Orders. The Classes comprise: I. ELEMENTE; II. LAMPRITE; III. OXYDE; IV. SPINELOTYPE; V. SILICOTYPE; VI. NITROTYPE; VII. GYPSOTYPE; VIII. HALITE; IX. ANTHRACITE.

The first Class is subdivided, as in ordinary chemical classifications, into METALLOIDE, SPRÖDMETALLE, and SCHWERMETALLE—the METALLOIDE including *Native Sulphur*, the *Diamond* and *Graphite*, three minerals utterly opposed to each other when viewed simply as *minerals*. In a work on chemistry, the *Diamond* and *Graphite*, as two forms of carbon, will necessarily be described together, or in close connection with each other. It is not, however, the element, or supposed element, *Carbon*, that we are here considering, but two tangible mineral bodies of natural occurrence that must, or should, be considered not as regards one character only, but as regards all their characters. Considered thus, can it for a moment be pretended that these three minerals, *viewed as minerals*, can properly be placed side by side in the same Class or Order.[1] The other Orders of this Class, in Tschermak's System, do not present the same inconsistencies. The third Order, indeed, that of the SPRÖDMETALLE, is a

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[1] This is practically admitted by Dr. Tschermak himself, when he states, under the Class *Elemente*: "Als I. Ordnung werden die Metalloide aufgeführt, welche freilich einander sehr unähnlich sind."

strictly natural subdivision adopted in most classifications. Tschermak's second Class, LAMPRITE, comprises four Orders: KIESE (Pyrites), GLANZE, FAHLE and BLENDEN. The minerals referred to the first of these Orders constitute a natural group; but in the second Order we find GALENA (the type-form of the GLANCES) in immediate association with *Molybdenite*, followed directly by *Stibnite* or *Antimony Glance*. Now these three minerals have certainly very little in common beyond their metallic-gray colour and the presence of sulphur in each. *Galena* is a mono-sulphide, exceedingly heavy, cubical in crystallization and cleavage, and readily fusible or reducible. *Molybdenite* is a bi-sulphide of very different aspect, cleavage and crystallization, and quite infusible—with other dissentient characters. *Stibnite* is a sesqui-sulphide, rhombic in crystallization, and so easily fusible as to melt readily if held (in the form of a small fragment) against the edge of a Bunsen flame or even that of a wax match. The presence of antimony as an essential component governs or determines, so to say, the nature of *Stibnite* as a mineral, and allies it far more closely to *Zinkenite* or *Jamesonite* than to *Galena*. But in Tschermak's System these latter antimonial minerals (with *Bournonite*, etc.), are placed in a distinct Order (FAHLE), on the plea that they are "sulphur-salts." On that reasoning, however, *Chalcopyrite* (Copper Pyrites) should be separated from the other KIESE, as it is also a "sulphur-salt." But the author places it, very properly, in his KIESE Order. In his fourth Order (BLENDEN), the infusible, or practically infusible, *Sphalerite* (ZnS) is associated among other minerals with the highly inflammable and easily fusible *Orpiment* (As_2S_3), a most astonishing and unwarranted collocation, although, as we have seen, adopted also by others. It may be urged that pyrognostic characters should not be taken into consideration: but in that case the true nature of the mineral becomes only half revealed to us.

A natural classification, among other desiderata, should enable us to determine more or less readily the position and name of a given mineral; but a desideratum of this kind is hardly attainable if we are to place in the same group minerals so dissimilar, in all their characters and composition, as *Zinc Blende* and *Orpiment.*

It is scarcely necessary to continue our analysis of this classification in order to show how greatly it departs from a "Natural System" properly so called. It may suffice to state in support of this assertion, that under the Class NITROTYPE, *Mimetesite* is placed with *Erythrine* in a common Order (PHARMACONITE); whilst *Pyromorphite*, so closely allied by crystallization, atomic constitution, etc., to *Mimetesite*, is placed with *Triplite*, *Vivianite*, and other alien species, in a separate Order. In this same Class also, though under different Orders, we find *Columbite* and *Saltpetre* (!); and in a succeeding Class (GYPSOTYPE)—*Gypsum*, *Crocoisite*, and *Wolfram* (!).

In venturing upon these remarks, the writer has no desire to disparage Dr. Tschermak's very valuable services to mineralogical science generally. His classification (in conjunction with that of other authors, many of whom are no longer with us), is here, alone, subjected to criticism—essentially in support of the allegation that no really natural classification of minerals has yet appeared.

9. *System of Weisbach.*—This is a comparatively recent attempt to form a natural classification of minerals by Professor Albin Weisbach of Freiberg. It is founded however, more or less closely, on the earlier classifications of Breithaupt, who preceded Weisbach as Professor of Mineralogy in the celebrated Mining School of that city. At first sight the classification presents a great appearance of simplicity, inasmuch as it contains but five classes, namely: HYDROLYTE (Salts); LITHE (Stones); METALLOLITHE (Metallic Stones); METALLITE (Ores); and KAUSTE (Combustibles). Of these, the LITHE (Class II.) and the METALLITE (Class IV.) are alone subdivided; the first into the three Orders of KUPHOXYDE, PYRITITE,[1] and APYRITITE; and Class IV. into the Orders: METALLOXYDE, METALLE, and THIO-METALLITE. The Order PYRITITE (Class II.) is in itself subdivided into four Families: SKLERITE, ZEOLITE, PHYLLITE, and AMORPHITE; and the Order THIO-METALLE of Class IV., into PYRITE, GALENITE, and CINNABARITE.

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[1] The term "Pyritite" according to the author of this system ("Characteres Mineralogici," Ed. 2, 1899), is derived from πυρίτιον, "new Greek for Silicium," as the Order is said to consist entirely of silicates, although some of these latter compounds are referred to Order III. The name, apart from its forced derivation, is certainly objectionable and likely to mislead from its similarity to that of the Pyrites group of sulphides, a name of old usage.

The System contains, therefore, only fourteen actual subdivisions. Some of these—the *Zeolites* and *Pyrites*, for example—are natural groups: but with so small a number of subdivisions it is not possible to avoid the association of many dissimilar minerals in one and the same subdivision. The following examples—among many others that might be cited—are sufficient to establish this assertion. The third Order, APYRITITE, of the Class LITHE, includes minerals as distinct in every way from one another as *Calcite*, *Pharmacolite*, *Boracite*, *Warwickite*, *Turquoise*, etc. In Class III., METALLOLITHE, in which there is no attempted subdivision into Orders, the artificial nature of the classification is shown very strikingly in the forced association of *Gadolinite*, *Chlorargyrite* (!), *Zircon* (!), *Pyromorphite* (!), *Wolfram* (!), *Siderite*, *Malachite* (!) and other altogether unrelated species. *Zinc Blende*, as of old, accompanies *Realgar* and *Orpiment* in another subdivision; and *Native Sulphur* goes, of course, with the "combustible" *Diamond*.

It is obvious that a classification of this kind is practically of little service as regards the discrimination of minerals. Professor Weisbach has therefore supplemented it by his "Tabellen zur Bestimmung der Mineralien mittels äusserer Kenszeichen." This latter work forms, for the student, a useful adjunct to the celebrated "Tafeln zur Bestimmung der Mineralien" of Von Kobell.

§ II

CLASSIFICATION-CHARACTERS IN MINERALOGY

10. A mineral may be regarded—apart from technical and geographical considerations—under two points of view. First, it may be viewed mineralogically, *i.e.*, as a tangible inorganic body of natural occurrence, possessing certain visible or ascertainable properties, as lustre, colour, form, cleavage, hardness, specific gravity, etc.; and also as possessing a certain (practically definite) composition—usually stated, for convenience, in percentage values.

The characters and composition that a mineral possesses now, it will retain—so long as it remains undecomposed—for an indefinite period of time, and if in the end it become partially or wholly decomposed by atmospheric or other agencies, it will give rise to a new product, and, so, its original specific definition will of course cease. In other words, an ordinary mineral (*e.g.*, a crystal of *quartz*, *garnet*, *cassiterite*, etc.) if put away carefully in a cabinet or other closed receptacle, will show, fifty or a hundred years hence, the same characters and the same percentage composition as it originally possessed.

On the other hand, a mineral may be looked upon as the embodiment of a chemical conception, that may, or may not, be free from error; and which, a dozen or fifty years hence, may very probably have been superseded by some newer assumption.

A mineralogist, strictly so called, will frame his classification in accordance with the first view: a chemist, naturally, in accordance with the second.

Thus, in reference to the position of *Quartz* in the System, the mineralogist would place it among the hard, stony, oxidized bodies of the mineral kingdom, irrespective of its assumed formula SiO_2; as otherwise he would be compelled to place it in more or less direct association with minerals—*e.g.*, *Rutile* TiO_2, *Pyrolusite* (or *Polianite*) MnO_2, and other bioxides—totally dissimilar in character and actual composition.

11. The two characters regarded commonly in modern systems as leading classification-characters, are (1) atomic (or molecular) constitution, and (2) crystallization. It is a question, however, as indicated above, whether the application of the first of these characters has not been carried too far; and the second also.

Take, for instance, the three common Iron Oxides: *Hæmatite* Fe_2O_3; *Limonite* (or *Gœthite*) $Fe_2O_3 + H_2O$; and *Magnetite* Fe_3O_4. It is impossible to deny that, *as minerals*, these belong to a common natural group of intimately associated "Iron Ores." And yet, being distinct in formulæ, these minerals, closely related by their general characters and actual components, are kept asunder—and, as regards *Hæmatite* and *Magnetite*, widely asunder—in modern chemical or chemico-crystallographic classifications. The manganese ores, and the representatives of many other natural groups, are separated on the same principle, and placed more or less widely apart. Of course, in these cases the formulæ differ to a greater or less extent, although the actual components are identical; and the entire nature of the mineral is practically governed by that of one or more of these components. In the Iron Ores, the Manganese Ores, etc., it is the metal which characterizes all. It is at least questionable, therefore, as to whether a difference of formulæ (in itself, of course, a good *specific* distinction) should be suffered to override fundamental characteristics in the general grouping of minerals, pure and simple.

12. Crystallization is undoubtedly, next to composition, the most important and by far the most interesting of all mineral characters. The very mystery attached to its manifestation, and its wide scope as regards its applications to mathematical and physical science, impart a peculiar attraction to its study. But, still, as a classification-character, however important, it forms but one among other available characters; and its value in Systematic Mineralogy, apart from specific distinctions, appears to have been somewhat exaggerated. A classification of minerals based simply on crystallization would lead to groupings as incongruous as one founded on Hardness or Specific Gravity. Minerals as distinct from each other in every way as the *Diamond*, *Native Copper*, *Galena*, *Garnet*, *Fluor Spar*, *Rock-Salt*, *Alum*, *Pharmacosiderite*, etc., etc., would on this principle be thrown together. *Pyroxene* and *Borax*, again, would fall into a common group, the crystal-

system and the interfacial angles being identical; whilst, in themselves, no two minerals could be less related. The same may be said of *Nitre* and *Aragonite*, *Soda-Nitre* and *Dolomite*, *Proustite* and *Calcite* or *Siderite*; and many additional examples might be cited to show that crystallization is by no means a definite character as regards composition and natural relations.

13. But when crystallization and molecular constitution, in one mineral, correspond virtually with these characters in another, the classification-value of the united characters becomes, obviously, very greatly increased—as in the case of *Spinel* and *Automolite*; *Rutile* and *Cassiterite*; *Calcite*, *Siderite*, and other *Rhombohedral Carbonates*; the various *Prismatic Carbonates* and *Sulphates*, respectively; the *Apatites*, *Vitriols*, and other natural groups. But even here there are certain cases in which, notwithstanding an agreement in this respect, the assumed classification-value of these combined characters may be strongly contested from a natural or mineralogical point of view.

Thus the vicarious sesquioxides Al_2O_3 and Fe_2O_3 are to the chemist closely related bodies, and as the minerals *Corundum* and *Hæmatite* (by which these compounds are typically represented in Nature) crystallize in the same system or crystal-group, and exhibit practically the same angles, in chemico-crystallographic classifications they are, naturally, placed together. But *Corundum* (which includes in its varieties the *Ruby* and the *Sapphire*) is a very hard, stony, mineral, quite distinct, *as a mineral*, from *Hæmatite* or *Red Iron Ore*. No one could by any possibility mistake one for the other, nor, ungoverned by prejudice, place them, as minerals, together. Lustre, colour and streak, hardness, density, aspect or "habitus" of the crystals, relations to heat, modes of occurrence, etc., all are distinct. The question then arises: should atomic constitution (an abstract conception that may not always hold its ground) be suffered in a *classification of minerals* to supersede natural conditions and relations? The agreement in crystallization may here be left out of our argument, as we have already seen that this agreement—as in the case of Augite and Borax, etc.—is known to occur in minerals that are chemically (and fundamentally) altogether unrelated.

The collocation of *Hauerite*, MnS_2, and *Iron Pyrites*, FeS_2, in one and the same group, as adopted in modern chemico-crystallographic classifications is another case in point. In *Iron Pyrites* we have a hard, metallophanic, brass-yellow mineral, a bisulphide of iron, crystallizing in the Tesseral or Regular System, with a marked tendency to parallel-hemihedrism. In *Hauerite*, a bisulphide of manganese, the crystallization is practically identical: but the brownish-black or dark colour, brownish-red streak, the sub-metallic or practically non-metallic lustre, the low degree of hardness and density, the electrical relations—in a word, the entire aspect and character of *Hauerite*—remove it, as a mineral, from the long-recognized PYRITES GROUP.[1] On the other hand, *Hauerite* cannot be placed, in a truly natural classification, apart from the manganese

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[1] See Tschermak's uncompromising remarks on this subject in the Introduction to his *Mineralogie*.

sulphide *Alabandine* MnS. Although differing in formulæ, these two sulphides of manganese have the same general aspect, the same marked cubical cleavage, and practically the same hardness and density, with other characters in common: although, of course, with certain specific distinctions. The two species, as minerals, are incontestably and closely related. And yet, if we follow arbitrarily the chemico-crystallographic method, these kindred minerals must be placed far apart. In some modern treatises, for example, a dozen or more species are described between the two.

Another example is offered by the rare Ruthenium sulphide or bisulphide, *Laurite.* As this mineral occurs in minute octahedrons, and is assumed to present the formula RuS_2 (although containing a certain amount of osmium), it ranks as a "pyrites" in chemico-crystallographic systems, and is thus placed with *Iron Pyrites*, *Cobaltine*, etc., in a common group. It is a very hard, metallic-gray or black mineral, and infusible; and, naturally, it does not become magnetic (*i.e.* attractable by the magnet) after ignition—differing thus essentially from all true pyrites. The equally rare platinum biarsenide *Sperrylite* has also been referred, from its formula and crystallization to the Pyrites Group. But neither *Laurite* nor *Sperrylite* is properly a "pyrites" in the long-established acceptation of the term. A mineral that does not contain iron (or other magnetic metal) as an essential constituent, combined with sulphur or arsenic, cannot strictly be so termed. Many minerals, on the other hand, long recognized, from their general character and known composition, as

" pyrites," are excluded by the chemist from that group, as not being bisulphides. *Pyrrhotine* or *Magnetic Pyrites* FeS (?), *Chalcopyrite* or *Copper Pyrites* (composed of nearly equal proportions of S, Cu, and Fe), and *Skutterudite* $CoAs_3$ (pyritohedral in crystallization), are thus excluded. But assuredly, viewed as natural products in all their characters and conditions of occurrence, these minerals are more strictly " pyrites," in the proper sense of the term, than are *Laurite* and *Sperrylite.* No one, of course, would think of ignoring or gainsaying the great chemical interest attached to this remarkable correspondence of molecular constitution and crystallization. But we are here seeking to maintain, that, in a *classification of minerals*, a correspondence of this kind, however important chemically, ought not to prevail against the actual composition and essential character of the mineral.

14. Other cases might be cited in which, with similar molecular constitution and system of crystallization, minerals of distinct character in other respects, have been placed together as members of a common group. *Wollastonite* ($CaSiO_3$), for instance, is thus very constantly, if not always, placed with *Pyroxene*, as a purely calcareous member of the augitic or pyroxenic series. But whilst these minerals have the same general formula, and crystallize equally in the Clino-Rhombic System, with the angles of the typical prism ($110 = \infty P$) closely alike, the cleavage is distinct; and, with other dissimilar characters, there is one of more importance than is generally admitted. This is the fundamentally distinct condition of the silica in

the two minerals. Whilst *Pyroxene* is unattacked by acids, *Wollastonite* is readily decomposed, the silica separating in a gelatinous or colloidal state.

In like manner, as agreeing in crystallization, *Euclase*, *Datolite*, and *Gadolinite* have been placed together as members of a common group. This view, although opposed by Naumann many years ago, is still retained in the recent works of Hintze, Klockmann, and others. It was also adopted by Zirkel in his edition of Naumann's treatise. But whilst *Euclase* resists altogether the action of acids, *Datolite* and *Gadolinite* are decomposed with gelatinization. The silica, therefore, in these latter minerals must be in a condition opposed to that which it presents in *Euclase*. These minerals, moreover, differ greatly in aspect and general character. Apart from their position as Silicates, no one would think of placing them together in a purely mineralogical classification, notwithstanding their practical agreement in crystallization, and their corresponding formulæ.

But the question suggests itself: Are we compelled, whilst accepting the accuracy of the analysis, to accept in full faith and confidence the formula deduced from this? In other words, do these formulæ[1] truly repre-

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[1] It must not be forgotten that in numerous instances, even in the case of minerals long known to us (Tetrahedrite, Bornite, Chalcopyrite, Scapolite, Tourmaline, Staurolite, Garnet, Muscovite, etc., etc.) the recorded formulæ are still of doubtful acceptance. See, also, the remarks attached to many of the Groups in the Distribution of Minerals given in Appendix A of this Essay. Among the silicates, especially, many of the usually accepted formulæ are quite problematical.

sent the minerals to which they are applied? They may be so received to-day, but will they be so received to-morrow? Their permanency is, at least, not free from doubt, when we recall the various changes which many have undergone.[1] Most of us once knew silica as SiO_3, now transformed into SiO_2. Zirconia figured at one time as Zr_2O_3, then became ZrO, and, finally, ZrO_2. It would seem rank heresy to suppose that alumina could be represented by any other formula than Al_2O_3. This formula, in the free or uncombined state of the compound, is, no doubt incontestable in the present state of our knowledge: but how are we to regard the formula in reference to alumina in certain combinations? In the darker varieties of *Augite* and *Hornblende* (minerals typically non-aluminous) alumina is often present, and in this case it is considered to replace a certain amount of silica—the percentage of the latter decreasing as the alumina becomes more and more abundant. Here then we have the vicarious replacement of a body of one constitution by a differently constituted body (SiO_2 in part by Al_2O_3)—a substitution not readily explainable, except by adopting the theory or hypothesis of "Heteromerous Isomorphism": a theory, apparently at present, not favourably entertained. This perhaps is not altogether to be regretted, as it might easily lend itself to extravagant conceptions, and so permit the construction

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[1] See the pertinent remarks on this subject of Von Kobell ("Über die Einführung der modernen chemischen Formeln in die Mineralogie"); and those of H. Kolbe ("Moden der modernen Chemic").

of any kind of formulæ that would accord with preconceived ideas.

15. There is another subject that may be referred to here as affecting more or less in some cases the accepted formulæ of certain silicates and other oxidized minerals. This is the condition of the iron, often present, especially as a colouring medium, in these bodies. Many minerals, for example, present both lightly coloured, transparent or translucent varieties, and also, as regards the same species, varieties that are deeply coloured or even quite black and opaque: *Tourmaline*, *Garnet*, *Amphibole*, *Pyroxene*, etc., are well-known examples. This remarkable fact is not explained, as a rule, by reference to published analyses: neither does it seem to have been considered worthy of any serious consideration. But it certainly demands some kind of explanation, even if in many cases the colouring matter be regarded as merely an accidental component.

And first, of what does the colouring matter in these dark and opaque tourmalines, augites, etc., consist? Analyses show clearly that, in the great majority at least, the only colouring matter in these dark silicates must be some compound of either iron or manganese. Manganic oxide (Mn_2O_3) is well known to constitute a colouring matter of great intensity in vitreous bodies. But many black tourmalines contain a smaller amount of this oxide than is present in almost colourless varieties; and in no case is the amount of manganese (in whatsoever form present) sufficient to produce blackness and opacity. It is to the iron, therefore, that we must evidently look as the source of this dark colour and opacity—unless the colour be regarded as due to the presence of intermixed carbon or carbonaceous matters, or to the problematical existence of a black, allotropic condition of the silica or other component present in these varieties.

Carbonaceous matter, we know, is frequently present in certain examples of quartz, obsidian, etc.; but this burns off more or less readily during ignition, while black tourmaline, even in fine powder exposed in a muffle-furnace to prolonged ignition, retains its black colour, or assumes merely a brownish tint upon the surface.

The existence of a black allotropic condition of silica (or any of the other components) is a very gratuitous assumption.

16. All things considered, therefore, it seems impossible to doubt that the black colour and opacity of these varieties are due to the presence of iron in some state of oxidation. The question is, in what state? As in ordinary analysis the iron is always obtained and weighed as sesquioxide, the exact condition, as a rule, is only determined indirectly when it does not happen to be that of Fe_2O_3. The older analyses mostly state it as being in this condition, or in that of Fe_3O_4; but the more recent analyses (as those of Rammelsberg and others) assume the iron to be present, in both light and dark examples, essentially as FeO—only, as a rule, in larger proportion in black or dark examples than in those of a light colour. In but few cases is

Fe_2O_3 also stated to be present, and then in comparatively small amount. This would lead to the inference that the dark colour and opacity arose from FeO; but in some deeply coloured varieties the amount is stated to be under 10 or 12 per cent. Volger has suggested that in ferruginous garnets the iron was originally present as FeO which became subsequently peroxidized.

It is questionable, however, if a larger percentage of FeO or Fe_2O_3 would cause these silicates to become dark and opaque. Neither FeO nor Fe_2O_3, when completely dissolved in a vitreous flux, produces blackness and opacity. As long ago stated by Berzelius, ferric oxide (Fe_2O_3) in a borax glass—and the reaction is the same in a fusible siliceous glass—imparts to this a yellowish tint. On partial reduction, when the Fe_2O_3 becomes Fe_3O_4, the glass becomes bottle-green; and with excess of the latter oxide it turns black and opaque. But on complete reduction of the iron compound to FeO (not easily effected when much colouring matter is present) the blackness and opacity give place to a clear green colour.

In connection with these reactions one may call to mind the oxidizing effect, and its results, of nitric acid on a crystal of ferrous sulphate: the blackening of the crystal at first, and the subsequent decoloration on the oxidation becoming complete. In other words, FeO in the lightly coloured translucent salt becomes transformed into Fe_3O_4, rendering the salt more or less black and opaque; and this in its turn is changed on further oxidation into Fe_2O_3, when the dark coloration disappears. In this case, as in that of the borax or silica glass, the depth of colour and the blackness are produced, not by FeO, nor by Fe_2O_3, but by Fe_3O_4.

It may be fairly assumed, therefore, that in the deeply coloured tourmalines, augites, etc., the iron is present either wholly or in great part as ferro-ferric oxide.[1] As regards formulæ this may not be of much consequence where but little iron is present; but in the contrary case, the currently accepted formulæ will necessarily be more or less affected. The hydrated phosphate, *Vivianite* presents another confirmation of the fact that ferrous oxide of itself does not produce a deep coloration in minerals. *Vivianite* in its normal or unaltered state consists (in whole numbers) of FeO 43, P_2O_5 28, and H_2O 29, per cent., and is practically colourless. But the ferrous oxide is rapidly changed, in part or wholly, into Fe_3O_4, and the mineral assumes a deep indigo-blue or dark blueish-green colour. In this altered condition the FeO is commonly stated to have passed in great part into Fe_2O_3; but whether we call the changed condition Fe_3O_4 or $FeO+Fe_2O_3$ the conclusion is the same. The tint, without doubt, would become lighter and clearer if all the iron were converted into peroxide. In fact, if slowly ignited

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[1] The cause of the difference of colour in the ordinary *Ruby* and *Sapphire* (varieties of the same mineral, *Corundum* Al_2O_3) has long been a moot point. Both colours are essentially due to traces of iron. If the conclusions advanced in the text be correct, may we not assume that in the *Ruby* the red colour is due to ferric oxide; whilst in the deep blue *Sapphire* ferro-ferric oxide is present? Both, of course, in traces only.

with free access of air (fusion being carefully avoided) *Vivianite* becomes on cooling pale grayish-red.

17. *Recapitulation and General Conclusions.*—Although minerals are essentially chemical bodies, chemistry alone, at least in the present state of our knowledge, is insufficient in many cases to define or individualize a mineral species. Certain "elements" occur in Nature under totally distinct conditions, forming, thus, distinctly different minerals; and as other "elements" have been obtained artificially in distinct conditions also, it is more than probable that each "element" individually, although affecting preferentially, as it were, but one specific condition, may be really capable of assuming various conditions. That this is true of many combinations (*e.g.* Titanic binoxide, Silica, Calcic Carbonate, etc., etc.) has long been known. It cannot be controverted, therefore, that chemical composition, taken by itself, is not in all cases, as regards the grouping of minerals, a classification-character so absolutely preponderating as to overweigh all other considerations, and force us to ignore completely the actual nature of the mineral viewed in its entirety.

18. A review of the entire subject would seem therefore to lead to the following conclusion, namely, that in a national collection, two separate systems of classification at least should be adopted: (1) a chemical or chemico-crystallographic classification; and (2) a classification in natural groups. By-and-by, probably, as our knowledge increases, the two may merge into one. At present, however, whilst these are necessarily

kept distinct, two additional modes of arrangement might advantageously be carried out. These would comprise: (3) a technological arrangement; and (4) a geographical distribution.

APPENDIX A

OUTLINE OF AN ATTEMPTED DISTRIBUTION OF MINERALS IN NATURAL GROUPS CONSECUTIVELY ARRANGED.

THE Distribution of Minerals now proposed as an attempt towards the elaboration of a Natural System, whatever objections may be urged against it on abstract chemical grounds, has, at least, certain points in its favour. So far, for example, as regards the great majority of its Groups—forming the Classification proper—it is free from the close association of minerals obviously distinct in aspect and character, as seen in ordinary chemical classifications,[1] whilst avoiding, at the same time, the separation of many evidently related minerals,[2] where these differ only, or

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[1] *E.g.*, the association of *Native Sulphur* and the *Diamond* in one and the same group. That, also, of *Minium* and *Hausmannite*; *Cuprite* and *Periclase*; *Pyrrhotine* and *Cinnabar*; *Corundum* and *Valentinite* (in the Group of Sesquioxides); *Quartz* and *Pyrolusite* (as Bioxides); not to cite a score or more of other examples of equally unnatural groupings to be found in almost every classification hitherto proposed.

[2] *E.g.*, *Hausmannite* and *Braunite*; *Hauërite* and *Alabandine*; *Hæmatite* and *Limonite*; *Skutterudite* (Tesseral Pyrites) and *Smaltine*, etc., etc., etc. See § 1, and also the remarks under many of the classification groups further on.

chiefly, in molecular constitution according to present views.

ENUMERATION OF PROPOSED GROUPS

The Distinctive Characters and Typical Representatives of each Group, with some explanatory notes, follow the Enumeration.

1. Sphyroids.
2. Hydrargyroids.
3. Platinoids.
4. Meteoroids.
5. Klastoids.
6. Graphitoids.
7. Para-Platinoids.
8. Pyritoids.
9. Hauëroids.
10. Sphaleroids.
11. Molybdenoids.
12. Ægloids.
13. Sylvanoids.
14. Stibnoids.
15. Kermesoids.
16. Pyrargyroids.
17. Cinnabaroids.
18. Thionoids.
19. Indigoids.
20. Cupritoids.
21. Ochroids.
22. Zincoids.
23. Manganoids.
24. Tungstoids
25. Sideroids.
26. Tantaloids.
27. Titanoids.
28. Adamantoids.
29. Boracitoids.
30. Corundoloids.
31. Spineloids.
32. Hyaloids.
33. Beryloids.
34. Cordieroids.
35, Topazoloids.
36. Cyanoids.
37. Stauroloids.
38. Granatoids.
39. Zirconoids.
40. Trigonoids.
41. Axinoids.
42. Chrysoloids.
43. Gadolinoids.
44. Epidoids.
45. Pyroxenoids.
46. Feldspatholoids.
47. Werneroids.
48. Halioloids.

49. Zeoloids.
50. Ryacoids.
51. Phylloids.
52. Talcoids.
53. Amianthoids.
54. Metaboloids.
55. Hydrargiloids.
56. Amblygonoids.
57. Monazoids.
58. Kaloids.
59. Wavelloids.
60. Cryoloids.
61. Fluoroids.
62. Apatoids.
63. Calcitoids.
64. Aragonoids.
65. Barytoids.
66. Scheelitoids.
67. Gypsoids.
68. Pharmacoloids.
69. Borocalcitoids.
70. Ceroids.
71. Heliochroids.
72. Malacoids.
73. Brochantoids.
74. Uranoids.
75. Olivenoids.
76. Atacamoids.
77. Vivianoids.
78. Scorodoids.
79. Karphosideroids.
80. Alunoids.
81. Vitrioloids.
82. Glauberoids.
83. Alums.
84. Thanatoids.
85. Boroids.
86. Natroids.
87. Haloids.
88. Nitroids.
89. Crystalloids.
90. Geoceroids.
91. Retinoids.
92. Asphaltoids.
93. Anthraxinoids.

As these Groups are somewhat numerous—although less so, actually, than the subdivisions adopted in many other Systems—it might be thought advisable to arrange them under a smaller number of subdivisions, representing Classes and Orders as in current classifications. This, however, can hardly be effected without placing under the same subdivision—as in ordinary chemical classifications—many types of unrelated character. In the Distribution, now proposed the various Groups follow each other (with a few unavoidable exceptions) in a kind of linked sequence: each Group being to some extent related to the Group which precedes, or to that which follows it, or to both. The Groups thus form a more or less unbroken or connected series; and to anyone having a slight knowledge of minerals, their names and relative positions will convey a sufficiently intelligible conception of their character and included types. Nevertheless, to facilitate this on the part of outsiders, so to say, and also the better to subserve determinative purposes, the classification may be subdivided roughly into fourteen sections or series, in keeping with the consecutive order of arrangement given above. It should be thoroughly understood, however, that these sections or subdivisions form no part of the classification proper, but are merely given by way of explanation. The names attached to them are thus of little importance, but may serve for convenient reference. A brief enumeration is given in the annexed scheme:

Series I. METALLIDS. These include the various Native Metals, and comprise Groups 1 to 5.

Series II. CARBONIDS. These form the single Group 6.

Series III. LAMPRIDS. Comprise the metallic sulphides, arsenides, and allied minerals. Groups 7 to 14.

Series IV. PHLOGIDS. This series includes Native Sulphur, and the inflammable (or quasi-inflammable) sulphides of non-metallic lustre. Groups 15 to 19.

Series V. OXIDS. These form properly three sub-series: (1) OCHRIDS—Copper, Lead, and Zinc Oxides. Groups 20, 21, and 22. (2) FERRO-MANGANIDS—Iron and Manganese Oxides: Groups 23, 24, 25. (3) STANNIC OXIDE and other so-called "METALLIC STONES." Groups 26, 27.

Series VI. LITHIDS. This series includes, practically, all the harder or non-sectile "Stones". Groups 28 to 50. Silicates form the more numerous representatives.

Series VII. DIARIDS. These comprise the micaceous, asbestiform, and sectile silicates. Groups 51 to 55.

Series VIII. LITHOPHANIDS. This series, Groups 56 to 60, is represented essentially by aluminous phosphates, many of which have a stone-like aspect and hardness.

Series IX. CALCIDS. The Calcids include a series of calcareous or other non-siliceous minerals of comparatively low hardness (2 to 5), the character of which is almost entirely due to the preponderating influence of CaO, MgO, FeO, or other allied base. Groups 61 to 69.

Series X. CERIDS. This series—occupying a somewhat uncertain position—is represented by a single Group (70), made up typically of the so-called "horn silvers" and other "corneous ores."

Series XI. ANTHERIDS. These comprise a comparatively large number of phosphates, arseniates, carbonates, and other brightly coloured minerals of low hardness and distinctly coloured streak, connected more especially by the base—PbO in one sub-series,—CuO in a second sub-series, and CO or FeO in a third section. Groups 71 to 77.

Series XII. PERISSIDS. These form a small series of hydrous phosphates, arseniates and sulphates—more or less aberrant types, in all of which the base is in a peroxidized condition. Groups 78 to 80.

Series XIII. HALOPHANIDS. This series includes several groups of soluble and sapid minerals, with a few closely related species of saline aspect and character. Groups 81 to 88.

Series XIV. AMPHOTERIDS. The various so-called Organico-Chemical bodies—Resins, Asphalts, Coals, etc., are referred to this series. Groups 89 to 93.

SYNOPSIS OF CLASSIFICATION

SERIES I. METALLIDS.

Native metals and alloys. These are malleable; or, otherwise, wholly or partly volatilizable, but without giving, BB, any sulphur reaction. See Appendix B.

Group 1. SPHYROIDS.

This Group includes the native malleable and fusible metals, all (typically) of Tesseral crystallization.

Principal Representatives:—Native Gold, N. Silver, N. Copper.

Native Tin and N. Lead belong also to this Group, but, as minerals, are of no importance.

Group 2. HYDRARGYRIDS.

This Group includes Native Mercury and the Native Amalgams.

Distinctive Characters:—Silver-white, fluid, otherwise in cleavable masses or Tesseral crystals. BB entirely or partly volatilizable: in the latter case, leaving a silver or gold bead.

Typical Representatives:—N. Mercury; Silver-Amalgam; Gold-Amalgam.

Group 3. PLATINOIDS.

This group is represented by N. Platinum and the so-called Platinum Metals.

Distinctive Characters:—Lustre metallic. Malleable (unless H. over 5·5, then more or less brittle). In some cases, magnetic. Tesseral or Hemi-Hexagonal, but occurring mostly in small scales or nuggets of high sp. gr. (11 to 23). Infusible.

Typical Representatives:—N. Platinum; Iron-Platinum; N. Palladium; Allo-Palladium; N. Iridium; Osmium-Iridium; Irid-Osmium. All but Platinum are of rare occurrence.

Group 4. METEOROIDS.

This group is represented by Meteoric and Terrestrial Iron; and, exceptionally, by some rare species of more or less doubtful occurrence as minerals.

Distinctive Characters:—Lustre, metallic. Tin-white, steel-gray. Magnetic, showing polarity. Malleable. Tesseral. Practically infusible.

Typical Representatives:—Meteoric and Terrestrial Iron (mostly nickeliferous).

Exceptional Species:—Silvestrite (nitrogenous iron); Schreibersite or Rhabdite (phosphoric nickel-iron); Cohenite (carbon-iron); Osborneite (silicon-iron).

Group 5. KLASTOIDS.

This group, although consisting practically of simple metals, has but slight affinities with the ordinary metals of this series, but has very close natural relations to the Group of STIBNOIDS, described below. In a truly natural arrangement its representatives should perhaps immediately precede the latter group. These representatives consist properly of the brittle or Rhombohedral metals with distinctly laminar structure.

Distinctive Characters:—Metallic lustre. Lead-gray or silver-white. Hemi-Hexagonal, but crystals rare. Cleavage rhombohedral. BB fusible or volatilizable: giving marked reactions of As, Sb, Bi, or Te (see these reactions in Appendix B).

Typical Representatives:—Native Arsenic, Arseno-Lamprite; Native Antimony, Allemontite; Native Bismuth; Native Tellurium. Tetradymite (Telluric Bismuth).

SERIES II. CARBONIDS.

Metallic or sub-metallic lustre, Hexagonal (tabular). Black, with black streak, very soft. Soiling and marking. Infusible. Deflagrating when fused with nitre.

Group 6. GRAPHITOIDS.

Typical Representative:—Graphite.

Doubtful Species:—Graphitite; Graphitoid; Schungite.

SERIES III. LAMPRIDS.

Sulphides and related compounds (Arsenides, etc.) mostly of metallic lustre. If lustre non-metallic or sub-metallic, the sulphide is infusible. All representatives give BB with Soda a strong hepar-reaction, or emit arsenical fumes. (*See* Reactions in Appendix B.)

Group 7. PARA-PLATINOIDS.

This group, represented only by two rare and inconspicuous minerals, is perhaps more nearly related to the group of Platinoids than to those with which it is here immediately associated. As its representatives, however, show the formula $PtAs_2$ or RuS_2 they have been regarded as "pyrites" by some mineralogists.

Distinctive Characters:—Metallophanic. Tin-white, iron-black. Tesseral: with parallel-hemihedrism. H. 6 to 8. G. 6·9 to 10·6. Mostly in small grains. Infusible.

Typical Representatives:—Sperrylite, Laurite.

Group 8. PYRITOIDS.

This group consists essentially of sulphides and arsenides of magnetic metals, associated in some examples with other metals. All the included species become magnetic after fusion or strong ignition, and all form BB, a "hepar" with soda, or give off arsenical fumes, or yield both of these results. (*See* Reactions under Appendix B.) Five natural sub-groups may be recognized:

Sub-group 1. *Tesseral Pyritoids.*

Distinctive Characters:—Metallophanic. Brass-yellow. Tin- or silver-white. Steel-gray. H. over 5. G. over 5. Tesseral: with parallel-planed hemihedrism. Fusible, yielding S or As reactions; also reactions of Fe, Co, or Ni. In typical forms, the formula $= RR_2$; in others, RR_3 or R_3R_4.

Typical Representatives:—Pyrite, Cobaltine, Smaltine.

Less common Representatives:—Gersdorffite, Chloanthite, Linneite (Siegenite), Skutterudite, Ullmannite (?) and others.

⁂ Linneite and Skutterudite, although possessing the characters and actual composition of the minerals of this group, have been separated from it, in some chemical systems, on account of their slightly divergent formulæ. But, as minerals, they are essentially "pyrites": far more so than Sperrylite or Laurite, although these may show the common pyrites formula.

Sub-group 2. *Prismatic Pyritoids.*

Distinctive Characters:—Metallophanic, and otherwise as in sub-group 1, but Orthorhombic in crystallization.

Typical Representatives:—Marcasite, Arseniopyrite (Mispickel), Glaucodot.

Less common species:—Löllingite, Safflorite, Rammelsbergite, Leucopyrite, and others.

Sub-group 3. *Hexagonal Pyritoids.*

Distinctive Characters:—Metallophanic. H. (typically) 3·5 to 4·5. Bronze-yellow, brass-yellow, pale copper-red. Hexagonal: but crystals very rare. The more common species, Pyrrhotine, is naturally magnetic, and in some examples it shows polarity. The typical formula of the group = RS or RAs.

Typical Representatives:—Pyrrhotine (Magnetic Pyrites), Nickeline, Millerite.

Other species:—Pentlandite (? perhaps Tesseral), Breithauptite, Horbachite, and others.

Sub-group 4. *Cupreous Pyritoids.*

Distinctive Characters:—Metallophanic. Rich brass-yellow, copper-red with deep purple tarnish, grayish-yellow. H. under 4·5. Tetragonal or Tesseral. BB fusible into a magnetic globule, and giving strong Cu reaction. (*See* under Copper, in Appendix B.)

Typical Representatives:—Chalcopyrite (Copper Pyrites), Bornite (Purple Copper Pyrites), Cubanite, Stannine (Tin Pyrites).

Sub-group 5. *Argentic Pyritoids.*

The representatives of this sub-group comprise a small series of aberrant pyritic types, still imperfectly known and of rare occurrence.

Distinctive Characters:—Metallophanic. Tombac-brown, grayish- or brownish-yellow, tin-white with yellow tarnish. H. under 2. Rhombic in crystallization (with pseudo-Hexagl. aspect). BB, fusible into a silver globule with encrusting magnetic slag.

Best-known Representatives:—Sternbergite, Friesite, Argyropyrite, Argentopyrite.

Group 9. HAUEROIDS.

This group contains but two (comparatively rare) species; both, sulphides of manganese (MnS_2 and MnS), very similar in general character, but commonly placed far apart in modern chemical classifications. The bisulphide Hauerite is regarded in these classifications as a "pyrites": although, as Tschermak has pointed out very forcibly, it differs totally in its physical characters from all the typical members of the pyrites group. In other systems the two representatives of the present group are placed, more naturally, among the "Blendes," although associated with many dissimilar minerals, as Cinnabar, etc. Properly, perhaps, they should form a sub-group of the Manganese Ores, with which, although sulphides, they have many affinities—the metal, here, as in numerous other cases, influencing, so to say, the character of the mineral.

Distinctive Characters:—Lustre, non-metallic or sub-metallic with dull tarnish. Dark-brown or black. H. 4. G. 3·4 to 5·2. Tesseral (mostly in octahedrons; or massive). Infusible: giving BB with Soda, S and Mn reactions. (*See* Appendix B.)

Typical Representatives:—Hauerite, Alabandine.

Group 10. SPHALEROIDS.

This group consists mostly of a small number of zinc sulphides, of which the widely distributed Sphalerite or Zinc Blende is the principal representative. It contains also an oxy-sulphide, a combination of ZnS and ZnO; and also a rare sulphide of cadmium (Greenockite). Its representatives have in many respects the character rather of oxidized compounds than that of ordinary sulphides, being essentially of non-metallic (or in some cases of sub-metallic) aspect, and practically infusible. Zinc Blende and Zincite (ZnO) have much in common, the character of the mineral in each case being dependent on the peculiar character of the zinc, so different from that of the metal in its free or normal state. At present, however, the two minerals (notwithstanding the oxy-sulphide Voltzine) could scarcely be placed in the same group without ruffling conventionality to too great an extent.

Distinctive Characters:—Lustre, non-metallic or occasionally sub-metallic. Tesseral (with marked dodecahedral cleavage), or Hexagonal. Black, brown, red, yellow, etc., with brown streak, or (rarely) nearly colourless, with white streak. H. under 5; G. 3.5 to 5 BB, infusible, but fritting slightly at point and edges in some dark, ferruginous examples. With soda, giving strong S reaction.

Typical Representatives:—Sphalerite (Blende), Marmatite, Wurtzite, Voltzine, Greenockite.

Group 11. MOLYBDENOIDS.

This group, as at present known, is represented by a single mineral, Molybdenite MoS_2, usually placed among the "Sulphur Glances." But whilst agreeing with the typical members of that group in its metallic lustre, lead-gray colour, low degree of hardness, etc., Molybdenite is distinguished by its infusibility, a very remarkable and aberrant character as regards the soft, lead-gray, metallic sulphides generally. It is also a bisulphide, whilst the ordinary Sulphur-Glances are simple sulphides. By its infusibility, and its deflagrescence when ignited with nitre, as well as by its flexibility, softness, property of marking, crystallization, and its peculiar greasy feel in both its foliated and fine-grained varieties, it approaches Graphite more closely than any other mineral. The cause of this peculiarity still remains unexplained.

Distinctive Characters:—Metallophanic. Light lead-gray. Very soft (H. under 2). Flexible in thin pieces, G. 4·4 to 4·8. Hexagonal: crystals thin, tabular, with basal cleavage; but found chiefly in leafy or scaly masses, which leave a black mark on paper, and a dull greenish streak on smooth porcelain. Infusible, tinging the flame border pale green. Deflagrating when fused with nitre.

Typical Species:—Molybdenite.

Group 12. ÆGLOIDS.

The members of this group form the majority of the "*Glances*" of many classifications. They comprise a series mostly of simple sulphides and selenides of silver, lead, or copper, in which the colour varies from lead-gray to steel-gray or iron-black. All are easily scratched by the knife, and are more or less readily fusible, yielding with soda a strong hepar reaction. They may be arranged conveniently under four sub-groups.

Sub-group 1. *Argyroids*, or *Silver Ægloids.*

Distinctive Characters:—Metallophanic. Iron-black or lead-gray. H. under 3. Typically, malleable. Tesseral; Rhombic. G. over 7. BB, yielding a silver globule.

Typical Representatives: — Argentite, Acanthite, Naumannite, Eukairite.

Sub-group 2. *Galenoids* or *Lead Ægloids.*

Distinctive Characters:—Lead-gray. Sectile, but not malleable. Tesseral, with cubical cleavage. G. 7 to over 8. Fusible, yielding lead globules. (*See* Appendix B.)

Typical Representatives:—Galena, Clausthallite.

Sub-group 3. *Mercury Ægloids.*

Distinctive Characters:—Dark lead-gray. Crystallization (?). H. 2 to 2·5. G. 7 to 7·4. Fusible and volatilizable.

Typical Representatives: — Tiemannite, Onofrite, Guadalcazarite.

Sub-group 4. *Copper Ægloids.*

Distinctive Characters:—Steel-gray, iron-black, rarely tin-white. H. 2·5 to 3. G. under 7, typically under 6.

Orthorhombic (crystals with hexag. aspect). Fusible; yielding copper globule and other Cu reactions.

Typical Representatives:—Chalcosine, Stromeyerite, Berzelianite.

Rare or Doubtful Species:—Digenite, Zorgite, Umanzite, Crookesite.

Group 13. SYLVANOIDS.

The representatives of this group are more or less closely related to those of Group 12. The two groups should perhaps be united, at least as regards Sub-group 1 of the present group. But they consist wholly of tellurides, and they have thus been kept separate, as forming a connecting link between the ÆGLOIDS and the STIBNOIDS. All, however, are of comparatively rare occurrence.

Distinctive Characters:—Metallophanic. Lead-gray or yellowish silver-white. Soft, sectile, in part malleable. H. 1·5 to 2·5. G. 6·8 to 9. Crystallization mostly Tesseral, Orthorhc., Clinorhc., or Hemi-Hexagonal. BB, easily fusible, evolving Te fumes, and (as regards Sub-group 1) leaving a malleable metallic globule. With soda all give (as in the case of sulphides and selenides), a marked hepar reaction. (*See also under* Tellurium in Appendix B.)

Sub-group 1. *Argentic and allied Sylvanoids.*

Mostly tellurides of silver, gold, or lead. The crystallization either Tesseral, Tetragonal, Orthorhombic, or Clinorhombic.

Typical Representatives:—Hessite, Petzite, Altaite, Sylvanite, Nagyagite (= Blättererz).

Little-known or Doubtful Species:—Calaverite, Bunsenite (Kreunerite), Coloradoite.

Sub-group 2. *Bismuthic Sylvanoids.*

These should perhaps be placed with the KLASTOIDS (Group 5) as isomorphous unions of Bi and Te. The crystallization is Hemi-Hexagl., but the angle of the typical rhombohedron differs somewhat from that of the Klastoids.

Typical Representative:—Tetradymite.

Related Species:—Joseite, Pilsenite.

Group 14. STIBNOIDS.

This group is distinguished especially by the predominating presence of antimony or arsenic, combined in most cases with sulphur, and thus forming, as regards the group generally, a series of so-called "sulphur-acids" and "sulphur-salts." In a few representatives, however, sulphur is absent, the mineral consisting simply of a metallic antimonide or arsenide. The lustre, throughout, is metallic, and the colour mostly lead-gray, or iron-black. Hardness under 4·5, chiefly under 3. G. 4·5 to 8. Crystallization mostly Rhombic, or Tesseral and hemihedral. BB easily fusible, with Sb or As fumes, and giving, in most cases, with soda a strong hepar reaction.

Six sub-groups may be conveniently adopted.

Sub-group 1. *Typical Stibnoids.*

Sesqui-sulphides of antimony and bismuth (Sb_2S_3 or Bi_2S_3). Lead-gray. Orthorhombic, but mostly in fibrous or acicular masses. H. 2 to 2·5. BB, very easily fusible, with Sb or Bi reactions. (*See* Appendix B.)

Typical Representatives:—Stibnite, Bismuthine.

Sub-group 2. *Lead Stibnoids.*

This sub-group consists of a somewhat numerous series of sulph-antimonites (essentially PbS, Sb_2S_3), but with Bi in place of Sb in some cases. Crystallization Ortho- or Clinorhombic, but most examples are in fibrous or, more rarely, in granular masses. Lead-gray. H. under 3 or 4. Very easily fusible with Pb, S, and Sb reactions (or in some cases with reactions of Bi and As). (*See* Appendix B.)

Typical Representatives:—Zinkenite,[1] Jamesonite, Boulangerite, Plagionite.

Rarer Species:—Geokronite, Meneghinite, Embrithite, Kilbrickenite, Scleroclase, etc.

Bismuthic Species:—Kobellite, Cosalite.

Arsenical Species:—Jordanite, Dufrenoysite (of v. Rath).

Sub-group 3. *Iron Stibnoids.*

Dark steel-gray. H. 2 to 3. Mostly fibrous or acicular. BB, fusible: yielding a dark, magnetic slag, with other reactions as above.

Typical Representative:—Berthierite.

Sub-group 4. *Prismatic Copper-Stibnoids.*

This sub-group comprises a small series of sulph-antimonites or sulpho-bismuthites, containing copper: with, also, two or three simple arsenides of copper of exceptional occurrence and still imperfectly known.

Distinctive Characters:—Metallophanic, Orthorhombic. Lead-gray or steel-gray. H. 3 or less. G. 5·5 to 7

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[1] This mineral, named after Baron v. Zinken, is often supposed to contain zinc, and the name is thus frequently misleading.

(exceptionally higher). Fusible, yielding Cu reactions with antimonial, arsenical, or bismuthic fumes.

Typical Representatives:—Bournonite, Aikinite.

Rarer Species:—Stylotype (argentiferous Bournonite), Klaprothite, Wittichenite, Emplectite, Wolfsbergite, Enargite, Lauzunite. With, exceptionally, Domeykite, Algodonite and Whitneyite.

Sub-group 5. *Tetrahedral Copper Stibnoids (Fahl Ores).*

The members of this sub-group are compounds of sesqui-sulphide of antimony or arsenic wiih sub-sulphide of copper (Cu_2S); but the latter metal is very commonly replaced in part by silver or iron, and occasionally by zinc and even mercury, whence Beudant's name of "Panabase," applied to the species generally. Part of the antimony or arsenic is also replaced in some cases by bismuth.

Distinctive Characters:—Lustre, metallic. Steel-gray or iron-black. H. 3 to 4. G. 4·3 to 5·3. Tesseral (hemihedral); crystals, regular tetrahedrons or of tetrahedral configuration. Fusible, giving reactions of Sb or As, and Cu.

Typical Representatives:—Tetrahedrite (Gray Copper Ore, Fahlerz), Tennantite (arsenical species).

Varieties and Rare Representatives:—Spanniolite (mercurial var.), Freiberite or Polytelite (silver var.), etc. etc. Also the Dufrenoysite of Damour.

Sub-group 6. *Argentic Stibnoids.*

This sub-group is represented by a small number of comparatively rare sulph-antimonites of silver, in some of which the Ag is partially replaced by Pb or Cu, and the Sb by As or Bi. The rare Antimonial Silver may also be referred to the sub-group.

Distinctive Characters:—Lustre metallic. Iron-black or dark lead-gray or steel-gray. Orthorhombic or Clinorhombic (the crystals mostly pseudo-hexag. in aspect). H. 2 to 3. G. 6 to 6·4. Fusible with Sb or As fumes, into a silver globule.

Typical Representatives:— Stephanite (= Brittle Silver Ore), Polybasite, Freislebenite, Brongniardite, Argento-Bismutite (?).

Related Species:—Discrasite (Ag_2Sb).

SERIES IV. PHLOGIDS.

The inflammable Native Sulphur is included in this series, together with certain inflammable or self-fusible[1] sulphides of non-metallic lustre; red, yellow or black streak; and low degree of hardness. But in some few cases the lustre approaches submetallic or even metallic. All give, BB, a strong hepar reaction with soda.

Group 15. KERMESOIDS.

This group connects the Phlogids with the Stibnoids, but is represented by a single mineral, Kermesite, a combination of sesqui-sulphide with sesqui-oxide of antimony.

Distinctive Characters:—Dark red with red streak and adamantine or sub-metallic lustre. H. 1·5. Clinorhombic, but mostly in fibrous groupings. Self-fusible, and more or less inflammable, with Sb fumes.

Typical Representatives:—Kermesite (= Antimon-Blende).

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[1] *I.e.*, fusible without aid of blowpipe.

Group 16. PYRARGYROIDS.

This group is also closely related to that of the Stibnoids. It is represented essentially by the so-called "Red Silver Ores"—sulph-antimonites and sulph-arsenites of silver.

Distinctive Characters:—Lustre non-metallic or sub-metallic. Red or reddish-gray, with red streak. More rarely iron-black. H. 2 to 2·5. G. 4·2 to 6. Self-fusible, with As or Sb fumes: yielding on charcoal, BB, a silver globule. Hexagonal (Rhombohedral), or Clino-rhombic.

Typical Representatives:—Pyrargyrite, Proustite.

Rarer Species:—Miargyrite, Rittingerite, Pyrostilpnite.

Group 17. CINNABAROIDS.

The present group comprises a small series of sulphides and selenides of mercury. These, in most of the so-called "Natural History" classifications, are regarded as "Blendes," and are thus, in spite of their inflammable nature and ready volatilization, placed in a common group with Zinc Blende, Hauerite, and other totally distinct minerals.

Distinctive Characters:—Lustre, non-metallic (or sub-metallic in some dark, exceptional varieties). Normally red, with red streak. H. 5 to 2·5. G. 7·5 to 8·2. Hexag. (Rhombohedral), but crystals rare. Also, in some rare forms, Tesseral (tetrahedral). Inflammable and vol., yielding Hg. reactions (*see* Appendix B). Giving also with soda a hepar reaction.

Typical Representative:—Cinnabar.

Exceptional Species:—Metacinnabarite, Tiemannite, Onofrite.

Group 18. THIONOIDS.

This group comprises Native Sulphur, Selen-Sulphur, and three more or less closely related arsenical sulphides; all inflammable, and of non-metallic aspect and low hardness. (See under § 1 of this Essay, pp. 4-5.)

Distinctive Characters:—Lustre, non-metallic (or, in one case, Orpiment, metallic pearly). H. 1·5 to 2. G. 2 to 5·5. Orthorhombic, Clinorhombic. Streak yellow or red. Inflammable and readily volatilizable with sulphurous or arsenical fumes. Giving hepar reaction, BB, with soda.

Typical Representatives:—Native Sulphur, Selen-Sulphur, Orpiment, Realgar, Lorandite ($Tl, As_1 S_2$).

Group 19. INDIGOIDS.

This is a somewhat aberrant subdivision, comprising at present but a single representative, the somewhat rare Covelline, or "Indigo-Copper": a dark blue, partially inflammable copper sulphide of non-metallic, earthy aspect in most examples, but occasionally in small, sub-metallic, hexagonal tables. H. 2 or less. G. 4·6 to 4·7. BB, fusible with Cu reaction, and giving hepar reaction with soda.

Typical Representatives:—Covelline (Kuperindig), Cantonite (?).

SERIES V. OXIDS.

This subdivision consists essentially of metallic oxides. It is therefore, from a natural point of view, a more or less arbitrary grouping, as many of its included types—viewed as minerals—

have absolutely little or nothing in common beyond their bare composition. It is adopted here, however, to render the classification more easily intelligible to those accustomed to other Systems; whilst its included Groups are in themselves fairly natural collocations. The present classification, it must be understood, is to be judged only by these Groups and their arrangement.

As the minerals referred to this Series are more or less dissimilar in character, although connected as metallic oxides, it is difficult to give in brief form a synopsis of distinctive characters applicable to all. But the groups arranged under the Series have in every case their determinative characters sufficiently defined: and these are given succinctly under each group. Collectively, the streak is in most cases coloured, but never green or blue. No METALOXID is malleable: neither does any species yield, BB, with soda, a hepar reaction.

Three convenient subdivisions might be adopted: (1) OCHRIDS, comprising the Cupritoids, Ochroids, and Zincroids; (2) FERRO-MANGANIDS, comprising, essentially, the Iron and Manganese Oxides of natural occurrence; and (3) STANNIC OXIDE and other so-called "METALLIC STONES."

§ 1. *Groups* 20, 21, 22.

Group 20. CUPRITOIDS.

This group comprises the copper oxides CuO and Cu_2O, but, as minerals, the latter only (=Cuprite or Red Copper Ore) is of special importance.

Distinctive Characters:—Lustre, non-metallic, sometimes approaching metallic. Black or red, with unchanged streak. H. under 4·5. G. 5·7 to 6·3. Tesseral, Hexagonal(?). Often earthy. BB, fusible and reducible to metallic copper.

Typical Representatives:—Cuprite (Chalcotrichite), Melaconite, Tenorite.

Doubtful Species:—Hydro-Cuprite.

Group 21. OCHROIDS.

The representatives of this group are of little importance as minerals. They comprise the lead oxides of natural occurrence. These, as commonly found, are red or yellow, and more or less earthy; but a somewhat doubtful bioxide (Plattnerite) is said to occur in small steel-gray hexagonal scales in certain lavas. In this case it may be regarded as representing Tenorite of the preceding group.

Distinctive Characters:—Lustre, mostly non-metallic, with red or yellow colour. More rarely metallic-gray or black. H. 1 to 2·5 or 3. G. 4·5 to 9·5. Mostly earthy, or, if steel-gray, hexag. (?). B B easily fusible and reducible to metallic lead.

Typical Representatives:—Minium (Red Lead), Litharge (Massicot).

Doubtful Species:—Plattnerite.[1]

Group 22. ZINCOIDS.

A single mineral represents this group, Zincite (ZnO, coloured by manganate of zinc), a mineral which closely approaches Zinc Blende in its general characters and infusibility. It differs from ordinary Blende in crystallization, but Wurtzite, with the same composition (ZnS) is, like Zincite, hexagonal; and in Voltzine the sulphide and oxide are present together.

Distinctive Characters:—Lustre non-metallic. Red or pink, with orange-yellow streak. Hexag., but occur-

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[1] As a bioxide, Plattnerite has actually been placed by some authors in a common group with quartz, cassiterite, zircon, rutile, etc.! See Zirkel's edition of Naumann's work.

ring chiefly in cleavable or lamellar masses. H. 4 to 4·5. G. 5·4 to 5·7. Infusible, BB. With soda giving strong manganese reaction.

Typical Representative: Zincite (Spartalite).

§ 2. *Groups* 23, 24, 25.

Group 23. MANGANOIDS.

This group includes the various oxides of manganese, here arranged in two sub-groups: Anhydrous and Hydrous Manganoids respectively.

Sub-group 1. *Anhydrous Manganoids.*

Distinctive Characters:—Lustre, metallic or sub-metallic. Steel-gray, iron-black, dark brown; streak black or brown. H. 2 to 7. G. 4 to 5. Tetragonal or Rhombic. BB infusible. Giving with soda strong manganese reaction. (*See* Appendix B.)

Typical Representatives:—Braunite, Hausmannite, Pyrolusite (?), Polianite.

Sub-group 2. *Hydrous Manganoids.*

Distinctive Characters:—As in Sub-group 1, but yielding water on ignition.

Typical Representatives:—Manganite, Psilomelane.

Decomposition Products:—Wad, Asbolan, Lampadite (copper and cobalt-holding manganese ochres).

Group 24. TUNGSTOIDS.

Wolfram—with its sub-species or varieties Ferberite (Ferro-Wolframite), and Hübnerite (Mangano-Wolframite)—the sole representative of this group, might be fairly placed, as a sub-group, among the Manganoids, Sideroids, or Tantaloids, but from these it stands apart by many of its characters, especially by its density and fusibility. Its composition, moreover, as at present regarded, is quite distinct; but if the tungstenum be really in the condition of WO_3, the actual aspect and general character of the mineral must be due to the preponderating influence of the iron or manganese which constitutes the base. Considered as a tungstate, Wolfram in all chemical systems is placed with the lead and calcium tungstates, Stolzite and Scheelite, in a common group. But whilst the two latter are closely related, they are utterly distinct, as regards all natural analogies, from Wolfram.

Distinctive Characters:—Lustre, sub-metallic, approaching metallic. Black or brown with similar (or slightly reddish streak. Clinorhombic. H. 5 to 5·5. G. 7·2 to 7·5. BB, fusible into a dark (commonly magnetic) globule with crystalline surface. With soda, yields strong manganese reaction. (*See* Appendix B.)

Typical Representatives:—Ferberite (Ferro-Wolfram), Hübnerite (Mangan-Wolfram).

Group 25. SIDEROIDS.

This Group is represented by the iron oxides, Hæmatite, Gœthite (including Limonite), and Magnetite. These are distinct in crystallization and other specific characters, and their formulæ are also distinct: Fe_2O_3, $Fe_2O_3 + H_2O$ and $Fe_3 O_4$. But they form incontestably, as minerals, a highly natural and closely connected group of species, due to the dominating presence of iron, in an oxidized condition, affecting all. In chemical systems these iron ores are necessarily placed apart, with many species intervening. Hæmatite is placed with Corundum (Al_2O_3; and Magnetite is referred to the Spinel Group. To those who look only to crystallization and molecular relations—apart from actual composition—this arrangement will necessarily be regarded as irrefutable: but Corundum and Spinel are undoubted STONES, whilst neither Hæmatite nor Magnetite is a "stone" properly so called. It seems to be overlooked that in many natural groups recurrent types occur, in which the same crystallization and the same molecular formulæ—but without actual identity of composition—reveal themselves.[1] But apart from this, it can hardly be maintained that Hæmatite is more closely related, *as a mineral*, to the Ruby and Sapphire than it is to Limonite—an oxidized iron ore so commonly associated with it, and into which it so frequently passes.

Distinctive Characters:—Aspect metallic, submetallic inclining to non-metallic, or earthy. Steel-gray (often with iridescent tarnish), brownish-red, brown, iron-black; streak, dull red, yellowish-brown, black. H. 1 to 6·5. G. 3·3 to 5·3. Hexagonal (rhombohedral), Orthorhombic; Tesseral. BB, infusible, or fritting only on thin edges, but becoming magnetic. In some cases, magnetic normally.

Typical Representatives:—These may be arranged under three sub-groups.

Sub-group 1. *Anhydrous Rhombohedral Sideroids*:—Hæmatite, Ilmenite.

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[1] It must not be forgotten, also, that in some instances formulæ have been simply deduced from crystallization.

Sub-group 2. *Hydrous Orthorhombic Sideroids*:—Gœthite, Limonite.

Sub-group 3. *Tesseral "Octaahedral" Sideroids*:—Magnetite, Franklinite, Chromite.

Disintegration Products:—Reddle (Red Ochre), Yellow Ochre.

§ 3. *Groups* 26, 27.

Group 26. TANTALOIDS.

The Tantaloids constitute a small series of comparatively rare minerals, often classed with the Titanoids, under the name of "metallic stones." The two groups form, indeed, to some extent a connecting link between metallic and lithoidal minerals.

Distinctive Characters:—Lustre, sub-metallic or non-metallic; typically black or dark brown, although brownish-yellow in one amorphous variety. Orthorhombic, Tetragonal. H. 5 to 6. G. over 5; in some species exceeding 7 or 8. Infusible.

Typical Representatives:—(1) Columbite or Niobite, Tantalite, Fergusonite, Wœhlerite, Yttrotantalite, Samarskeite. (2) Uraninite (Pitchblende).

Doubtful Species, or Varieties:—Mossite, Tapiolite, Kochelite, Sipylite, Tyrite, Bragite, Hjelmite, Koppite, Microlite, Cleveite.

Disintegration Products:—Uran Ochre, Lindakerite.

Group 27. TITANOIDS.

This group is closely related to that of the Tantaloids; and its representatives are equally if not more thoroughly entitled to the designation of "metallic stones." They comprise, chiefly, the three well-known forms of Titanic anhydride, constituting distinct species; together with the natural representative of Stannic anhydride, closely akin to one of these species. All are bioxides. In many modern classifications Zircon is also referred to the same group. It is questionable, however, if the latter mineral—regarded as a silicate of zirconia—should be removed from the silicates proper, with some of which (viewed in its entirety) it has manifest relations. Crystallographically—and in its formula also, according to present views—it agrees with Rutile and Cassiterite: but it is widely separated from these by its actual composition, and more or less by its general habitus and conditions of occurrence. Its formula is now written, to conform with that of these minerals, as $ZrSiO_4$ or as $ZrO_2 SiO_2$. If crystallization and chemical formulæ, however, are alone to be considered, Plattnerite, PbO_2, and Polianite, MnO_2, must go in the same group; an arrangement that may look very well in a paper classification, but one that can hardly be admitted on mineralogical grounds. It has been thought advisable, therefore, in the present distribution, to let Zircon retain its old position among the silicates, from which, as regards its actual composition and general character, it cannot readily be separated.[1] In the Group of Titanoids, however, certain silico-titani-

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[1] Of recent authors who adopt a chemico-crystallographic classification, Prof. H. A. Miers in his able work on Mineralogy appears to be the only one who has left *Zircon* in its old position among the silicates. See remarks on Group 39.

ates, as a sub-group, may legitimately claim a place. Of these, the only important species is the well-known Titanite, the lighter varieties of which, known as Sphene, should properly rank as a sub-species.

Distinctive Characters:—Lustre, lithoidal, or in some cases verging on metallic-adamantine. Red, brown, gray, black, indigo-blue, yellowish, etc. H. 5 to 6·5. G. 3·4 to 7·1. Typically, Tetragonal. In other cases Orthorhombic or Clinorhombic. Rarely Tesseral. Often in geniculated and other twins. BB, infusible as regards most species (although yielding metallic tin in the case of Cassiterite); but fusible as regards the siliceous sub-group.

Typical Representatives:—(1) Cassiterite (Tinstone). (2) Rutile, Anatase, Brookite, Arkansite. (3) Perowskite (?), Pyrochlore (?).

Siliceous Sub-group:—(1) Titanite (Sphene). (2) Schorlomite, Keilhauite, Rinkite, Mosandrite, Johnstrupite.

Related Species:—Mengite, Polymignite, Euxenite, Æschynite, Warwickite, etc.

SERIES VI. LITHIDS.

This series (including Groups 28 to 45) is represented by the harder or more typical "stones" comprising the Diamond, the hardest of all minerals, and the only "Element" known at present that presents examples of the lithoidal type. Also the hard Boracite, and the Corundums and Spinels, together with Quartz and the harder or non-sectile silicates, Many of the latter form highly natural groups, as the Feldspars, the Pyroxenes and Amphiboles, the Zeolites, etc.; but in some cases the groups into which the silicates are referred in this distribution, although offering more or less allied representatives, are unavoidably, in the present state of our knowledge, "groups of convenience only.

General Characters:—Lustre, non-metallic (mostly adamantine, vitreous, or, in part, pearly). Typically colourless, and of white streak; but commonly coloured by an accidental (rarely essential) percentage of some metallic oxide. Crystallization represented by all the crystal systems. H., mostly, 6 to 10; more rarely about 5 or 5·5. G. 2·5 to 4 (rarely lower; mostly 2·7 to 3·7). Fusible in many examples (see under the separate groups below), infusible in others.

Group 28. ADAMANTOIDS.

In this subdivision, the Diamond, the lithoidal representative of the element Carbon—with its black variety or sub-species "Carbonado"—is alone comprised.

Distinctive Characters:—Lustre, vitreo-adamantine. Colourless or variously tinted. H. 10 (hence the hardest known mineral), but slightly less in the black "Carbonado." G. 3·5. Tesseral: chiefly octahedral and tetrahedral, with octahedral cleavage. BB, infusible.

Typical Representative:—Diamond.

Sub-species or variety:—Carbonado.

Group 29. BORACITOIDS.

As known at present, this subdivision is represented almost wholly by the mineral Boracite: essentially a magnesian borate combined with a certain amount of chloride of magnesium; but the rare aluminous borate Rhodizite also belongs to it. These minerals are separated from ordinary borates by their extreme hardness (which equals or exceeds that of quartz), as well as by other characters. They might perhaps be placed with equal justice in a distinct group among the *Lithophanids.* Boracite, the only representative of common occurrence, is referred by Möhs and Haidinger to their Order "*Gemmen*" (which includes the Diamond, Corundum, Quartz, etc.); and in Kengott's classification it is placed between the Diamond and Tourmaline, although, apart from its manifestation of pyroelectricity, it has little in common with the latter species.

Distinctive Characters:—Lustre, vitreous. Colourless or lightly tinted. H. 7 to 8. G. 2·9 to 3·3. Tesseral (mostly hemihedrally modified). Pyroelectric. BB, fusible, with B_2O_3 reaction. (*See* Appendix B.)

Typical Representative:—Boracite.

Rare Species:—Rhodizite.

Group 30. CORUNDOLOIDS.

This is a small but highly characteristic aluminous group, comprising the different varieties of Corundum; and also the related Chrysoberyl or Cymophane, consisting of alumina and glucina. Corundum (Al_2O_3) is isomorphous with Hæmatite, but, as already stated (see under Group 25), it is quite distinct from that species *as a mineral.* Although the two agree in their molecular relations and in crystallization, it has yet to be proved that an agreement of this kind, however important chemically, is sufficient (*in a classification of minerals*) to override all other considerations.[1] Corundum and Chrysoberyl are typical stones of closely related character and composition,

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[1] See remarks prefixed to Group 25.

and may thus fairly be placed together in a common group.

Distinctive Characters:—Lustre vitreous. Colourless and variously coloured, red, blue, green, etc. H. 8 to 9. G. 3·6 to 4·2. Hexagonal (rhombohedral) in Corundum; Orthorhombic in Chrysoberyl. BB, infusible. Yielding with cobalt solution a strong alumina reaction. (*See* Appendix B.)

Typical Representatives:—Corundum (with its varieties: (1) Ruby, Sapphire, etc.; (2) Common Corundum or Adamantine Spar; and (3) Emery).

Chrysoberyl or Cymophane (Alexandrite).

Group 31. SPINELOIDS.

The alumino-magnesian Spinels (MgO, Al_2O_3) constitute the typical representatives of this group. But in some examples the MgO is replaced by FeO or ZnO. They are isomorphous with Magnetite and related iron ores; but are here placed in a distinct group (contiguous to that of the Corundoloids) in reference to their essentially lithoidal character (see remarks under Group 25). The rare Periclase (MgO) may also be referred, from its aspect, hardness, crystallization, and other conditions, to the present group. If not placed here, it must be relegated to a place of its own among the stony minerals, as to place it with Tenorite, Zincite, and other simple oxides of natural occurrence would be to ignore entirely its mineralogical character.

Distinctive Characters:—Lustre, non-metallic. Red, pink, green, black, rarely colourless. H. 6 to 8. G. 3·5 to 4·1. Tesseral (octahedral). BB, infusible.

Typical Representatives:—Spinel, Gahnite, Pleonaste.

Allied Species:—Periclase (?).

Group 32. HYALOIDS.

This group consists of purely siliceous representatives, all consisting simply of SiO_2 or of $SiO_2 + H_2O$. The more important species comprise the Hexagonal or Rhombohedral Quartz, and the amorphous (usually hydrated) Opal, with their somewhat numerous varieties. They represent two distinct sub-groups, or even more definite subdivisions, but the non-hydrated Opals are connected with the Quartz sub-group by some of the practically amorphous Calcedonies. To these types must be added the Orthorhombic Tridymite, and the still more recently discovered Christobalite of Tetragonal or Tesseral (?) crystallization.

Sub-group 1. *Crystalline or Quartzose Types.*

Distinctive Characters:—Vitreous, or, otherwise non-metallic. H. 7. G. 2·5 to 2·8. Typically, Hexagonal (rhombohedral). Exceptionally, Orthorhombic, Tetragonal, or Tesseral (?). BB, infusible. Forming with soda a clear glass, and giving other silica reactions. (*See* Appendix B.)

Typical Representatives:—Quartz (Rock Crystal, Amethyst, Calcedony, Chrysoprase, Jasper, Flint, etc.), Tridymite, Christobalite (a rare and still obscurely known species).

Sub-group 2. *Amorphous or Opaline Types.*

Distinctive Characters: — Vitreous, waxy, etc.

Colourless, yellowish, gray, brown, green, etc. Translucent or opaque; translucent varieties often show a coloured iridescence. Amorphous. H. 5·5 to 6·5. G. 1·5 to 2·5. BB, infusible. Yielding water (in variable amount) in most varieties.

Typical Representatives:—Opal, Semi-Opal, Menilite, Hyalite, etc. Probably, also, Chrysocolla, as a cupreous "Semi-Opal" (?). See under Group 42.

Group 33. BERYLOIDS.

This group is represented by a small number of hard, vitreous silicates, in which, as regards the typical species, glucina is always present. They are thus in a measure allied to the aluminous Chrysoberyl.

Distinctive Characters:—Vitreous. Green of various shades, bluish, yellowish, colourless. Hexagonal, Orthorhombic, Clinorhombic. H. 7·5 to 8. G. 2·6 to 3. BB, infusible, or fritting on thin edges only. Give silica reaction with Phosphor-salt.[1]

Typical Representatives:—Beryl (Emerald), Phenakite, Euclase, Bertrandite (?).

Group 34. CORDIEROIDS.

A single species, the alumino-magnesian silicate, Iolite or Cordierite (often known as Dichroite), represents this group. The species is very subject to alteration, becoming hydrated, and passing into a number of more or less distinct minerals, Pinite, Fahlunite,

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[1] Beryl is commonly stated to dissolve entirely in this reagent. But at a certain stage a "silica skeleton" always appears, and the portion of silica, dissolved at first, precipitates as the glass cools, rendering this opalescent or milky. (*See* Appendix B.)

Weissite, etc. Some of these, however, although commonly referred to Iolite, are probably derived from other species. They are all of low hardness and of pseudomorphous character, and are thus placed, in this distribution, in a special group (Metaboloids). Iolite itself occupies in different systems a very variable position, but is commonly placed near Beryl.

Distinctive Characters:—Vitreous, resino-vitreous. Normally blue, but pleochroic (bluish-grey, yellowish, etc.) in different directions by transmitted light. Orthorhombic, but commonly massive. H. 7 to 7·5. G. 2·5 to 2·7. Infusible, or fritting on thin edges only. Yielding silica reaction, BB, with Phosphor-salt.

Typical Representative:—Iolite (Cordierite).

Group 35. TOPAZOLOIDS.

The well-known Topaz is the typical representative of this group. In general aspect—apart from crystallization—Topaz often approaches the Beryls, but its pronounced basal cleavage is especially characteristic, and its density is higher. In its composition, fluorine largely replaces oxygen.

Distinctive Characters:—Vitreous. Yellow, colourless, pink, pale-greenish, etc. Orthorhombic. H. 7·5 to 8. G. 3·4 to 3·6. BB, infusible.

Typical Representative:—Topaz (Pycnite, Pyrophysalite).

Group 36. CYANOIDS.

This group is made up typically of sub-silicates of alumina, and is thus related to the Topazoloid Group; but its representatives present a very different aspect.

One of these, Andalusite, occurs commonly in dull coarse crystals of the Orthorhombic System, usually in a more or less altered condition. The other representatives are either Orthorhombic, Triclinic, or Clinorhombic, but are commonly found in bladed or flat-fibrous masses.

Distinctive Characters:—Vitreous, pearly, etc. Gray, white, blue, dull red. H. 4·5 on flat surfaces, 7 on edges of component lamellæ. G. 3·1 to 3·7. Orthorhombic, Triclinic, Clinorhombic. BB, infusible. Silica reaction with Phosphor-salt.

Typical Representatives:—Andalusite (Chiastolite), Sillimanite, Cyanite, Diaspore.

Rare Species (placed here doubtfully):—Sapphirine. Prismatine, Cornuropine, Dumortierite.

Group 37. STAUROTOIDS.

The type-form of this group is the Staurolite or Staurotide, a mineral often placed, in classifications, in the immediate vicinity of Topaz and Andalusite. But it contains FeO[1] (and in some examples MgO and MnO) and thus differs in composition essentially from the latter, although holding equally (if free from intermixed quartz) a comparatively low percentage of silica. It was also at one time regarded as allied to the Garnets, from which, however, it is altogether removed by its composition, crystallization and typical infusibility.

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[1] First made known by the author in 1848. See "Chemical Gazette," July 15 of that year. Also Erdmann's "Journ." XLVI., p. 119. Thirteen years later, Rammelsberg's analyses confirmed this. Previously, the iron was always stated as peroxide.

Distinctive Characters:—Vitreous, but frequently dull and stony in aspect. Brown, red, gray, etc. Orthorhombic (crystals frequently in cruciform twins). H. 7 to 7·5. G. 3·4 to 3·8. BB, infusible. Yielding silica reaction with Phosphor-salt.

Typical Representative:—Staurolite.

Related Species or Sub-species:—Nordmarkite (a manganese Staurolite, stated to be fusible) (?).

Group 38. GRANATOIDS.

The various Garnets are the main representatives of this group. They comprise a series of hard Tessular silicates, crystallizing mostly in the form of the Rhombic Dodecahedron, or in that of the Trapezohedron 212. To this group, however, may also be referred the Tetragonal Idocrase or Vesuvianite, closely allied to many Garnets by its aspect, hardness, and conditions of occurrence generally, although distinct in crystallization.

Distinctive Characters:—Vitreous. Red, brown, green, yellow, pink, black, rarely colourless. Tessular. Tetragonal. H. 6·5 to 7·5. G. 3·2 to 4·3. Fusible. Giving silica reaction with Phosphor-salt.

Typical Representatives:—(1) Lime-alumina Garnet (Grossular, etc.), Magnesia-alumina Garnet (Pyrope, etc.), Manganese Garnet (Spessartine, etc.), Iron-alumina Garnet (Almandine, etc.), Lime-iron Garnet (Andradite, Aplome, Melanite, etc.), Chrome Garnet (Uvarovite). (2) Vesuvian or Idocrase (Wiluite).

Group 39. ZIRCONOIDS.

The Zircon, a silicate of zirconia, is practically the sole representative of this group. It is isomorphous with Cassiterite and Rutile, and thus, of late years, very commonly associated in classification with these bioxides, its formula being modified to agree virtually with that of the latter minerals. But this coincidence, interesting as it may be, is hardly sufficient to warrant the removal of Zircon from its natural allies, the scleroid silicates, with many of which it has intimate mineralogical and geognostic relations. If, moreover, we place it with the bioxides in question, it follows, logically, that we must place in the same group both Polianite (MnO_2) and Plattnerite (PbO_2). The first of these cannot be separated on natural grounds from the group of manganese oxides (however variable in formula) to which it belongs; whilst the second, the lead bioxide Plattnerite, is absolutely without any mineralogical relations to Zircon. Here, as in other instances, we have molecular and crystallographic relations on the one hand, opposed to actual chemical composition and mineralogical conditions on the other. The first view may be thought—especially by those who follow blindly the lead of others—to present the more scientific aspect: but it may be doubted, after all, if it will ultimately prevail against the more practical and natural view of the question. *See* remarks to Group 27.

Distinctive Characters:—Vitreous or resino-vitreous. Tetragonal (the basal form of extreme rarity). H. 7·5. G. 4·4 to 4·7. Brown, red, yellow, etc.; rarely colourless BB, quite infusible. Silica reaction with Phosphor-salt.

Typical Representative:—Zircon (Hyacinth).

Related Mineral:—Malacon (an altered Zircon)(?).

Group 40. TRIGONOIDS.

(So named from their triangular crystallization.)

This group—composed of hard, vitreous Borosilicates—is represented typically by the various Tourmalines including the black, fusible variety or subspecies Schorl.

Distinctive Characters:—Vitreous. Green, red, brown, yellowish, blue, black; rarely colourless. Hexagonal (rhombohedral); the prisms generally triangular. H. 7 to 7·5, G. 2·9 to 3·3. Pyroelectric. BB, infusible in clear varieties; fusible readily in the black Schorls and in some other examples. Yielding silica reaction with Phosphor-salt.

Typical Representatives:—Tourmaline (including Rubellite, Indicolite, etc.), Schorl.

Group 41. AXINOIDS.

This group is represented by some hard, vitreous and readily fusible silicates, in which, as in the Tourmalines, boracic anhydride is present. The chief representative is the long-known species Axinite, a mineral which differs materially from Tourmaline in its aspect, crystallization and other characters. Its formula, moreover, is very uncertain: the part usually accorded to the B_2O_3 being quite problematical. It is therefore made in this classification the type-form of a distinct group, immediately following that of the Tourmalines. Another boro-silicate, the Danburite, in spite of its Topaz-like crystallization, should probably find a place also in this group. Whilst presenting a singular agreement in its crystals, with those of certain varieties of Topaz,[1] its composition is entirely different, and it differs remarkably from Topaz by its ready fusibility.

Distinctive Characters:—Vitreous. Brown, amethystine, green, gray, yellow (often chloritic). Triclinic. Orthorhombic. H. 6·5 to 7. G. 2·9 to 3·3. BB, readily fusible, tinging the flame-point green.[2] Silica reaction with Phosphor-salt.

Typical Representatives:—Axinite, Danburite (?). The latter is comparatively rare in distinct crystals.

Group 42. CHRYSOLOIDS.

This group comprises a number of vitreous, mostly hard, translucent silicates, of varied crystallization, but presenting typically the quality of being decomposed by hydrochloric (or by sulphuric) acid, with separation of the silica in a gelatinous condition, distinct, therefore, from its condition in ordinary siliceous minerals.

Distinctive Characters and sub-groups: (1) *Magnesian Types*:—Orthorhombic. Green, yellow, reddish-brown, orange-red, rarely colourless. H. 6·5 to 7. G. 3·1 to 3·6. BB, infusible in most cases, but some varieties slag at the point and sides.

Typical Species:—Olivine (= Chrysolite and Peridot).

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[1] In Topaz crystals, the macro-pinakoid, or front vertical form 100, is however quite unknown or exceedingly rare; whilst it is commonly present in both the Connecticut and Swiss crystals of Danburite. There are also other points of difference.

[2] In the fusible Tourmalines, containing 9 or 10 p. c. of B_2O_3, the flame remains uncoloured, whilst in Axinite, which contains less than 6 p. c., the green coloration is very marked. This is still without explanation.

Monticellite, Forsterite, Hyalosiderite, Chondrodite, Humite.

(2) *Manganese Types*:—Vitreous, resino-vitreous. Yellow, brownish, yellowish-green, flesh-red, reddish-gray. Tesseral (tetrahedral); Hexagonal (rhombohedral). H. 5·5 to 6·5. G. 3·2 to 4·1. BB, fusible into a dark bead.

Typical Species:—Helvine, Danalite, Tephroite.

(3) *Bismuthic Type*:—Tetrahedral (crystals very small). Vitreo-resinous. Brown, yellow, grayish. H. 4·5 to 5. G. 6. Easily fusible.

Typical Species:—Eulytine.

(4) *Zinc Types*:—Vitreous. Colourless, gray, brown, red, green, blue. Hexagonal (rhombohedral); Orthorhombic. H. 5 to 6. G. 3·2 to 4·2. BB, infusible, or vitrified slightly at point and sides.

Typical Species:—Troostite, Willemite, Calamine.

(5) *Cupreous Type*:—Vitreous. Emerald green. Hexagonal (rhombohedral). H. 5·5. G. 3·3. BB, infusible. Blackens, and gives with fluxes copper reactions. (*See* Appendix B.)

Typical Species:—Dioptase.

NOTE.—Chrysocolla, often placed with Dioptase, is an amorphous silicate of copper, yielding on ignition about 20 p. c. of water. It may be regarded, not unreasonably, as consisting originally of malachite or other cupreous species destroyed by intermixture with amorphous silica.

Group 43. GADOLINOIDS.

This group is closely related to that of the Chrysoloids, and should perhaps form part of the latter; but whilst its representatives are equally decomposed (and, typically, with marked gelatinization) by hydrochloric acid, they present, as a rule, a dark or black colour, and are for the greater part opaque. They may be referred to two series: an iron-manganese and a ceritic series, respectively.

Distinctive Characters:—Lustre, resino-vitreous, inclining to sub-metallic in some examples. Reddish-gray, brown, black. Orthorhombic or Clinorhombic; but, except in Ilvaite and Orthite, crystals are very rare. H. 5·5 to 7. G. 3 to 5. BB, readily fusible (Fayalite Knebelite, Ilvaite, Orthite); or infusible (Cerite, Gadolinite). Gelatinizing in acids.

Typical Representatives:—(1) Knebelite, Fayalite Ilvaite (Lievrite). (2) Cerite, Gadolinite, Thorite, Orangite, Orthite.

Group 44. EPIDOIDS.

The Epidotes and allies—hard, alumino-calcareous silicates, practically insoluble in acids—are the typical representatives of this group. Most of these are of dull green colour, varying from yellowish-green to very dark green or black. But in certain manganese examples the colour is red; and in the almost iron-free Zoizites, gray, yellowish, etc. Orthite (Group 43, above) is related crystallographically to Epidote; and the more typical Epidotes have undoubted affinities with the Pyroxenes and Amphiboles of Group 45.

Distinctive Characters:—Vitreous. Green of various shades, black, brown, red, gray, etc. Orthorhombic (Zoizite). Clinorhombic in the true Epidotes, the crystals mostly elongated transversely. H. 6 to 7. G. 3·2 to 3·5. BB, fusible.

Typical Representatives:—Epidote (Pistacite, Thulite, etc.), Bucklandite, Piedmontite, Zoizite.

Group 45. PYROXENOIDS.

The representatives of this group are typically hard, or moderately hard, non-aluminous silicates of magnesia and lime, these bases being in the darker varieties largely replaced by FeO, or Fe_2O_3, or both. Alumina is however present in some varieties (partially replacing the silica); and alkalies (exceptionally) in others. Practically, four more or less distinct Sub-groups may be recognized: Amphiboles, Pyroxenes, Rhodonites, Bronzites.

Sub-group 1. *Amphiboles.*

Distinctive Characters:—Vitreous, or otherwise lithoidal. Greenish-white, light or deep green, brown, black. Clinorhombic, with prism-angle of about 124° 30′. Prisms mostly 6-sided (= 110, 010), the ortho-pinakoid or front-vertical form (100) being very rarely present. Pleochroic. H. 5·5 to 6. G. 2·9 to 3·4. BB fusible.

Typical Representatives: — Tremolite, Actynolite, Hornblende, and varieties.

Rarer Species or Varieties:—Arvedsonite, Breislakite, Glaucophane, Nephrite, etc.

Sub-group 2. *Pyroxenes.*

Distinctive Characters:—Clinorhombic, with prism-angle of about 87° and 93°. Prisms usually 8-sided, the orthopinakoid being almost invariably present. Not (or only exceptionally) pleochroic. Other characters as in Sub-group 1.

Typical Representatives: — Diopside, Malacolite, Augite, and varieties (Sahlite, Fassaite, etc.).

Less common Representatives:—Jade (an alkali-Diopside), Acmite (Soda-Augite), etc.

Sub-group 3. *Rhodonites.*

Distinctive Characters:—Black, rose-red, weathering black. Triclinic, but crystals rare. Fusible. Other characters as above.

Typical Representatives:—Rhodonite, Babingtonite, Fowlerite, etc.

Sub-group 4. *Bronzites.*

Distinctive Characters:—Gray, greenish-white, brown, green, etc., with commonly a vitreo-pearly, or pearly-metallic lustre. Orthorhombic, but crystals rare: mostly in laminar or shaly masses. H. 4 to 6. G. 3 to 3·5. Easily fusible in some cases, infusible in others.

Typical Representatives:—Anthophyllite, Bronzite, Diallage, Hypersthene, Enstatite, Glaucophane, Bastite (*Schiller Spar*).

Group 46. *Feldspatholoids.*

The various Feldspars (Clinorhombic and Triclinic) constitute the typical representatives of this group. They consist essentially of alkalino-aluminous silicates, in which the silica is comparatively of high amount, usually exceeding 60 or more per cent. As a rule, they are of light colour, never black; and are easily cleavable. Through Spodumene they are connected with the Pyroxenoids (Group 45). Spodumene, indeed, is generally regarded from its crystallization as a pyroxene, and its position in the present group may probably be considered altogether unorthodox. But in its aspect and general character, its light coloration, lamellar structure, etc., and especially in its high percentage of silica, it is more closely related to the feldspars. The normal presence of alumina and alkali, also, and the absence of lime and magnesia in its composition, go far to confirm this view, and to separate it from the typical calcareo-magnesian, non-aluminous pyroxenes. It is, in fact, simply a Feldspar of augitic crystallization: just as Borax in its crystallization is an augitic or pyroxenic Borate. Through Anorthite (a calcareous species with comparatively low percentage of silica) there is a transition into Group 47.

Three Sub-groups may be recognized: (1) Augitic Feldspars; (2) Orthoclasic Feldspars; and (3) Albitic or Anorthic Feldspars.

Distinctive Characters: — Vitreous, vitreo-pearly, lithoidal. Mostly light-coloured: white, apple-green, red, gray, brownish, etc. Clinorhombic. Triclinic. Spathoidal. H. 5·5 to 6. G. 2·5 to 3·1, mostly under 3. BB, fusible in thin splinters. In some species easily fusible. With Phosphor-salt, marked silica reaction.

Typical Representatives: — (1) *Augitic Feldspars*: Spodumene (Triphane). Petalite.[1] (2) *Orthoclasic Feld-*

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[1] Petalite is placed with Spodumene in this Sub-group from its feldspathic aspect, high percentage of silica, the presence of lithia, and, in part, from its crystallization as shown in the Castor variety.

spars (Clinorhombic): Orthoclase, Microcline, Hyalophane. (3) *Albitic Feldspars* (Triclinic): Albite, Oligoclase, Labradorite, Anorthite.

Group 47. WERNEROIDS.

The minerals referred to this group, although forming as regards their general characters a somewhat heterogeneous assemblage, undoubtedly occupy a natural position between the Feldspars and the Zeolites. They are mostly aluminous silicates of lime or alkalies, but some are non-aluminous. Wollastonite belongs to the latter series. This mineral, a simple silicate of lime, is commonly regarded in modern classifications as an augite or proxene. It differs, however, from the typical augites by the absence of magnesia, a very characteristic component of the latter; and also by its property of being readily decomposed with gelatinization by acids. Its density, moreover, is below that of the typical pyroxenes, and the aspect of its rare crystals is very different.[1]

Distinctive Characters: — Vitreous, vitreo-pearly. White, gray, yellowish, red, greenish, etc. Mostly Tetragonal; but in some species Tesseral (?), Hexagonal, or Clinorhombic. H. 4 to 6. G. 2·4 to 3. BB, easily fusible in most cases; but, in Leucite, infusible. Yielding silica reaction (*see* Appendix B) with Phosphorsalt. Decomposed, with or without gelatinization, by hydrochloric acid.

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[1] Wollastonit zeigt nach Dichte, Spaltbarkeit, chem. Verh. und Axenschiefe wesentliche Abweichungen von den monoklinen Augiten, sodass er von manchen Autoren nicht zur Augitgruppe gerechnet wird. Klockmann: Min. 1900.

Typical Representatives:—(1) Leucite. (2) Wernerite (Scapolite, Caclocasite, Dipyre, Wilsonite), Meionite, Mariolite, Sarcolite, Gehlenite, Nepheline (Elæolite), Mellilite. (3) Wollastonite. (4) Leucophane, Melinophane (?).

Group 48. HALIOLOIDS.

This group, in many respects, is very closely related to the last. It is made up of a small number of gelatinizing silicates containing either an alkaline chloride or an alkaline sulphate or sulphide. Helvine and Danalite (Group 42) are related types.

Distinctive Characters:—Vitreous. Colourless, blue, bluish-green, gray, greenish-white. Tesseral (dominant form, the rhombic dodecahedron). Orthorhombic. H. 4 to 5·5. G. 2·1 to 3. BB, fusible. Silica reaction with Phosphor-salt. *See also*, in Appendix B, reactions of Cl and SO_3. Gelatinize in hydrochloric acid.

Typical Representatives:—Sodalite, Hauyne, Nosean, Ittnerite (altered Sodalite), Lapis Lazuli.

Group 49. ZEOLOIDS.

The more typical representatives of this group form a closely connected series of hydrated silicates; although in some species the water (or its hydrogen) appears to be entirely constitutional, whilst in others it is regarded as partly constitutional and partly adjunctive, and in others, again, as wholly adjunctive. The solution of this question, however, is still uncertain. The Zeolites appear to have been derived mostly from Feldspars and Scapolites. All occur typically in fissures and amygdaloidal cavities in trappean or basaltic rocks, or form part of the actual substance of the latter. All, moreover; are readily fusible, the greater number with marked bubbling or intumescence, whence the original name. They are decomposed also very readily (Prehnite excepted) by hydrochloric acid, mostly with separation of gelatinous silica, but in some cases the silica separates in a granular-slimy condition. Certain species—Datolite and Prehnite, more especially—have been relegated in some systems to other groups. Datolite (a boracic species) has been placed, indeed, in a common group with Euclase and Gadolinite, the three species being regarded as isomorphous. The isomorphism of these minerals (if somewhat forced) is undoubtedly a curious and very interesting discovery, but in view of the dissimilar composition, general characters and geological conditions of the three species, it is surely exacting too much to compel us—in a *classification of minerals*—to unite them, in common, as members of a natural group.[1] (See *ante*, § 1, page 27). Whether Prehnite should be regarded as a Zeolite, is, to some extent, an open question. But the ignition-characters of this mineral, its general aspect, and its occurrence as a constant associate of "trappean" rocks, hardly admit of any other conclusion.

Distinctive Characters:—Vitreous or vitreo-pearly

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[1] Der Isomorphismus mancher Mineralien kann uns, selbst in denjenigen Fallen da er mit einer formellen Analogie ihrer chemischen Constitution verbunden ist, nicht bestimmen sie in der Gruppirung der Species neben einander zu stellen, sobald ihrer qualitative Zusammensetzung sehr auffallend verscheiden ist.—NAUMANN, *Min.* 8 *Auflage.*

externally, more or less pearly internally. Colourless, red, brown, yellow, greenish, etc., with white streak. Tesseral (Analcime, Faujasite), Tetragonal (Apophyllite, Edingtonite). Hexagonal-Rhombohedral (Chabasite). Orthorhombic (Prehnite, Thomsonite, Natrolite). Clinorhombic (Laumontite, Scolezite, Heulandite, Stilbite, Brewsterite, Harmotome, Phillipsite). H. 4·5 to 7, mostly about 5 or 5·5. G. 2 to 3. BB, fusible, mostly with intumescence, but in some cases quietly. Soluble in acids, mostly gelatinizing, or with separation of slimy-granular silica. Yielding water on ignition.

Typical Representatives:—(1) *Calcareous types*: Prehnite (Chlorastrolite), Datolite (Botryolite), Laumontite, Okenite, Scolezite, Stilbite, Heulandite. (2) *Calcareo-Alkaline types*: Thomsonite (Comptonite), Gmelinite, Gismondine, Zeagonite, Chabasite, Phillipsite, Harmotome (a barytic sp.), Brewsterite, Edingtonite Apophyllite. (3) *Alkaline types*: Faujasite, Analcime, Natrolite.

Group 50. RYAKOIDS.

This group (named from ῥύαξ, a lava stream), includes only certain amorphous, volcanic products, the claim of which to rank as simple minerals is now very generally repudiated. Without some reference to them, however, our list of minerals would be certainly incomplete. All are silicates of alumina and alkalies, with small amounts of lime, etc., and in the more typical examples the silica exceeds 70 per cent. The well-known Obsidian, a hard, volcanic glass, breaking with sharp edges and conchoidal fracture, is the principal representative. Some related types contain less silica, and yield a little water on ignition.

Distinctive Characters:—Lustre, vitreous, pearly. Black, gray, white, greenish, reddish, etc., sometimes zoned. H. 6 to 7. G. 2·2 to 2·6. Amorphous. BB, very readily fusible.

Typical Representatives: — Obsidian (Marekanite), Pitchstone, Pearlstone, Pumice (a light-coloured, fibrous lava), Tachylite, Sideromelane, Hydro-Tachylite.

SERIES VII. DIARIDS.

This Division includes Groups 50 to 55 (inclusive), and is represented by a series of soft, fissile, fibrous, or sectile silicates, composed for the greater part of easily separable particles; or being, otherwise, sufficiently soft to be easily scratched by the knife-point if not by the finger-nail. Many are pseudomorphous substances, and nearly all, on strong ignition, yield water varying from a small amount to a comparatively high percentage. If a mineral give a silica reaction BB, with Phosphor-salt (*see* Appendix B), and yield readily to the knife, it will belong, as a rule, to this Series.

Group 51. PHYLLOIDS.

This group is represented by the various Micas, Chlorites, and allied species—aluminous silicates (mostly of K_2O, MgO, Li_2O, or more rarely CaO), possessing in a remarkable degree a finely-foliated or scaly structure, and being thus easily separable into thin leaves or scales. In all cases a certain amount of water is evolved on strong ignition, but this varies from 1 or 2 to 10 or 12 per cent. All are easily scratched on the cleavage-surfaces. Four leading

Sub-groups may be conveniently recognized: (1) Micas; (2) Lepidolites; (3) Stereolites, comparatively hard, rigid types; and (4) Chlorites proper.

Sub-group 1. *Micas* (Potassic and magnesian or ferro-magnesian species).

Lustre, metallic-pearly, but streak practically uncoloured. White, brown, black, etc. Component laminæ flexible and elastic. Clinorhombic (crystals pseudo-hexagonal in aspect). H. 1·5 to 3·5. G. 2·8 to 3·2. BB, fusible as a rule on edges only. In some cases expanding greatly. With Phosphor-salt, give silica reaction.

Typical Representatives:—Muscovite, Biotite (Phlogopite), Lepidomelane.

Less common types:—Damourite, Sericite, Astrophyllite, Fuchsite, Oellacherite, Rubellane (altered Biotite)(?), Vermiculite (altered Phlogopite)(?), etc., etc.

Sub-group 2. *Lepidolites* (Lithia Micas).

Lustre more or less pearly. Rose-red, white. In Zinwaldite, brown, gray, violet, dark green, etc. Clinorhombic, but mostly in six-sided tables or in scaly-granular masses. H. 2 to 3. G. 2·8 to 3·1. BB, fusible: typically with intumescence or bubbling, colouring the flame-point red.

Typical Representatives:—Lepidolite, Zinwaldite (Cryophyllite).

Sub-group 3. *Stereophyllites.*

Lustre, pearly or vitreo-pearly. White, yellow, green, brown, reddish, etc. Clinorhombic, but mostly in hexagonal, scaly, or foliated masses. Thin leaves, brittle.

H. 3·5 to 5·5 or 6. G. 3 to 3·6. BB, fusible as a rule on edges only.

Typical Representatives:—(1) Margarite (Pearl mica, lime mica). (2) Xanthophyllite, Brandisite (Disterrite), Seybertite (Clintonite), Chloritoid, etc.

Sub-group 4. *Chlorites.*

Lustre pearly or vitreo-pearly. Dark green, clear green, red, gray, brownish, etc. Streak greenish, or grayish. Clinorhombic (crystals tabular, and pseudo-hexagonal in aspect), but occurring chiefly in foliated and crypto-scaly or fine-granular masses. H. 1 to 3. G. 2·5 to 3. BB, fusible, but in general, on edges only. Yield water (9 to 12 p. c.), on ignition.

Typical Representatives:—(A) *Chlorites proper.* Prochlorite, Ripidolite (Clinochlore), Pennine. (B) *Rhodochlorites*: Kæmmerrerite (Rhodochrome, Rhodophyllite), etc. (C) *Siderochlorites*: Cronstedtite, Thuringite, Delessite, Aphrosiderite.

Group 52. TALCOIDS.

This group includes the Talcs, Steatites, Serpentines, and various allied magnesian, hydrated (non-aluminous) silicates; all of low degree of hardness, and marked sectility. In some, the Talcs proper, the water does not exceed 4 or 5 p. c. and is essentially basic, but in the Serpentines and allies, and in Brucite, the amount is considerably higher, varying from about 10 or 12 to over 30 p. c.

Distinctive Characters:—Lustre, pearly, or (in the compact or crypto-scaly varieties) sub-resinous or lithoidal. White, greenish-white, yellow, green, reddish, brown, etc., two or more colours often present together. H. 1 to 1·5 (in Talc proper); 2 to 3 in other species. G. 2·6 to 2·8. Clinorhombic (?) but commonly in foliated, scaly, slaty, compact, scaly-granular, or fibrous masses. Thin plates, in Talc, flexible but non-elastic; in slaty Serpentine, brittle. BB, fuse, as a rule, on edges only, or remain infusible. In the bulb-tube, harden and generally blacken, evolving water in most cases, but practically none in pure Talc. With Phosphor-salt (Brucite excepted) all give a silica reaction.

Typical Representatives:—1. *Talcs proper*: Talc, Steatite. 2. *Serpentines*: A. Serpentine proper. B. Antigorite (slaty var.). C. Rœtisite, Garnierite, Genthite (nickeliferous vars.). D. Mountain Cork, etc. E. Chrysotile, Baltimorite, Metaxite (asbestiform vars.). 3. *Hydro-Talcs*: Meerschaum, Dewelite, Brucite (a simple magnesian hydrate, of talcoid character), Pimelite, etc.

Group 53. AMIANTHOIDS.

A series of soft, fibrous, asbestiform substances represent this group. Most of these are undoubtedly altered varieties of Hornblende or Augite; but some are varieties of other species (Wollastonite, Scapolite, etc.). In the present classification they are placed in a separate group, as their physical characters are so totally distinct; and many differ also to some extent from the amphiboles, etc., in composition. The present classification is not intended only to exhibit (according to the Author's view) the relations and affinities of minerals, but to serve, as well, for their more ready determination. Hence it is considered that varieties, so called, which depart in a pronounced degree from their parent types, may be fairly regarded as practically distinct minerals.

Distinctive Characters:—Aspect, silky, cotton-like or more or less pearly. White, greenish, yellowish, bluish, etc. H. 1, or exceptionally 1 to 4. G. 2·7 to 2·9. In fibrous (often silky) masses. BB, more or less easily fusible. With Phosphor-salt, give silica reaction.

Typical Representatives:—Asbestus or Amianthus, proper. Okenite (Wollastonite-Asbestus), Crocidolite. Carpholite. (*See* Serpentine-asbestus in Group 52, §E.)

Group 54. METABOLOIDS.

This group is composed entirely of products of alteration, derived from Iolite, Olivine, Augite, and other silicates, whence the name of the group, from μεταβολή, As contended, however, in the remarks prefixed to the preceding group, products of alteration when differing materially from the supposed parent type may justly be regarded as distinct minerals. Pinite, for example, if an altered Iolite, is so entirely different in character and in actual composition, as to be virtually distinct from that species. Probably there are but few minerals that have not been derived to some extent from others. Those of the present group of course represent extreme cases. They are essentially hydrated silicates, of low hardness. Many occur in dull, opaque, more or less earthy crystals, regarded, correctly, as pseudomorphs; and others, in earthy or nodular masses, or in coatings. Some adhere to the tongue, and fall to pieces in hot water. Two sub-groups may be recognized: *Pinites* and *Green Earths* respectively. The latter are essentially ferruginous (or chloritic), and yield on ignition a large amount of water. Viewed generally, the Metaboloids are related closely to many Serpentines, and also to the succeeding group of Hydrargilloids.

Distinctive Characters:—Lustre, mostly dull, earthy, waxy, or sub-pearly. Gray, white, brown, dark green, etc. Crystals, pseudomorphous. Commonly massive. H. 1 to 3. G. 2·4 to 2·8. BB, fusible, or fusible on edges only. With Phosphor-salt give silica reaction. In bulb-tube, yield water (4 to over 30 per cent).

Typical Representatives:—(1) *Pinites*: Pinite, Weissite, Pyrargillite, Fahlunite, Esmarkite, Bonsdorffite, Aspasiolite, Gigantolite, Oosite, Iberite, Villarsite, Gieseckite, Liebnerite, etc. (2) *Green Earths*: Seladonite, Glauconite, Chamoisite, Chloropheite, Kirwanite, Miloschin, Wolchonskoite, Nontronite, Hisingerite, etc.

Group 55. HYDRARGILLOIDS.

This is a hydrated, aluminous group, but many of its representatives have a singular resemblance to the Talcs and other magnesian minerals belonging to Group 52. When moistened, however, with a drop or two of cobalt nitrate, and then ignited, the Hydrargilloids, assume on cooling a distinct blue colour; whilst the Talcoids become pale red. Two sections may be recognized: (1) Pyrophyllites (with 5 to 15 p. c. water); and (2) Hydrargillites (with 30 to 40 p. c. water).

Distinctive Characters:—Lustre, pearly, or earthy. White, yellowish, gray, reddish, greenish or bluish-white. H. 1 to 3. G. 1·9 to 2·9. BB, fusible, but as a rule on edges only. With Phosphor-salt give silica reaction.

Typical Representatives:—(1) *Pyrophyllites*: Pyrophyllite, Kaolin, Nacrite, Pholerite, Halloysite, Cimolite, Agalmatolite, etc. (2) *Hydrargillites*: Gibbsite, Bauxite, Kollyrite, Allophane, etc.

SERIES VIII. LITHOPHANIDS.

This series, comprising Groups 56 to 60 inclusive, consists of Phosphates and Fluorides (mostly aluminous) which present in many species (Amblygonite, Turquoise, etc.) a lithoidal aspect and hardness—whence the name Lithophanids. In most cases, lithia or other alkalies also enter into the composition of these minerals; and in some, MgO, YO, or CeO forms the base or an essential portion of this. Most lithophanids are of comparatively rare occurrence, and some are very rare. Some are readily fusible, others infusible; the flame in most cases being coloured green or red from the presence of P_2O_5 or Li_2O. With Phosphor-salt, BB, a silica reaction is never manifested.[1] All dissolve, partially or wholly, in nitric acid. The diluted solution yields a canary-yellow precipitate if warmed with a few drops (or some small fragments) of ammonium molybdate.

Group 56. AMBLYGONIDS.

This is a small group of anhydrous phosphates, some of which present a feldspathic appearance and are hard enough to scratch glass.

Distinctive Characters:—Aspect lithoidal, sub-resinous, sub-pearly. Colourless, greenish-white, bluish-green, gray, dark-brown. Triclinic, Clinorhombic or Orthorhombic, but occurring generally in cleavable masses. H. 4·5 to 6, mostly 5 or 5·5. G. 2·9 to 3·5. BB,

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[1] This holds good as regards all succeeding groups: the reaction, therefore, will not be again referred to. The Silicate cease with Group 55.

fusible readily in most cases, with green or red coloration of the flame, but some species vitrify on the edges only, and some colour the flame yellow.

Typical Representatives:—(1) Amblygonite. (2) Triphylline, Triplite, Zwieselite. (3) Baryllonite, Wagnerite.

Group 57. MONAZOIDS.

This is a comparatively unimportant group, somewhat closely allied to the last. It comprises a few very rare phosphates of CeO, LaO, YO, or ThO, and one or two related fluorides, also of rare occurrence.

Distinctive Characters: — Vitreous, sub-pearly. White, yellowish, brownish, pale red. Clinorhombic. Tetragonal. H. 4·5 to 5·5. G. 4·4 to 5·4. BB, infusible, or fusible on edges only.

Typical Representatives:—(1) Monazite, Cryptolite (Phosphocerite), Xenotime. (2) Fluocerite, Hydrofluocerite, Yttrocerite.

Group 58. KALOIDS.

This is an amorphous, hydrated group, represented by the Kalaite or Turquoise and some related aluminous phosphates.

Distinctive Characters:—Lustre, vitreous. Amorphous. Blue, bluish-green. H. 4·5 to 6. G. 2·6 to 2·8. BB, infusible. Yielding water (20 to 27 p. c.) on ignition.

Typical Representatives:—Turquoise, Variscite.

Group 59. WAVELLOIDS.

A small group of crystalline, hydrated and essentially aluminous phosphates, many of which present a radiated, fibrous structure. Wavellite is the typical representative, and the only species of common occurrence belonging to the group.

Distinctive Characters:— Vitreous, vitreo-pearly. Green, greenish-white, blue, yellowish, etc. Orthorhombic. Clinorhombic. H. 3·5 to 5·5, commonly about 4 or 5. G. 2·3 to 3·3. BB, fibrous varieties exfoliate and become white; other varieties lose colour, but all are practically infusible. In the bulb-tube all yield water.

Typical Representatives:—(1) Lazulite, Berlinite. (2) Wavellite, Fischerite, Peganite, etc.

Group 60. CRYOLOIDS.

This group is represented by Cryolite (a Fluoride of aluminium and sodium), and by a small number of related fluorides of very rare occurrence. Its affinities lie more nearly with the aluminous phosphates, or fluophosphates, than with the calcium fluoride, Fluor-spar.

Distinctive Characters:—Pearly or resino-vitreous. White, gray, yellowish, reddish. Clinorhombic, but found mostly in granular-cleavable masses. H. 2·5 to 4. G. 2·8 to 3. BB, very easily fusible, colouring the flame yellow. Give also (*see* Appendix B) marked reactions of alumina and fluorine.

Typical Representative:—Cryolite.

Rare, obscurely known species:—(1) Chiolite, Arksutite, Niphorite, Fluellite. (2) Pachnolite, Thomsenolite, Prosopite.

SERIES IX. CALCIDS.

The dominating presence of calcium, or that of its oxide CaO (often replaced by one or more of the vicarious and closely related oxides, BaO, SrO, MgO, PbO, etc.), characterizes the minerals of this series. In other respects the composition varies greatly, the series including certain fluorides, phosphates, carbonates, sulphates, etc., but these are connected, under special groups, by their calcareous or related composition; and, as a rule, by their general conditions of occurrence. The series includes Groups 61 to 69. Its representatives have typically a pearly or vitreous aspect and white streak. Their hardness never exceeds 5, and is generally about 3 or 4. When fused with borax they dissolve rapidly, the saturated bead becoming white and opaque on cooling, or by flaming, or otherwise yielding (on charcoal), reduced lead.

Sub-Series A. *Anhydrous Calcids.*

Group 61. FLUOROIDS.

Fluorite or Fluor Spar is the only commonly-occurring or important representative of this group. It is more nearly related (as a mineral) to Apatite, Calcite, and other calcareous minerals of this series, than to any fluoride of natural occurrence. Here, as in many other cases, it is the base that influences the character of the mineral. There can be no doubt, for instance, that Calcite and Fluorite are more nearly allied, *as minerals*, than Calcite and Malachite; although these latter, as carbonates, come under one and the same Class in all chemical classifications. At the same time, although members in common of the same natural series, Fluorite and Calcite are necessarily representatives, within this series, of distinct groups.

Distinctive Characters:— Lustre, vitreous, pearly. White, amethystine, green, yellow, red, etc. Tesseral, with octahedral cleavage; or (in Sellaite) Tetragonal. H. 4 to 5. G. 3 to 3·2. BB, fusible into a white enamel. In most examples, phosphorescent under gentle ignition.

Typical Representatives:—Fluorite (Fluor Spar). Sellaite (a very rare magnesian species).

Group 62. APATOIDS.

This is essentially a group of calcareous and lead phosphates, combined with a fluoride or chloride of the same metal, or, in some cases, with both. An arseniate and a vanadiate of lead also belong to the group. These representatives are Hexagonal in crystallization, and alike in general formula, constituting, thus, a very natural assemblage. The lime phosphate Apatite, the lead phosphate Pyromorphite, and the corresponding arseniate Mimetesite, are the principal representatives. As regards the Apatites proper, the analytical formula commonly adopted gives $3\,(3\ RO, P_2O_5)+R\,(ClF)_2$, in which R equals Ca. But as neither $CaCl_2$ nor $PbCl_2$ "dissolves out" in boiling water, neither of these chlorides can, evidently, be present, unless in some cryptomorphic condition, totally unlike its ordinary normal state.

Distinctive Characters: — Lustre, vitreous, vitreo-resinous. White, green, brown, gray, violet, orange-yellow. Typically Hexagonal (crystals often curved). H. 3·5 to 5. G. 2·9 to 7. BB, infusible, or nearly so, in the calcareous representatives. Readily fusible into a bead with crystalline surface (or, otherwise, reducible), in the lead species.

Typical Representatives:—(1) Apatite (Phosphorite, Moroxite, Francolite, Osteolite). (2) Pyromorphite (Miesite, Polysphærite). Mimetesite (Kampylite). Vanadinite (a lead chloro-vanadiate, allied to the *Heliochroids* of Group 71, but agreeing in crystallization and formula with the lead chloro-phosphates, etc., of the present group, also belongs to it.

Doubtfully related species:—Wagnerite, Berzeline (Kuehnite) (?), Svabite (?) Endlichite (?)

Group 63. CALCITOIDS.

This is also a very natural group, represented by the "Rhombohedral Carbonates." The common formula $=RCO_3$ or, analytically, RO, CO_2, in which RO= lime, magnesia, zinc oxide, or the protoxides of manganese and iron respectively: two or more of these being often present in the same example. All crystallize in the Hexagonal System, but occur chiefly in rhombohedrons with marked rhombohedral cleavage, the typical angle lying between 105° and 108°.

Distinctive Characters:—Vitreous, pearly, etc. Colourless, white, brown, yellow, etc. Hexagonal (chiefly in rhombohedrons and scalenohedrons, often terminating an hexagonal prism). Also in cleavable masses, stalactites, etc. H. 3 to 5, commonly 3 to 3·5. G. 2·6 to 4·5 (in Calcite 2·6 to 2·8). BB, mostly infusible; becoming caustic in many examples after strong ignition; or becoming magnetic, in ferruginous species. Soluble with effervescence in hot or cold acids.

Typical Representatives:—Calcite (Calc Spar), Dolomite, Magnesite, Ankerite, Siderite, Rhodocrosite, Smithsonite (Calamine).

Group 64. ARAGONOIDS.

A group of "Prismatic Carbonates" represented by species of Orthorhombic crystallization, in which the protaxial prism-angle lies between 116° and 117°30′. The species possess, in common, the formula $RCO_3=$

RO, CO_2, as in the preceding group of Rhombohedral Carbonates. RO = CaO, BaO, SrO, or PbO.

Distinctive Characters:—Lustre, vitreous, adamantine, vitreo-resinous. Colourless, white, yellowish, violet, pale blue, gray, etc. Orthorhombic (compound-crystals often pseudo-hexagonal in aspect). Occurring also in fibrous, coralloidal, and other irregular forms. H. 3·5 to 4. G. 2·9 to 6·6. Soluble with effervescence in diluted hydrochloric acid.

Typical Representatives:—Aragonite, Tarnowitzite, Witherite, Alstonite, Strontianite, Cerussite, Iglesiasite (a zinc-holding Cerussite).

Group 65. BARYTOIDS.

This group is composed of anhydrous sulphates, presenting the common formula $RSO_4 = RO,SO_3$, in which RO = CaO, BaO, SrO, or PbO. All are Orthorhombic in crystallization, with the protaxial prism-angle[1] between 101°40′ and 104°30′. In many respects they closely approach the orthorhombic carbonates of corresponding base.

Distinctive Characters:—Lustre, vitreous, vitreo-pearly, adamantine. Colourless, white, yellow, blue, brown, reddish, etc. Orthorhombic. H. 3·5 to 4. G. 2·8 to 6·4. BB, fusible; in some cases reducible. With soda, all yield a strong hepar reaction.

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[1] In the position adopted by Miller, Negri, Cathrein, and others. This position, unfortunately, differs from that adopted by most German crystallographers, in which the vertical form $\infty P = 110$ (as here adopted) is made a macrodome or front-polar form.

Typical Representatives: — Barite, Baryto-Calcite, Celestine, Anglesite, Anhydrite,

Related Sulphato-carbonates (mostly Clinorhombic): —Lanarkite, Caledonite, Leadhillite, etc.

Group 66. SCHEELITOIDS.

This group is composed of a small number of Tetragonal Tungstates and Molybdates of CaO or PbO: typically of light tint, unless coloured by the (probably) extraneous presence of a small percentage of lead chromate or vanadate. With these, in all chemical systems, Wolfram is also placed. But that species, commonly regarded as a tungstate of iron and manganese, is so distinct in aspect and in all its characters, that it cannot be referred mineralogically to the same group. Perhaps the view originally entertained, but now discarded, that the tungstenum is in a lower degree of oxidation than WO_3, although obtained in this form in analysis, and calculated as such, may not be altogether inadmissible? If not, the very striking difference presented by Wolfram to other natural tungstates must be due to the predominating influence of the iron and manganese in that mineral. In the present classification, Wolfram is placed in a special Group (24) between the Manganoids and Sideroids (Groups 23 and 25), with which, as well as with the Tantaloids (Group 26), it has undoubtedly many close relations. The common formula of the natural tungstates is $RWO_4 = RO, WO_3$.

Distinctive Characters: — Vitreous, adamantine, vitreo-resinous. Gray, white, yellow, greenish, red.

Streak, practically uncoloured. H. 3 to 5. G. 5·9 to 8·1. Tetragonal (crystals mostly pyramidal or tabular). BB, infusible in some species, easily fusible (and reducible) in others. *See also* tungsten and molybdenum reactions in Appendix B.

Typical Representatives:—(1) Scheelite, Stolzite. (2) Wulfenite (PbO, MoO_3).

Rare Species or Varieties:—Reinite (?), Powellite.

Sub-series B. *Hydrous Calcitoids.*

Group 67. GYPSOIDS.

With this group commences the series or sub-series of the Hydro-Calcitoids—sulphates of lime, magnesia, etc.—in all of which a considerable amount of water is evolved on ignition. Some are slowly or partially acted upon by water; but for determinative purposes they may be viewed as insoluble. Selenite or Gypsum, and Polyhallite (which contains CaO, MgO and K_2O), are the only important species.

Distinctive Characters:—Lustre, vitreous, pearly or silky. Colourless, white, gray, reddish, yellowish, etc., with white streak. Clinorhombic, Orthorhombic (?). Frequently in fibrous, granular and lamellar masses. H. 1·5 to 3·5. G. 2·2 to 2·8. BB, fusible. Giving with soda (*see* Appendix B) marked sulphur reaction. Yielding water on ignition, and becoming opaque-white.

Typical Representatives:—Gypsum, Polyhallite, Syngenite, Kieserite.

Group 68. PHARMACOLOIDS.

This is a comparatively unimportant group, composed of a few calcareous, magnesian, and related arseniates, all hydrated species. The principal representatives, Pharmacolite (with 24 p.c. water, and Clinorhombic crystallization), Brushite, Haidingerite, Roesslerite, etc., support the collocation of this group near that of the Gypsoids. The Pharmacoloids, however, occur mostly in earthy crusts and fine acicular groupings on arsenical ores; and crystals, as a rule, are rare, or quite inconspicuous.

Distinctive Characters: — Aspect, earthy, pearly, resino-vitreous. Colourless, white, greenish, reddish, etc. H. 1 to 3, mostly 1 to 2. G. 2·4 to 2·75. Clinorhombic, Orthorhombic. BB, fusible, with emission of arsenical fumes. Yield water on ignition in the bulb-tube.

Typical Representatives:—Pharmacolite, Brushite(?) Haidingerite, Wapplerite, Rösslerite, Hopeite (a ZnO-holding species).

Rare and obscurely known Species:—Fillowite, Dickinsonite, Brandtite, Messelite, etc.

Group 69. BOROCALCITOIDS.

A few rare and more or less imperfectly known calcareous and related borates (all hydrated species) constitute this group. These, in most cases, form earthy incrustations and fibrous aggregates, but one species (Colemannite) occurs in Clinorhombic crystals and in cleavable masses somewhat harder than Calcite.

Distinctive Characters: — Aspect, vitreous, vitreo-pearly, earthy. Colourless, white, yellowish, reddish. Clinorhombic; but mostly in fibrous or encrusting examples. H. 1 to 3·5. G. 2·5 or less. BB, fusible, colouring the flame distinctly green, especially if the test-fragment be moistened with glycerine. In the bulb-tube, yield water.

Typical Representatives:—Colemannite, Borocalcite, Ulexite, Priceite, Sussexite, Lagonite, etc.

SERIES X. Cerids.

This series comprises but one Group, having for its chief representatives the so-called "Horn Silvers," AgCl, AgBr, AgI—to which may be added the chloride of mercury, Calomel; and also certain lead chlorides and oxychlorides, all of rare occurrence as natural bodies.

Group 70. Ceroids.

This group, as stated in the preceding notice, is composed essentially of the so-called "Corneous Ores" (chlorides and related compounds) of Silver, Mercury or Lead.

Distinctive Characters:—Aspect, mostly horny, waxy, or vitreo-resinous. Gray, white, yellow, greenish, violet-brown, etc. H. 1 to 3. Mostly sectile. G. 5·3 to 7·5. Tesseral. Tetragonal: but found chiefly in compact, interlacing, fibrous, or acicular examples. BB, easily fusible or volatilizable. Giving reactions of chlorine, bromine, or iodine; and also those of Ag, Hg, Pb. (*See* Appendix B.)

Typical Representatives:—Cerargyrite or Chlorargyrite, Bromargyrite (Embolite, etc.), Iodargyrite, Calomel, Cotunnite, Phosgenite.

SERIES XI. Antherids.

This Series (named from ἀνθηρός, flowering, blooming) comprises a large number of brightly-coloured minerals, mostly red, orange-yellow, green, or blue, of vitreous, vitreo-adamantine, or pearly lustre, and coloured streak. All are of comparatively low hardness, and are easily scratched by the knife. Most exhibit a fibrous structure, or occur in groups of small crystals belonging to the Tesseral, Tetragonal, Hexagonal, Orthorhombic, or Clinorhombic System. As regards composition, the Series contains Carbonates, Sulphates, Chromates, Phosphates, Arseniates, and some Oxy-Chlorides—the bases being chiefly PbO, CuO, or FeO. The essential aspect and character of the individual species are due in the chromates to the influence of both acid and base; and in the other compounds almost entirely to the latter. Viewed generally, the Antherids may be arranged under three sections, comprising: § 1. Lead Antherids; § 2. Copper Antherids; § 3. Iron and Cobalt Antherids.

§ 1. *Lead Antherids.*

Group 71. HELIOCHROIDS.

This is a small group of red or orange (rarely yellowish-brown or greenish) coloured species, with base of lead or bismuth; but the only important representative is the lead chromate Crocoisite. The lead vanadiate, although referred from its crystallization and formula to the Apatite Group (62), has much in common with the present group. Some rare copper-vanadiates (Volborthite, Mottramite) with yellow streak may also be referred provisionally to this Group. Also the cupreous Vauquelinite.

Distinctive Characters:—Lustre, vitreo-adamantine, resinous, vitreo-pearly. Deep red, orange-yellow, yellowish-brown, with orange-yellow streak. Clinorhombic, Orthorhombic. H. 2·5 to 3·5. G. 5·7 to 6. BB, fusible and reducible: giving, with fluxes, reactions of chromium and lead or copper. (*See* Appendix B.)

Typical Species:—Crocoisite (Krokoite), Phœnicite, Dechenite, Vauquelinite (?) Pucherite (a bismuthic species).

§ 2. *Copper Antherids.*

Group 72. MALAKOIDS.

This is a small but important group of hydrated copper-carbonates, represented especially by Malachite and Azurite, of green and blue colour respectively, as the names indicate. Both are apparently compounds of copper carbonate and copper hydrate: with about 8·2 p.c. water (as obtained on ignition) in Malachite, and 5·3 p.c. in Azurite; but whilst Malachite occurs mostly in botryoidal and other examples of fibrous structure, and is rarely crystallized, Azurite is found very generally in groups of small, prismatic or tabular (Clinorhombic) crystals.

Distinctive Characters:—Lustre, vitreous, pearly. Green of various shades (often banded) or rich blue; with paler streak in each case. Clinorhombic. H. 3 to 4 in ordinary examples. G. 3·7 to 4·1. BB, fusible and reducible, with strong Cu reactions. (*See* Appendix B.) Soluble with effervescence in diluted acids.

Typical Representatives:—Malachite, Azurite (Chessylite).

Allied Species:—Aurichalcite (contains ZnO), Buratite.

Group 73. BROCHANTOIDS.

A small and somewhat unimportant group, consisting essentially of copper sulphates mostly associated with copper hydrate. Although of comparatively rare occurrence, these species are interesting in showing their closer relationship—in a mineralogical sense—to many of the copper phosphates and arseniates of this series, than to the ordinary copper sulphate or Blue Vitrol. Brochantite, for example, the chief representative of the group, is in its general characters quite distinct from the soluble sulphate, Chalcanthite: whilst mineralogically, it closely approaches Libethenite, Olivenite, and Euchroite.

Distinctive Characters:— Lustre, vitreous, pearly. Dark or bright green, bright blue. Orthorhombic. H. (typically) 3 to 4. G. 3·8 to 5·5 (the latter in lead-holding species). BB, fusible and reducible. With soda (*see* Appendix B) give hepar reaction.

Typical Representatives:— Brochantite (Kœnigite, Langite, Warringtonite), Linarite, Caledonite, Leadhillite, Lettsomite (Woodwardite).

Group 74. URANOIDS.

This group is represented chiefly by the phosphate of uranium and copper (Torbernite, Chalcolite), and by the closely related uranium and lime phosphate, Uranite—distinguished by their emerald-green and yellow colours and their phylloidal or micaceous structure. They occur also very commonly in small crystals belonging respectively to the Tetragonal and Rhombic Systems, but presenting a cuboidal aspect. To this group belong also some unimportant arsenical and other varieties of the two preceding species.

Distinctive Characters:—Lustre, metallic-pearly or vitreo-pearly. Emerald-green, greenish-yellow, with paler streak. Tetragonal. Orthorhombic (with tetragonal aspect. H. 2 to 2·5. G. 3 to 3·6. BB, fusible with uranium (or uranium and copper) reactions. (*See* Appendix B.)

Typical Representatives:— Torbernite (Chalcolite, Copper-Uranite), Autunite (Lime Uranite).

Allied Species or Varieties:—Barium Uranite (Uranocercite), Zeunerite (Arsenical Copper-Uranite), Uranospinnite (Arsenical Lime-Uranite.)

Group 75. OLIVENOIDS.

This group is represented by a considerable number of copper phosphates and arseniates, many of which are of comparatively frequent occurrence in copper districts. All, typically, are green or blue in colour; and they occur especially in groups of small crystals, or in leafy, fibrous, or mamillary examples.

Distinctive Characters:—Lustre, vitreous, otherwise pearly or vitreo-resinous. Dark green, emerald-green, light blue. Rhombic., Hexag., Clinorhomb. H. 2 to 4. G. 3·4 to 4·4. BB, fusible, reducible: the arsenical species mostly deflagrating on charcoal. The water, evolved on ignition, varies from about 3 to over 20 per cent.

Typical Representatives:—(1) Olivenite, Libethenite, Clinoclase (Abichite), Erinite, Phosphorchalcite, Ehlite, Tagilite. (2) Euchroite, Chalcophyllite (copper mica), Liroconite, Tirolite.

Group 76. ATACAMOIDS.

The minerals of this group comprise a small series of hydrous oxy-chlorides of copper, or (in one case) of copper and lead. In their general aspect they much resemble the copper phosphates and arseniates of preceding groups. Atacamite, the more common representative, is Orthorhombic in crystallization; but some of the rarer species of the group are Tesseral, and these occur in small but well-defined crystals (= 100 and 110) of a rich blue colour.

Distinctive Characters: — Lustre, vitreous. Dark green, emerald-green, light blue, deep blue. Orthorhombic; Tesseral. H. 3 to 4. G. 3·7 to 3·8. BB, fusible and reducible, giving chlorine and copper reactions. (*See* Appendix B.)

Typical Species:— Atacamite, Percylite, Boleite (Cumengeite).

§ 3. *Iron and Cobalt Antherids.*

Group 77. VIVIANOIDS.

In this group the copper-salts of the preceding groups are replaced by phosphates and arseniates of iron, cobalt, or nickel: but the base (unless subsequently peroxidized, as in Vivianite), still remains in the condition of RO. The iron phosphate, Vivianite, the red, cobaltic arseniate, Erythrite, and the nickeliferous arseniate Annabergite, are the only important representatives. All are hydrated species, yielding on ignition a large percentage of water.

Distinctive Characters: — Lustre, vitreous, vitreo-pearly. Deep blue, bluish-green, greenish-white, red, pearl-gray. Clinorhombic, but occurring chiefly in bladed and fibrous examples, or in an earthy efflorescent condition. H. 1·5 to 2·5, or less. G. 2·9 to 3·1. BB, easily fusible, giving, with Borax, reactions of Fe, Co, or Ni (*see* Appendix B), and evolving in most cases an arsenical odour. The iron species give a magnetic bead or slag.

Typical Representatives: — Vivianite (Symplesite), Ludlamite, Erythrite (Kottigite), Annabergite (Cabrerite).

SERIES XII. PERISSIDS.

The representatives of this Series consist of phosphates, arseniates, and certain sulphates, and are characterized especially by the base being in the condition of R_2O_3, or in that of RO, R_2O_3—hence the name, from Περισσός (beyond the average). Of the three groups belonging to the Series, the first, consisting of arseniates and phosphates, has many affinities with some of the preceding groups in which the base is normally present as protoxide; whilst the second and third groups, although composed of insoluble species, are more or less related to some of the succeeding HALOPHANIDS.

Group 78. SCORODOIDS.

This group consists of hydrated arseniates and phosphates of iron, in which the base is in the condition of Fe_2O_3 or in that of FeO, Fe_2O_3. The principal representatives are Pharmacosiderite (the so-called "cube ore"), and Scorodite among the arseniates; and the phosphate Childrenite. All yield on ignition a considerable amount of water.

Distinctive Characters:—Aspect, vitreous, vitreo-resinous, silky. Green, yellow, red-brown, red, dark blue. Tesseral (often hemihedral). Orthorhombic. H. 2 to 3, or less. G. 3 to 4. BB, fusible, mostly with arsenical fumes, a magnetic bead or slag resulting.

Typical Representatives:—(1) Pharmacosiderite, Scorodite, Arseniosiderite, Durangite. (2) Childrenite, Strengite, Dufrenite, Kakoxene, Beraunite, etc.

Group 79. KARPHOSIDEROIDS.

This group is composed of a considerable number of ferric sulphates of more or less unstable composition, and, in some cases, partially soluble in water. They are mostly of dull shades of colour, brownish, yellow, reddish, dull green, etc.; and are often of earthy aspect. As minerals they are of but little importance. In most cases they occur in fibrous and botryoidal examples, or in earthy crusts. All evolve water on ignition, and also sulphurous acid (SO_2).

Distinctive Characters:—Aspect, earthy, sub-pearly, vitreo-resinous. Red-brown, green, brownish-black, yellow, etc. Hexagonal (Rhombohedral); Triclinic(?), but occurring mostly in fibrous, scaly, mamillary, and encrusting examples. H.1 to 4, but mostly under 3. G. under 3·3. BB, yield a magnetic slag. With soda give strong hepar reaction. See also preceding remarks.

Typical Representatives:—Karphosiderite, Glockerite, Utahite, Hohmannite, Pissophane, Pittizite, Raimondite, Jarosite, etc., etc. See also under the Vitrioloids, Group 81.

Group 80. ALUNOIDS.

This group is very closely allied in its chemical relations to the preceding group; but the representatives of the two groups present a very different aspect, notwithstanding the isomorphism of Jarosite (Group 79) with Alunite. Distinct crystals, however, are of rare occurrence: fibrous, acicular, earthy, fine-granular and other indefinite examples prevailing. In the Karphosiderites and allies, the base consists of Fe_2O_3 and examples are very prone to alteration, and are usually coloured, and even partially soluble in water; whereas in the Alunoids, the base consists of Al_2O_3, and examples are white or lightly coloured, and quite insoluble. Hence the latter have been placed provisionally (though with some doubt) in a separate group. In both groups the representatives evolve SO_2 on strong ignition (*see* Appendix B), together with a large percentage of water.

Distinctive Characters: — Aspect, lithoidal, silky, earthy. Hemi-Hexag.(rhombohedral-angle, as in Jarosite, 89°), but commonly found in fine-granular or sub-earthy masses, the latter adhering to the tongue. White, pale yellowish, etc., with uncoloured streak. H. 1 to 4·5. G. 1·8 to 2·8. BB, infusible; evolve water and SO_2. With cobalt solution, become bright blue on cooling. With soda give strong hepar reaction.

Typical Representatives: — Alunite (Alumstone), Læwigite, Websterite, (Aluminite), Halotrichite, Felsobanyite.

SERIES XIII. HALOPHANIDS.

The soluble and sapid "salts" of natural occurrence, with a few closely related bodies of saline aspect and character, are included in this Series. The more important representatives comprise: the soluble sulphates, carbonates, borates and chlorides of natural occurrence.

Group 81. VITRIOLOIDS.

This group comprises the soluble sulphates (all hydrated) of magnesia, iron, cobalt, nickel, manganese, copper and uranium respectively. These occur mostly in efflorescent or encrusting examples, distinct crystals being comparatively rare. Four sections may be recognized: (1) and (2) Orthorhombic and Clinorhombic species, with the analytical formula $RO,SO_3 + 7H_2O$;

(3) Triclinic species, with the formula RO,SO_3+5H_2O; and (4) partially altered species. The latter are mostly ferruginous, and are very closely allied to the minerals of Group 79, although distinctly soluble. All possess a strongly bitter or "metallic" taste.

Distinctive Characters:—Sapid. Vitreous, silky, earthy. Colourless, opaque white, greenish-white, green, blue, reddish; mostly efflorescent. For crystal systems see above. H. 1 to 2. G. 1·7 to 2·3. BB, fusible, yielding water (in most cases over 30 or 40 p. c.), and in the ferruginous species, SO_2. With soda give strong hepar reaction.

Typical Representatives:—(1) Epsomite, Tauriscit, Goslarite, Morenosite, Fauserite (?). (2) Melantherite, Bieberite, Johannite. (3) Chalcanthite. (4) Coquinibite (Hexagonal), Botryogene (Clinorhombic), etc.

Group 82. GLAUBEROIDS.

This group consists essentially of alkaline (or alkaline-earthy) sulphates, soluble or practically soluble in water, and possessing a distinct taste. They fall into two sections: (1) an anhydrous, and (2) a hydrous section. As minerals they are comparatively unimportant.

Distinctive Characters:—Sapid. Vitreous, pearly, silky, earthy. Colourless, white, grayish, yellowish, pale red. Hexagonal (rhombohedral), Orthorhombic, Clinorhombic; but mostly efflorescent. H. 1 to 2·5 or 3. G. 2·1 to 2·8. BB, fusible. With soda give strong hepar reaction. Some species (those of §1) are anhydrous: others yield on ignition a considerable percentage of water.

Typical Representatives:—(1) Glaserite, Hanksite, Arcanite, Mascagnine, Thenardite, Glauberite. (2) Mirabilite(Glauber salt), Blœdite(Astrakanite), Kainite (contains KCl.).

Group 83. ALUMS.

This group is represented by the various Alums—soluble, hydrated sulphates, including, chiefly, the common potassic species (= K_2O 9·95, Al_2O_3 10·82, SO_3 33·75, H_2O45·48), the soda species, ammonia species, magnesia species, iron species, etc. As occurring in nature, the Alums are commonly in earthy crusts and acicular efflorescences on aluminous shales; but they crystallize from solution in the form of the regular octahedron, or, more rarely, in other Tesseral forms.

Distinctive Characters:—Soluble, with marked taste. Earthy or efflorescent. BB, with soda give hepar reaction. In the bulb-tube yield a large amount of water,

Typical Representatives:—Kalinite or Potash Alum, Soda Alum, Tchermigite or Ammonia Alum, Pickeringite or Magnesia Alum, Apjohnite or Manganese Alum, Alunogene (Hair-salt in part) or Iron Alum.

Group 84. THANATOIDS.

The more simple oxidized-compounds of antimony and arsenic belong to this group. Some of the included species are soluble; others but slightly so; and some are practically insoluble. It might be thought that, as simple oxides, these species should find, more appropriately, a place under the "Oxids" in an earlier part of the System; but whilst they have no direct relations or resemblances, from a mineralogical point of view, to the metallic oxides of that series, their white streak and other characters, and the close connection of their soluble and insoluble representatives, seem to justify their position (as here adopted) among the "Halophanids."

Distinctive Characters:—Pearly, vitreo-adamantine, earthy. White or lightly tinted, with white streak. H.1 to 2·5. G.3·6 to 5·6. Tesseral (octahedral); Orthorhombic; but, in large part, efflorescent. BB, on charcoal, fusible or reducible with antimonial or arsenical fumes.

Typical Representatives:—(1) Arsenolite, Claudetite. (2) Senarmontite, Valentinite, Cervantite. (3) Antimony Ochre, Stiblite.

Group 85. BOROIDS.

The present group includes Boracic Acid, mineralogically known as Sassoline, and two or three alkaline borates. All are hydrated bodies, soluble in hot or cold water. Sassoline and the ammoniacal borate Larderellite occur mostly in white, pearly and crystalline scales. The only other representative of ordinary occurrence is the sodium-borate Tincal or Borax. This occurs in small granular masses and in clinorhombic crystals which bear a close resemblance in form and measurements to the common augite-crystals. Some related (insoluble) species are referred to the Borocalcitoids, Group 69.

Distinctive Characters :—Soluble. Pearly, resinovitreous, earthy. White or mechanically tinted, with white streak. Triclinic; Clinorhombic; scaly or granular. H. 1 to 2·5. G. 1·4 to 1·8. BB, fusible with intumescence, colouring the flame green; but this reaction in the case of Borax is only produced by moistening the test-substance with glycerine or with sulphuric acid, by which the yellow soda-flame is effaced.

Typical Representatives:—(1) Sassoline. (2) Larderellite, Tincal or Borax. (3) Szailbeyite (partially soluble).

Group 86. NATROIDS.

This group is composed of a small number of more or less soluble, hydrous carbonates. As minerals they are comparatively unimportant.

Distinctive Characters:—Soluble, or partly soluble, Effervescent in acids. Vitreo-pearly, earthy. White, grayish, etc. Essentially in efflorescent, fibrous, or crystalline crusts. (Artificial crystals, clinorhombic or orthorhombic). H. 1 to 2·5. G. 1·4 to 2·6. BB, fusible with yellow coloration of the flame. In the bulb-tube, yield water.

Typical Representatives:—(1. Soda species), Natron, Trona, Thermonatrite. (2. Soda-lime sp.) Gaylussite.

Group 87. HALOIDS.

This group consists of soluble chlorides—alkaline, or earthy alkaline, as regards the base. The only important species is the widely distributed Chloride of Sodium, or Rock-Salt.

Distinctive Characters:—Soluble. Vitreous, pearly, in some examples earthy, in aspect. White, gray, red, violet, etc., with white streak. Tesseral (with cubical cleavage) in the anhydrous species; in other species, Orthorhombic or Clinorhombic (or Hexagonal ?). H. 1

to 2. G. 1·6 to 2·2. BB, fusible or volatilizable. With Phosphor-salt and CuO, give chlorine reaction. *See* Appendix B.

Typical Representatives:—(1. Anhydrous species): Halite or Rock-Salt, Sylvine, Salmiac, Chlorocalcite. (2. Hydrous species) Carnallite, Tachydrite, Kremersite, Bischofite, (3) Kainite, etc., etc.

Group 88. NITROIDS.

A few soluble and partially soluble nitrates form the representatives of this group. The soluble species comprise the potassic Nitre or Saltpetre, agreeing in crystallization with Aragonite, but of natural occurrence only in acicular, efflorescent, and fine-granular examples; and Nitratine or "soda-nitre," a rhombohedral species agreeing in crystallization very closely with Dolomite (*see ante*, page 23). The partially soluble species consist of hydrated, calcareous and magnesian nitrates—earthy or efflorescent species of no special interest.

Distinctive Characters:—Soluble or partially soluble. Vitreous, pearly, earthy. White, or accidentally tinted. Orthorhombic, Hexag. (rhombohedral); but occurring naturally in efflorescent or granular crusts H. 1 to 2. G 1·9 to 2·2. BB, fusible: on charcoal, deflagrescent.

Typical Representatives:—(1. Anhydrous species): Nitre (Saltpetre); Nitratine. (2. Hydrous species): Nitrocalcite; Nitromagnesite.

SERIES XIV. AMPHOTERIDS.

This series forms properly an appendix to the Mineral Kingdom, being composed of substances derived in chief part, if not wholly, from animal or vegetable bodies. Hence the name given to the series (from ἀμφότερος), indicating both their organic and mineral nature. It is questionable, however, if all bituminous minerals, although commonly ranked as "organico-chemical substances," are of this character. The series may be conveniently subdivided into five groups, comprising: Crystalloids, Geoceroids, Retinoids, Asphaltoids, and Anthraxinoids.

Group 89. CRYSTALLOIDS.

This group is made up of a small number of crystallized substances, mostly hydrated compounds of an organic acid with alumina or ferrous oxide. With these, however, may be placed (in a separate section) the ammoniacal phosphate Struvite, a substance derived from the decomposition of animal remains.

Distinctive Characters:—Resinous, resino-vitreous, earthy. White, gray, yellowish, brownish. Orthorhombic, Tetragonal (hemimorphic); acicular. H. 1 to 2·5. G. 1·5 to 2·4. BB, fusible, otherwise becoming alkaline or magnetic. In the bulb-tube yield water.

Typical Representatives:—(1) Struvite, see above. (2) Mellite, Oxalite, Whewellite (perhaps Clinorhombic).

Group 90. GEOCEROIDS.

Certain hydro-carbons of a more or less pearly or waxy aspect represent this group. Those of Section 1 occur chiefly in white crystalline scales or laminæ; the others, in soft waxlike masses. On ignition, they take fire and are volatilized.

Distinctive Characters: — Pearly, waxy. White, yellowish, brownish, red. H. 1, or less, to 1·5. G. about 1. BB, combustible, fusible.

Typical Representatives:—(1) Scheererite, Hartite, Fichtelite, etc. (2) Ozokerite, Hatchettine.

Group 91. RETINOIDS.

The so-called "mineral resins," of which Amber is the only important representative, constitute this group. All are inflammable, amorphous bodies of low hardness and sp. gr., burning with a peculiar aromatic odour. They consist essentially of carbon and hydrogen, but some contain also a small percentage of oxygen.

Distinctive Characters:—Lustre, resinous. Yellow, yellowish-white, brownish, dull red. Amorphous: mostly in nodular masses; otherwise in thin layers and granules in certain Brown Coals. H. 1 to 2·5. G. about 1. Electric by friction. BB, inflammable, burning with yellow flame and aromatic odour.

Typical Representatives:—Amber, Retinite, Ioxylite, Piauzite, Krantzite, etc.

Group 92. ASPHALTOIDS.

The representatives of this group, as regards their general nature and composition, have close relations with both mineral resins and coals; but they occur mostly in either a fluid, semi-fluid, or very soft condition, although solidifying in many cases into comparatively hard or brittle masses. Some, indeed, occur naturally in the latter state. As regards composition, they consist of C, H, and O in somewhat variable proportions; with, in one coal-like representative (Albertite), a small amount of nitrogen.

Distinctive Characters:—Aspect, oily, pitch-like, or coaly. Brown, black, yellowish: the light-coloured fluid varieties (Naphtha, etc.) more or less fluorescent. H. 0 to 2·5. G. 1, or less, to 1·2. BB, inflammable, burning with yellow flame and bituminous odour.

Typical Representatives:—(1) Petroleum (Naphtha). (2) Asphalt, Elaterite. (3) Albertite, Stellarite.

Group 93. ANTHRAXINOIDS.

This group contains merely the different species or sub-species of coal. Apart from some bituminous shales and varieties to which special names have been given, these comprise Anthracite, Bituminous Coal, and Lignite or Brown Coal, including Jet, Paper Coal, etc.

Distinctive Characters: — Aspect, vitreo - resinous, sometimes approaching sub-metallic; in typical Brown Coals, more or less ligneous or sometimes earthy, but many examples are dense and black, and thus closely approximate to ordinary coal, although occurring at a higher geological horizon. Black, brown, with black or brown streak. H. 1 to 2·5. G. 1·2 to 1·8. BB, anthracite is infusible and non-inflammable, the other coals burn with yellow flame—the caking or "fat" varieties, fusing.

Typical Representatives:—Anthracite and Anthracitic Coals (with 80 or more p. c. carbon); Bituminous Coal (with 60 to 70 p. c. carbon, and variable amounts of hydrogen, oxygen, and nitrogen); Brown Coal or Lignite (with usually from 50 to 60 p.c. carbon, and variable amounts of H, O (and N). In addition to these normal constituents, all coals contain a certain amount of earthy matter or "ash," as well as a variable amount of hygroscopic moisture. In many, also, sulphur, from pyrites, is present.[1]

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[1] A convenient method of examining coals by the blowpipe was published by the author in the "Phil. Mag." in or about 1858, *See*, *also*, Bruno Kerl's *Löthrohr-Untersuchungen*, 1862; Plattner's *Probirkunst*, 1878; and the author's "Blowpipe Practice," Toronto, 1880-93.

APPENDIX B

IN the Remarks prefixed to the various groups of the preceding Classification, allusion is frequently made to certain blowpipe-reactions: as those of sulphur in sulphides and sulphates, silica in silicates, chlorine in chlorides, and so forth; together with those of certain metals and metallic oxides of common occurrence in minerals, as copper, iron, manganese, lead, bismuth, antimony, etc. In order therefore to avoid the necessity of reference, on the part of the reader, to special works on the Blowpipe, it has been thought advisable to give in this Appendix a brief summary of these reactions. But only the more conclusive and easily obtained reactions are given, and those only of bodies which admit of blowpipe detection.

BLOWPIPE REACTIONS.

[The bodies, to which these reactions refer, follow each other in alphabetical order. **S** = sodium carbonate. **B** = Borax. **PS** = "Phosphor-salt."]

Alumina.—When free from iron oxides or other strongly colouring matters, alumina, moistened with a drop or two of cobalt nitrate and strongly ignited on charcoal, assumes on cooling a bright blue colour.

Aluminous silicates, phosphates, sulphates, etc., show equally the reaction.

Antimony.—The presence of antimony is revealed, when the test-substance is ignited on charcoal, by the emission of dense white fumes, and deposition of a white coating on the support. The flame is tinged pale bluish-green. The fumes have no special odour. Oxidized antimonial compounds fused with **PS** form a practically clear glass which becomes dark gray or black and opaque on cooling, especially if pressed when hot on a small strip of tin. Bismuth compounds show the same reaction, but are at once distinguished by the marked reactions given under *Bismuth*, below.

Arsenic (Arsenides, Arseniates).—Arsenic in minerals is readily detected by simply igniting a small portion of the test-substance on charcoal. If arsenic be present a strong odour of garlic is evolved. In minerals of non-metallic aspect the addition of a small quantity of **S** assists the reaction. Ignited gently in an open glass tube, arsenical compounds deposit above the test-matter a crystalline sublimate consisting of microscopic octahedrons of As_2O_3.

Baryta.—Barium oxide in carbonates, sulphates, etc., (but not in silicates), colours the flame yellowish-green. It dissolves entirely in the flux when fused on platinum wire with **S**. With **B**, on cooling, it forms an opaque white glass.

Bismuth.—Bismuth and its compounds when fused (either alone or with **S**) on charcoal, deposit a yellow coating on the support. This, though deeper in colour, much resembles the coating formed by lead; but the reduced lead globule is soft and malleable, whilst bismuth is more or less brittle. Fused with **PS** the bismuth glass (like that of antimony) becomes dark and opaque on cooling, especially if treated with tin or tin chloride. The most marked of all bismuth-reactions, however, is the deposition of a vivid scarlet coating on charcoal when the test-matter is fused with a mixture (of about equal parts) of sulphur and potassium-iodide.

Boracic Acid.—Most borates (and some boro-silicates, *i.e.*, axinite, etc.), impart *per se* a green coloration to the point and border of the flame; and practically all produce this coloration if previously saturated with sulphuric acid, or moistened with glycerine. The same colour is communicated to the flame of alcohol when the substance is previously treated with sulphuric acid.

Bromine.—See under *Chlorine*, below.

Cadmium.—Occurs, in Nature, only in the rare sulphide Greenockite, and in certain examples of Zinc Blende and other zinc-holding minerals. Fused with **S** on charcoal or on a small fragment of porcelain, a dark red-brown or yellowish-brown coating is in most cases deposited on the support.

Carbon Dioxide (in Carbonates).—The presence of CO_2 (" carbonic acid "), in minerals, is best ascertained by warming the substance with a few drops of dilute hydrochloric acid, when a more or less vigorous effervescence is produced. In most cases, the acid may be used without being warmed. When, however, an acid is not at hand, a small fragment of the test-substance may be fused on platinum wire with a previously fused borax glass. Thus treated, carbonates dissolve in the glass with strong effervescence; but certain substances which evolve oxygen on ignition cause the same reaction. These however are rare as minerals, and are easily recognized by other tests.

Cerium.—Not readily detected in minerals by the blowpipe alone. Cerium oxide forms with **B** a reddish or yellowish glass before an O.F., and a colourless glass in the R.F. Both become opaque when flamed.

Chlorine (in Chlorides).—The presence of chlorine in minerals is revealed by the bright azure coloration of the flame when the test-matter is fused on a loop of of platinum wire into a previously fused glass of **PS** coloured by copper oxide. Bromides, thus treated, produce a blue flame streaked and edged with green; and Iodides colour the flame intensely green, without any blue admixture. Iodides, however, are best detected by warming the substance in a test-tube with a few drops of sulphuric acid, when the tube becomes filled with strongly smelling violet-coloured vapours which impart a deep-blue stain to matters containing starch. A strip of moistened tape may be held at the top of the tube.

Chromium.—The presence of chromium in minerals, when no other colouring bodies are present, can generally be ascertained by the fine emerald-green glass which results (on the glass becoming cold) after fusion in the R.F. with **B**. Chromates, treated with sulphuric acid and alcohol, form a rich green solution which remains green (though paler) on dilution.

Cobalt.—Fused with **B** or **PS** all cobaltic compounds (after roasting, in the case of sulphides or arsenides) form a deep-blue glass.

Copper.—Metallic copper, BB, fuses readily. In an oxidating flame the fused globule becomes covered with a black coating of oxide. Chloride ot copper colours the blowpipe-flame azure-blue; all other copper compounds impart a deep-green colour to the flame. Fused (after roasting) with **B** or **PS**, the resulting glass in the O.F. is green whilst hot, and light blue when cold. In the R.F. it becomes on cooling (especially if a small cutting of metallic tin or iron wire be added to the fused glass) brick-red and opaque.

Fluorine.—The presence of fluorine (in fluorides, proper) is best detected by warming the test-matter, in powder, with a few drops of sulphuric acid in a small test-tube, or in a platinum vessel covered with a plate of glass. Fumes which corrode the glass are evolved. The corrosion is best seen when the glass has been washed and dried. A moistened strip of Brazil-wood paper, placed at the mouth of the tube, is rendered yellow. The same reaction is produced, though less readily, if the substance be fused in a test-tube with potassium bisulphate. When present in fluo-silicates (as in Topaz), fluorine, however, is not readily recognized.

Gold.—Pure gold fuses before the blowpipe and retains a bright surface in an oxidating flame. If alloyed with much silver the globule is white on the surface; but by fusing it in a platinum spoon with some potassium bisulphate, the surface shows a gold-yellow colour, the silver (at the surface) being dissolved.

Iodine.—See under *Chlorine*, above.

Iron.—The presence of iron, if the metal be not in very small quantity, is generally revealed by the substance becoming magnetic after ignition or fusion. With **B** in the O.F. the glass is reddish or yellowish whilst hot, but becomes colourless, or is very lightly tinted, when cold. After subjection to a good R.F., the glass assumes on cooling a bottle-green colour. In silicates and other "oxygen-salts," FeO may be distinguished from Fe_2O_3 by the following process. Fuse some copper oxide with **B** so as to form a well-coloured bead. To this add the test-matter, and fuse for an instant only. If the iron be in the state of FeO the glass will present, on cooling, opaque red spots or streaks, due to the conversion of CuO into Cu_2O—the FeO acting as a reducing agent, and becoming itself converted into Fe_2O_3.

Lead.—The presence of this metal is easily detected by fusing the test-substance alone or with **S** on charcoal. A yellow coating of oxide is formed on the support, and malleable metallic globules result. Pure lead, in volatilizing, imparts a light-blue colour to the flame.

Lime.—Calcareous bodies (certain silicates, etc., excepted) impart a more or less distinct red colour to the flame. Carbonates, sulphates, phosphates, etc., containing lime, dissolve readily in **B**, the saturated glass becoming opaque-white on cooling or when "flamed." Lime is insoluble in **S**; it forms with that reagent an infusible mass. Its spectrum is especially characteristic.[1]

Lithia.—A crimson colour is imparted to the blowpipe-flame by this alkali. The flame-coloration is distinguished from that caused by strontium compounds by fusing the test-matter in a loop of platinum wire with some barium chloride. This intensifies the crimson colour produced by lithia, whilst it destroys the strontia coloration.

Magnesia.—This "alkaline-earth" does not colour the blowpipe flame. Its presence in bodies is generally revealed by igniting the test-substance on charcoal, after moistening it with a few drops of nitrate of cobalt. On cooling, a flesh-red colour comes out. But magnesia in calcareous bodies (as in dolomite and dolomitic limestones) is best detected by a simple liquid process. The substance is dissolved in a few drops of hydrochloric acid, and the diluted solution is then freed from lime by ammonia and ammonium oxalate, care being taken to see that the precipitation is complete. The magnesia is then thrown down by some phosphor-salt, and can be tested by ignition with cobalt nitrate, as described above.

Manganese.—The presence of manganese, in any of its forms, is readily detected by fusion in a loop of platinum wire with **S**. The resulting bead becomes on cooling of a turquoise blue or bluish-green colour and opaque. When manganese is present in traces only, the reaction is assisted by pressing the bead whilst hot

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[1] For the more readily developed flame-spectra in minerals, see the Author's "Outline of Blowpipe Analysis."

on a small crystal of nitre. In the case also of calcareous carbonates and other bodies insoluble or nearly so in **S**, a small portion of **B** should be added. With **B** alone, the glass before an O.F. assumes an amethystine colour, but becomes colourless after subjection to the R.F. Unless quickly cooled, however, the glass resumes (by oxidation) an amethystine tint.

Mercury.—This metal occurs in but few minerals—notably in Cinnabar, its only ore. Its presence is best detected by fusing the test-substance (in powder) with some perfectly dry **S**, or iron filings, at the bottom of a "closed tube." If mercury be present, a dark gray metallic sublimate will be formed on the upper part of the tube: and this, when rubbed with an iron wire or other hard body, will run into small drops which can be poured out of the tube, and are easily recognized as metallic mercury. A strip of gold leaf, held just within the tube, becomes whitened.

Molybdenum (Molybdates).—Molybdenum sulphide imparts a livid-green colour to the Bunsen or blowpipe flame. Molybdic acid and molybdates form with **PS** in a reducing flame a fine green glass. Warmed with a few drops of sulphuric acid, and some alcohol added, they yield a rich blue solution.

Nickel.—Substances containing this metal form with **B** (after previous roasting for elimination of sulphur and arsenic, if necessary) a violet-brown glass in the O.F., which becomes gray and opaque (from reduced metal) in the R.F. If well saturated, it also becomes magnetic. With **S** on charcoal in a good R.F., strongly shining magnetic particles of reduced nickel are obtained by washing the fused mass in the agate mortar used in blowpipe operations.

Nitrates.—As minerals, these bodies are soluble or partly soluble in water. All deflagrate when ignited on charcoal. Fused with potassium bisulphate in a test tube (or warmed with a few drops of sulphuric acid), they evolve ruddy fumes of nitrous acid.

Phosphates.—Moistened with a drop of sulphuric acid, phosphates impart a green coloration to the point and edges of the blowpipe flame: but the same reaction is produced by certain other bodies, and is, therefore, more or less inconclusive. The safest method is to warm the test matter (in powder) with a few drops of nitric acid, and (after slightly diluting the solution) to place in it a small fragment or two of ammonium molybdate, and again warm. In the case of phosphates, a canary-yellow precipitate is formed. The reagent, used in the solid state, is easily carried in the blowpipe case.

Platinum.—BB, platinum is practically infusible and inoxidizable; and it is not attacked by the ordinary blowpipe fluxes.

Potash.—Alone, and in many of its compounds, potash imparts a pale-violet colour to the flame-point and edge. In the case of silicates, however, and in the presence of soda and some other bodies, the coloration is hidden. Potassic carbonates, sulphates, nitrates, etc., dissolve entirely, BB, in **S**. The presence of potash in most bodies is readily revealed by a small (direct vision) pocket spectroscope, and a Bunsen burner. A thin red line, close to the red end of the spectrum, is its chief characteristic. All other red lines (as those produced by lithium, calcium, etc.), may be cut off by the intervention of a piece of deep blue glass.

Selenium (Selenides).—See under *Sulphur.*

Silica (Silicates).—Silica alone is quite infusible, although it dissolves, BB, with effervescence in **S**, forming a clear glass with that reagent used in proper proportions. Silicates are readily detected by fusion with **PS**. Whilst the bases dissolve, the silica remains in the form of a translucent mass (technically known as a "silica skeleton"). A small portion commonly dissolves, however; but this precipitates as the glass cools, rendering it milky or semi-opaque. Carbonates, sulphates, phosphates, etc., dissolve readily, BB, in this reagent, and are thus easily distinguished from Silicates.

Silver.—This metal, BB, is readily fusible, the fused globule retaining a bright surface in an oxidating flame. In alloys, silver is best detected by fusing the test substance with metallic lead (or with litharge and **S** in a charcoal cavity), and then cupelling the resulting globule on a bone-ash support. *See* the Author's "Outline of Blowpipe Analysis."

Soda.—Compounds in which soda is present communicate a marked yellow colour to the blowpipe flame. Its presence is also readily revealed by its yellow spectroscopic line (or lines). *See* the Author's "Outline of Blowpipe Analysis."

Strontia.—Compounds containing strontium in any form impart a rich carmine colour to the blowpipe flame. This reaction is distinguished from the flame-coloration due to lithia by becoming practically obliterated if the test matter be fused on platinum wire with some barium chloride: whilst in the case of lithium compounds the crimson coloration becomes intensified by that treatment. Strontia alone, or in carbonates, sulphates, etc., dissolves wholly, BB, in **S.** With **B,** it forms (by flaming or on cooling) an opaque white glass. In its flame spectrum, a broad orange line, a group of red lines, and a single blue line, are especially characteristic.

Sulphides and *Sulphates.*—These are readily distinguished by fusion on charcoal with **S** in a reducing flame. In the case of bodies not readily soluble, BB, in **S,** a very small quantity of **B** should be added to that reagent. The fused mass, removed by the knife-point, when placed upon a moistened silver surface as that of a coin, stains this dark brown or black. Selenides and Tellurides (all of exceedingly rare occurrence) produce the same reaction. But Selenides, during fusion, emit a strong odour of decomposing vegetable matter; and Tellurides colour the flame green when fused alone. See also under *Tellurium,* below.

Tellurium.—This metal and the few known Tellurides fuse easily; and, volatilizing (in part or wholly) tinge the flame distinctly green. With **S** on charcoal (as in the case of Sulphur and Selenium compounds) they form a so-called "hepar," which, when moistened, produces a dark stain on a silver coin or piece of lead test-paper. The safest plan for the detection of tellurium is to dissolve the test-substance in a small amount of strong sulphuric acid, warming if necessary. On diluting the purple-red solution with water, this becomes dark, and more or less opaque, and black flecks are gradually deposited.

Thallium.—So far as regards blowpipe operations, the detection of this metal is very limited. Its chief characteristic is the property of imparting a vivid green coloration to the blowpipe flame or that of a Bunsen burner. Fused on a fragment of thin porcelain (as a piece of a broken crucible, etc.), or on a boneash cupel, it forms a dark brown coating on the support. Its flame-spectrum consists essentially of a single brilliant green line.

Tin.—This metal, in Nature, occurs chiefly as a binoxide. In this form it is easily reduced on charcoal, if fused with a mixture of **S** and **B**, or with potassium oxalate, or other reducing flux. When a small piece of metallic tin is melted with a similar piece of lead (bismuth or thallium) a remarkable oxidation ensues. The fused mass becomes rapidly encrusted; and it continues, on removal from the flame, to push out excrescences of white and yellow oxide.

Titanium.—Titanic anhydride (TiO_2) and titaniates, form with **B** in the O.F. a yellowish glass, which, if tolerably saturated, becomes opaque white on cooling or by flaming. In the R.F. the glass assumes a brownish amethystine or blackish-blue colour. When flamed, a light gray-blue film spreads over the surface of the bead. With **PS**, in the R.F., the glass assumes a fine amethystine colour on cooling, unless iron is present, in which case it becomes red-brown or blood-red. For the detection of titanium in titaniferous iron ores see the Author's "Outline of Blowpipe Analysis."

Tungstates.—Tungstic anhydride forms with **PS** in the R.F. a greenish-blue glass, unless iron be largely present, in which case the glass becomes deep red. With **B** in the R.F. the glass is yellowish-brown, and on cooling or by flaming it becomes opaque. The presence of tungstenum may also be detected by fusing the powdered test-substance with 3 or 4 parts of **S** and a little nitre in a platinum spoon or loop of stout platinum wire, dissolving the alkaline tungstate, thus formed, in a little water, adding a few drops of hydrochloric acid, and placing in the solution a piece of zinc. A dark blue coloration will rapidly result—WO_3 being reduced to W_2O_3.

Uranium.—The borax glass in the O.F. is yellow. In the R.F. it is dingy brownish-green; and, if saturated, it becomes black when flamed. The **PS** glass in the R.F. is bright chrome-green. This difference readily distinguishes uranium from chromium compounds, unless other colouring matters be largely present.

Vanadium.—Vanadates form with **PS** in the O.F. a yellow glass which remains yellow when cold, unless other colouring matters are present. With a few drops of hydrochloric acid and alcohol, vanadates form a green solution which becomes light blue on dilution (von Kobell).

Zinc.—The presence of zinc in minerals is best detected by fusing the powdered test-substance on charcoal with a mixture of **S** and **B** (the **S** in excess). A characteristic ring-deposit is formed. This is lemon-yellow and somewhat phosphorescent whilst hot, but becomes white on cooling. Moistened with a drop of cobalt nitrate, and again carefully ignited, it assumes on cooling a light green colour.

INDEX TO MINERALS CITED AS EXAMPLES OF THE CLASSIFICATION-GROUPS IN APPENDIX A.

N.B.—The figures after the names refer to the Groups. See top of pages in Appendix A. The figures in brackets refer to sub-groups or sections. Thus, 45 (2) *indicates Sub-group* 2 *of Group* 45.

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