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IV.—*On Mineral Classification.*

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THE difficulty of devising a natural classification of minerals has been recognized by most mineralogical writers, and up to the present time no very satisfactory arrangement has been generally adopted. In the classification of the animal and vegetable kingdoms, although the systems have greatly varied from time to time, something like uniformity has pretty generally existed ever since Linnaeus proposed his famous system of double nomenclature; but in mineralogy every writer does that which is right in his own eyes—not because there is no king—but because they are many and mutually antagonistic.

The magnificent national collection is arranged on the excellent chemico-crystallographic system of Gustav Rose—his second system,—the primary groupings being based upon the acidic constituents after the separation of the native elements to form the first division.

The collection at the Royal School of Mines, in Jermyn Street, is also arranged on a chemical system; but here, for an important part of the collection, the *basic* ingredient determines the place in the system, and the old unphilosophical distinction between metallic and non-metallic minerals is thereby strengthened and intensified.

Mohs, Weiss, and other German mineralogists have regarded chemical composition as only one among many important properties, considering form, structure, physical condition, &c., to be also of great and sometimes

of paramount importance. Dana has supplemented and modified his chemical classification by giving considerable although very unequal importance to crystalline form, but he does not seem to regard other properties as of much importance. Very curious results are often arrived at when attempts are made to classify minerals on rigid theoretical principles. Thus, Dana, in his *System of Mineralogy*, places water in the division of anhydrous oxides, and sulphuric acid—which never occurs in nature except as a very dilute solution—with the anhydrous sulphates. Similar incongruities are to be seen in almost every mineralogical work or mineralogical collection.

The first difficulty in mineral classification is to define what is a *mineral*. A very simple and general definition is that minerals are “natural homogeneous inorganic bodies;” but this definition must be taken with certain limitations and explanations which naturally occur to all mineralogists. Thus, if we take the term inorganic, if strictly applied, it *excludes* such bodies as peat, coal, amber, and the natural hydro-carbons generally; and it might probably be made, at any rate very frequently, to exclude such undoubted minerals as apatite and pyrites. On the other hand it includes such bodies as water, air, hydrogen and other gases, and many naturally occurring substances which are not at all like what is usually understood by the term mineral; some, I believe, have never been regarded as minerals, and others—as carbonic acid—would be sometimes minerals and sometimes not, according to their immediate source or mode of origin.

Again, homogeneity is a character which cannot be strictly applied. Apparently, *homogeneous* rocks, like basalt and serpentine, were formerly regarded as minerals; but here the microscope has rendered good service in many cases, and shewn us that such rocks are often distinct aggregates of two or more minerals.

The new mode of research has, however, while removing old difficulties, introduced new ones, for it has shewn us that many minerals hitherto supposed to be pure, are really aggregates of two or more, differing only in degree from the rocks just mentioned. Moreover, the information obtainable by the microscope is very uncertain and partial, as it is confined to the minerals which are more or less transparent, leaving untouched the whole series of opaque minerals.

If it is difficult to apply accurately the terms *homogeneous* and *inorganic*, there is no less difficulty in the application of the word *natural*. How is it possible to separate in any scientific sense the stalactites formed in a natural cave from those formed in an artificial excavation or under a railway arch? the crystals of specular iron formed on the lavas of Vesuvius from those developed on certain slags? or the crystals of alum formed in old mine-workings from those produced by Mr. Spence, in his large crystallizing cylinders?

Passing over the first difficulty, of determining what is a mineral—a difficulty like many others, more theoretical than real—a species has been defined as including “all minerals which possess the same chemical composition and external form;” but here, too, if this be accepted, it becomes necessary to add certain limitations, not to speak of so-called irregularities of forms. Many well characterized species, as *Limonite* and *Psilomelane*, have *no* form in any crystallographic sense. The chemical composition of species must also be taken with much latitude. “Pure substances, such as are described in works on chemistry, are very rare in the mineral kingdoms” (or anywhere else). “Even the most brilliant diamond consumed by the solar rays leaves some ash behind.” Such non-essential mixtures must be neglected, or each specimen would form a distinct mineral species. Again, the principle of isomorphism introduces a wide range of varieties, and renders the limitation of species still more difficult. Where these mixtures or replacements are small in amount, variable in different specimens, or do not greatly affect the form or other physical characters of the mineral, they may safely be disregarded. Where, however, the mixture or replacement is greater, or occurs in definite chemical proportions, the compounds should be considered as distinct species, especially if the difference should be accompanied by differences in form and other external characters.*

Having in spite of such difficulties decided upon our mineral species, it will next be necessary to settle how they shall be grouped. The primary division of all minerals into metallic and non-metallic—unphilosophical and inexact as it is, and must be, if applied in any ordinary sense—will probably still last for some time, at any rate, in popular collections, and in many private collections. But for all scientific purposes it has long been useless, and must, I think, be given up. The elaborate grouping into varieties, species, genera, families, orders and classes, adopted for animal and vegetable organisms, may probably be somewhat simplified here, since the whole number of minerals is never likely to approach the present number even of the order of animals. At the present time the number, including many doubtful species, is considerably less than 1,000. For the same and other reasons, a double nomenclature seems undesirable. Probably *classes*, *groups*, *species*, and *varieties*, will be enough of sub-division for a long time, and our endeavour should be to render the sub-divisions as equal and natural as possible. The question now arises, what weight should be given to each mineral property in determining the limits of these terms.

Such characters as cleavage, colour, and lustre, vary even in minerals which all mineralogists would accept as good species, but they often afford

* Nicol's Manual of Mineralogy, 1849, p. 100.

good ground for the establishment of *varieties*. Thus, *chlorophane* is an uncleavable variety of Fluor, *amethyst* a purple variety of quartz, and *rosin* or *resin tin* a variety of Cassiterite, possessing distinctly resinous lustre.

Hardness and specific gravity are usually characters of more importance; indeed, I believe it will be found that marked variations are generally accompanied by other physical and often chemical differences. Thus, *red ochre* differs in many respects from red hematite, besides the mere difference of hardness. In general, however, good species are separated by better characters than these. Optical properties, depending as they often do upon internal structure, afford great aid in determining the limits of species; but, unfortunately, they are inapplicable to the great number of opaque minerals. When, however, they can be applied, they are usually closely or even exactly related to external form, so that no antagonism is likely to arise from the practical application of optical results in classification.

Practically then, we find ourselves limited to *chemical composition and form* in determining what should be a mineral species; but having fixed our species, these less important physical characters may afford useful aid at times in grouping.

Having analysed our mineral, and made up our minds as to what is to be regarded as essential and what as accidental, we have next to determine which ingredient shall have the preference in our major classification. Doubtless, in a majority of cases the *acidic* elements have more influence in determining the physical character of minerals than the *basic*, as pointed out by Berzelius long since. Thus, taking all *sulphides*, we see that they resemble each other in more characters than do all minerals in which *iron* is the chief base. Accordingly, we find in most arrangements of minerals a disposition to give great weight to the general character of the combination in the primary division into classes.

In the Museum of Practical Geology, however, and in many other places where the needs of practical men have to be studied—for minerals containing the ordinary metals this has been abandoned for a mixed arrangement, which brings together all the minerals containing a given metal in workable proportions, and there is much to be said for such an arrangement.

My own opinion is, that having established our *species* as definitely as possible, and having broadly arranged these species in a small number of primary *classes* according to the general character of their chemical constitution, it will be better in establishing the minor subdivisions or groups to give considerable weight to external characters. We shall thus sufficiently recognize these characters, and shall at the same time give a

convenient practical aspect to our science without offending any reasonable scientific susceptibility.

Form. This is a character of partial application only, owing to the great number of amorphous minerals and the comparative rarity of crystals. Moreover, the existence of dimorphous and trimorphous substances warns us not to give too much prominence to this character. A classification which, for instance, places a large interval between Aragonite and Calcite, Pyrites and Marcasite, is evidently forced and unnatural. Still, the numerous connexions observable between crystalline form and chemical composition, some of which were pointed out by our President in his anniversary address, at Plymouth, should prevent us from giving *too little* weight to the forms of crystallized minerals. In the determination of *species*, it is a character of great value wherever it can be applied; and, if we disregard somewhat the differences between the rhombic, oblique, and anorthic systems—those in which the axes are all unequal,—we have in the *Cubic*, *Tetragonal*, *Hexagonal*, and *Anisometric* systems, useful group characters.

One of the chief difficulties in grouping minerals on purely chemical principles, especially if we take the basic constituents as our guide, is met with in placing *double salts*. In collections where a purely chemical system, either *acidic* or *basic* is adopted, it is best to place, if possible, one or more specimens under each group concerned. Thus, *Jamesonite* would be placed both with the ores of lead and those of antimony, and *Leadhillite* would appear with the carbonates and also with the sulphates. But if the whole series of characters is to some extent observed and weighed before determining the place of the mineral, such double placing is not likely to be often necessary.

The primary divisions or *classes* adopted by Dana in his "System" are as follows:—

- 1.—Native Elements (including combinations of *like* elements).
- 2.—Sulphides, antimonides, arsenides, &c.
- 3.—Chlorides, bromides, &c.
- 4.—Fluorides.
- 5.—Oxides and oxygen salts.
- 6.—Hydro-carbon compounds.

With all deference to so eminent an authority, and fully recognising the advantages of this excellent primary classification, I would still suggest several modifications, which appear to me to be improvements.

1st.—The separation into distinct classes of Chlorides, Bromides, and Iodides, on the one hand, from Fluorides, on the other, seems unphilosophical and unnecessary; unphilosophic in view of the close

chemical relationships existing between their negative elements, and unnecessary because of the comparative smallness in the number of such minerals.

2nd.—On the other hand, the union of oxides and all oxygen salts into one class seems forced and unnatural on account of their great chemical differences, and unadvisable in view of the great numbers of such bodies. It would certainly seem more natural, as well as more convenient, to separate the *oxides* from the *salts*. Bearing in mind the great number of the silicates and the many similarities existing among them, and also the peculiar and almost unique character of silica as regards its properties, I think we should separate these also from the great body of oxygen salts.

Having separated the silicates and oxides, we have still left the great body of oxygen salts. Here the carbonates, sulphates, nitrates, &c., seem to fall very naturally into one category; the phosphates and arseniates into another; and the chromates, tungstates, and molybdates into a third.

3rd.—We should aim as far as possible to make the primary classes as equal as possible, in number as well as in other respects.

4th.—It would evidently be a great convenience to devise characteristic names for the several classes for ordinary use instead of long descriptions, and I venture to suggest the following :—

Class I.—ELEMENTS—corresponding with Class I (Dana,) and with division I (British Museum).

Class II.—PYRITIDS, corresponding with Class II (Dana), and with division II (British Museum).

Class III.—HALOIDS, or unoxygenated Salts, including Classes III and IV (Dana), and division III (British Museum).

Class IV.—OXIDES.

Class V.—SPATHOIDS, including the ordinary Spars, as calcite, chalybite, barytes, &c., and generally all Carbonates, Sulphates, Nitrates, &c.

Class VI.—PLETHOIDS, including Phosphates, Arseniates, &c.*

Class VII.—BRITHOIDS—including Tungstates, Molybdates, Columbates, &c.†

Class VIII.—SILICATES.

Classes IV to VIII correspond with the IVth division in the British Museum, and with Dana's 5th Class.

Class IX.—HYDROCARBONS—corresponding with the British Museum Appendix and with Dana's class VI.

* *πληθος* a great concourse, a crowd—in allusion to the complexity of their molecules.

† *βρίθως*, heavy—in allusion to their high specific gravity.

By adopting their primary classes, any mineral may be readily placed in its own proper class after one or more very simple mechanical or *qualitative* chemical experiments, and often indeed on inspection.

The relations of the proposed primary classification to those of the British Museum and of Dana may be thus shewn in a tabular form.

BRITISH MUSEUM.	PROPOSED.	DANA.			
Div. I.	1. Elements....	Class I.			
Div. II.	2. Pyritoids....	Class II.			
Div. III.	3. Haloids.	Class III & IV.			
Div. IV....	<table border="0" style="display: inline-table; vertical-align: middle;"> <tr> <td style="font-size: 3em; vertical-align: middle;">}</td> <td style="padding: 0 5px;"> 4. Oxides. 5. Spathoids. 6. Plethoids. 7. Brithoids. </td> <td style="vertical-align: middle;">}</td> </tr> </table>	}	4. Oxides. 5. Spathoids. 6. Plethoids. 7. Brithoids.	}	Class V.
}	4. Oxides. 5. Spathoids. 6. Plethoids. 7. Brithoids.	}			
Appendix	8. Silicates. 9. Hydrocarbons.	Class VI.			

Having established these nine *classes*—each composed of a large number of *species*—we have next to consider how they may be best grouped for convenience of study. Here perhaps the plan adopted need not be the same for each class, it may even be advantageous to adopt a different method of grouping in each. They should be dealt with as a librarian deals with his books rather than as a zoologist deals with an assemblage of animals.

In a former paper* I ventured to suggest a mode of grouping a number of amorphous mineral substances based upon their variations in chemical composition, which I am glad to say has been well received by several mineralogists of repute. In the present, I propose to review very briefly Dana's subdivisions of Class 1 (native elements), and to suggest a mode of conveniently grouping the various species which naturally fell under Class II. Dana's class 1 is divided into six groups which he arranges into two series, as follows:—

SERIES I.	SERIES II.
1. <i>Gold Group.</i>	1. <i>Arsenic Group.</i>
Gold.	Arsenic.
Silver.	Antimony.
2. <i>Iron Group.</i>	Allemontite.
Platinum.	Bismuth.
Platiniridium.	2. <i>Sulphur Group.</i>
Palladium.	Tellurium.
Allopalladium.	Sulphur.
Iridosmine.	Selen-Sulphur.

* "On gramenite and the chloropal group of minerals."

Quicksilver.
 Amalgam.
 Arquerite.
 Goldamalgan.
 Copper.
 Iron.
 Zinc.
 Lead.

3. *Tin Group.*
 Tin.

3. *Carbon & Silicon group.*
 Diamond.
 Graphite.

The most obvious objection to this grouping is that platinum, mercury, gold-amalgam, arquerite, and palladium are made to appear more nearly allied to copper, iron, zinc and lead, than they are to gold and silver. These peculiar arrangements are made to satisfy a theory of oxidation, which really seems to have little or no bearing upon mineralogy or even upon practical chemistry. I believe most mineralogists will regard the following grouping as preferable.

<i>Gold Group.</i>	<i>Copper Group.</i>
Gold.	Copper.
Silver.	Lead.
Platinum.	Tin.
Palladium.	<i>Arsenic Group.</i>
Allopladium.	Arsenic.
Platiniridium.	Antimony.
<i>Mercury Group.</i>	Allemontite.
Mercury.	Bismuth.
Amalgam.	<i>Sulphur Group.</i>
Gold-amalgam.	Sulphur.
Arquerite.	Selen-sulphur.
<i>Iron Group.</i>	Tellurium.
Iron.	<i>Carbon Group.</i>
Zinc.	Diamond.
	Graphite.

CLASS II.—PYRITIDS.

With regard to this class I would first remark, that as the minerals included in it have been already brought together *as a class* by their more electro-negative constituents, it may be desirable now to use basic characters in establishing the secondary groups. One advantage of this course—not less philosophical *per se* than the other—is that it enables us to effect a grouping which is convenient for practical purposes, without being unscientific, one which answers to the requirements of the miner and the metallurgist without offending the susceptibilities of the

scientific mineralogist. The method is to select for each characteristic basic element one or more representative minerals, and to group the others around or under them, using only *qualitative* characters for this purpose. This plan is essentially elastic, as the groups may be readily again divided without material re-arrangement of their members, as and when the discovery of new minerals renders this course desirable.

Among such representative minerals in this class, most mineralogists would probably recognise the following.

Sylvanite.	Tetrahedrite.	Bismuthinite.
Cinnabar.	Chalcopyrite.	Antimonite.
Argentite.	Chalcocite.	Blende.
Stephanite.	Galena.	Realgar.
Pyrrargyrite.	Zinkenite.	Molybdenite.

Beginning with pyritoids containing gold as an essential ingredient we may take *Sylvanite* as the head of the group. The group is by no means a good natural one, but the few pyritoids containing gold are so commercially valuable that it will probably be advantageous for the present at least to bring them together.

Sylvanite Group.—All opaque, metallic lustre, H below 3, G from 6·5 to 9·5 All give a bead of more or less pure gold B.B. with or without fluxes.

Sylvanite	(Ag Au) Te ₃
Nagyagite	(Pb Au) ₂ (Te Sb S) ₃
Petzite	($\frac{1}{4}$ Au $\frac{3}{4}$ Ag) ₂ Te
Schirmerite	(Au Fe) Te ; \ ; Te

Tetradymite might perhaps be placed here by the group characters, if highly auriferous, *i.e.* it would yield a minute grain of gold B.B. Its general characters, however, are very different.

The next group may very well be based upon the presence of mercury, taking Cinnabar as the representative of the group.

Cinnabar Group.—Yield mercury if heated with oxide of lead in matrass, H. below 3, G from 7 to 9. Almost entirely volatile on C.

Cinnabar	Hg S.
Metacinnabarite	Hg S.
Tiemannite	Hg Se.
Lehrbachite α	($\frac{1}{2}$ Hg $\frac{1}{2}$ Pb) Se, Dana, anal. 3.
" β	($\frac{1}{3}$ Hg $\frac{2}{3}$ Pb) Se, " " 1.
" γ	($\frac{1}{8}$ Hg $\frac{7}{8}$ Pb) Se, " " 2.
Onofrite	4 Hg S + Hg Se.
Guadalcazarite	6 Hg S + Zn S.
Livingstonite.. .. .	Hg S + 3 Sb ₂ S ₃ .

Some varieties of Tetrahedrite contain mercury, but their general characters are very different to the minerals above-mentioned, as there is always a large non-volatile residue.

The number of pyritoids containing considerable proportions of silver is very numerous, and the variation in physical characters is very great. I am inclined to think that at least three groups should be adopted as follows:—

Argentite Group.—All opaque; metallic, or sub-metallic lustre; black streak; H. below 4, G. 6 to 10, readily fusible; easily give bead of silver B.B. on C.

The following will be included:—

Argentite	Ag ₂ S.
Daleminzite	Ag ₂ S.
Acanthite	Ag ₂ S.
Hessite	Ag ₂ Te.
Dyscrasite <i>α</i>	Ag ₂ Sb.
,, <i>β</i>	Ag ₃ Sb.
,, <i>γ</i>	Ag ₄ Sb.
Naumannite	Ag Se.
Sternbergite	($\frac{1}{3}$ Ag $\frac{2}{3}$ Fe) S.
Stromeyerite	(Ag Cu) S.
Eucairite	(Ag Cu) Se.
Crookesite	(Cu Tl Ag) Se.

By this grouping Argentite, Daleminzite, and Acanthite are brought together notwithstanding their difference of form, not only because they are chemically the same, but because we thus bring together a greater number of resemblances than could be effected by any re-arrangement. Some might regard it as advantageous to subdivide still farther, making Argentite and Naumannite to form one (cubical) group, while the others were grouped around Stromeyerite (rhombic); but this could only be done by violently separating such intimate relations as Argentite, Daleminzite, and Acanthite. It would be easy to show that the *totality* of similarities and resemblances would be in this way much reduced.

Another very convenient natural assemblage, having much the same general characters as the Argentite group, except that all contain antimony or bismuth, which shew themselves as incrustations when the minerals are heated in charcoal B.B., may be gathered around the mineral Stephanite.

Stephanite Group.—All opaque, metallic or sub-metallic lustre, black streak, H below 4, G 6 to 10 fusible, give bead of silver BB on C with or without fluxes.

Stephanite	5 Ag ₂ S + Sb ₂ S ₃ .
Polybasite	9 Ag ₂ S + Sb ₂ S ₃ .
Polyargyrite	12 Ag ₂ S + Sb ₂ S ₃ .
Brongniardite Ag ₂ S + Sb ₂ S ₃ + Pb S.
Diaphorite	2 Ag ₂ S + Sb ₂ S ₃ + Pb S.
Freieslebenite	3 Ag ₂ S + 3 Sb ₂ S ₃ + 4 Pb S.

Taking Pyrrargyrite as the characteristic member of the next group, we having the following very convenient group characters:—

Pyrrargyrite Group.—Transparent to sub-translucent; streak red, yellow, or brown; other characters like Stephanite group.

Miargyrite	Ag ₂ S + Sb ₂ S ₃ .
Pyrrargyrite	3 Ag ₂ S + Sb ₂ S ₃ .
Proustite	3 Ag ₂ S + As ₂ S ₃ .
Xanthoconite	3 Ag ₂ S + As ₂ S ₃ .

Possibly Bolivianite, Rittingerite, and Pyrostilpinitite, may also find a place here.

The above three groups of silver Pyritoids may be conveniently brought together under the name of the *Argentoid Section* as under,—

Naumannite	Ag Se.
Crookesite	(Cu Tl Ag) Se.
Eucairite	(Ag Cu) Se.
Stromeyerite	(Ag Cu) S.
Sternbergite	($\frac{1}{3}$ Ag $\frac{2}{3}$ Cu) S.
Argentite	Ag ₂ S.
Daleminzite	Ag ₂ S.
Acanthite	Ag ₂ S.
Hessite	Ag ₂ Se.
Dyscrasite	Ag ₂ Sb.
„ β	Ag ₂ Sb + Ag.
„ γ	Ag ₂ Sb + 2 Ag.
Miargyrite	Ag ₂ S + Sb ₂ S ₃ .
Pyrrargyrite	Ag ₂ S + Sb ₂ S ₃ + 2 Ag ₂ S.
Stephanite	Ag ₂ S + Sb ₂ S ₃ + 4 Ag ₂ S.
Polybasite	Ag ₂ S + Sb ₂ S ₃ + 8 Ag ₂ S.
Polyargyrite	Ag ₂ S + Sb ₂ S ₃ + 11 Ag ₂ S.
Diaphorite	Ag ₂ S + Sb ₂ S ₃ + Ag ₂ S + Pb S.
Brongniardite	Ag ₂ S + Sb ₂ S ₃ + Pb S.
Freieslebenite	(3 Ag ₂ S + Sb ₂ S ₃) + 4 Pb S.
Proustite	Ag ₂ S + As ₂ S ₃ + 2 Ag ₂ S.
Xanthoconite	Ag ₂ S + As ₂ S ₃ + 2 Ag ₂ S.

Passing now to the cupreous pyritoids, we have three well-marked groups which may be referred to Chalcocite, Chalcopyrite, and Tetrahedrite respectively.

Chalcocite Group—Opaque, metallic lustre, steel-gray colour, readily fusible, partly volatile BB, but yield a bead of copper on C; H, not more than 3; G 4 to 7.

Chalcocite	$\text{Cu}_2 \text{S}$ (like Argentite, with Cu instead of Ag.)
Berzelianite	$\text{Cu}_2 \text{Se}$ (like Hessite do.)
Crookesite .. (Cu Tl Ag) Se	(like Eucairite do.)
Covellite	Cu S (like Sternbergite do.)

This group is therefore as a whole comparable to the Argentite group, the next, or Tetrahedrite group, has more resemblance to the Stephanite group.

Tetrahedrite Group—Opaque or nearly so, dark-gray, brown, or black, metallic or sub-metallic lustre; readily fusible BB, and yield a bead of copper, with or without soda; all contain arsenic or antimony. H=2·5—5. G=4—6.

Tetrahedrite	$4 \text{Cu S} \div \text{Sb}_2 \text{S}_3$.
Tennantite	$4 \text{Cu}_2 \text{S} + \text{As}_2 \text{S}_3$.
Styloctenite	$3 (\text{Cu Ag Fe})_2 \text{S}_1 + \text{Sb}_2 \text{S}_3$.
Bournonite	$3 \text{Cu}_2 \text{S} + \text{Sb}_2 \text{S}_3 + 2 (3\text{Pb S} + \text{Sb}_2 \text{S}_3$.
Wolfsbergite	$\text{Cu}_2 \text{S} + \text{Sb}_2 \text{S}_3$.
Enargite	$3 \text{Cu}_2 \text{S} + \text{As}_2 \text{S}_3$.
Julianite	$2 \text{Cu}_2 \text{S} + \text{As S}_3$.

The following are more or less abnormal, or imperfectly known:—Binnite, Algodonite, Whitneyite, Epigenite, Domeykite, Luzonite, Famatinite.

Chalcopyrite Group.—All contain copper, iron, and sulphur; opaque; met. or sub-met. lustre, fusible to strongly magnetic bead. H. below 4, G. from 4 to 5.

Chalcopyrite	$(\text{Cu Fe}) \text{S}_2 = \text{Cu}_2 \text{S} + \text{Fe S}_3$.
Erubescite	$3 \text{Cu}_2 \text{S} + \text{Fe}_2 \text{S}_3$.
Barnhardtite	$2 \text{Cu}_2 \text{S} + \text{Fe}_2 \text{S}_3$.
Cubanite	$\text{Cu}_2 \text{S} + \text{Fe}_2 \text{S}_3 + \text{Fe S}_3$.

Stannite, Castillite, and Chalcopyrrhotite, are probably mixtures or altered substances. They may be conveniently placed here, at least, for the present.

Pyrites Group.—Opaque, metallic lustre, all readily fusible to a magnetic bead, form a yellow solution in nitric acid or aqua regia H=3·5—6·5. G=4—7·5. The following are included :—

Troilite	Fe S	
Pentlandite	$(\frac{2}{3} \text{Fe}_3^1 \text{Ni}) \text{S}$	
Pyrrhotite β	$\text{Fe}_3 \text{S}_4$	(Dana, anal. 8)
Leucopyrite	$\text{Fe}_3 \text{As}_4$	
Pyrrhotite α	$\text{Fe}_7 \text{S}_8$	
Pyrites	Fe S_2	
Marcasite	Fe S_2	
Horbachite	$(\frac{8}{10} \text{Fe} \frac{2}{10} \text{Ni}) \text{S}_2$	
Mispickel	Fe (S, As)_2	
Cobaltite γ	$(\frac{7}{10} \text{Fe} \frac{3}{10} \text{Co}) (\text{S, As})_2$	(Dana, anal. 7, 8, 2)
Lollingite	Fe As_2	
Smaltite ϵ	$(\frac{6}{10} \text{Fe} \frac{4}{10} \text{Ni}) \text{As}_2$	(Dana, anal. 11)
Smaltite ζ	$(\frac{6}{10} \text{Fe} \frac{3}{10} \text{Ni} \frac{1}{10} \text{Co}) \text{As}_2$	„ „ 12
Smaltite δ	$(\frac{1}{3} \text{Co} \frac{2}{3} \text{Fe}) \text{As}_2$	„ „ 3
<i>Glaucopyrite</i>	$(\text{Fe Co}), (\text{As S Sb})_2$	
Pacite	$\text{Fe}_2 (\frac{4}{5} \text{As} \frac{1}{5} \text{S})_5$	

Our next group is characterised by the presence of considerable proportions of cobalt.

Smaltite Group.—Opaque, metallic lustre, readily fusible to a dark metallic bead; pink solution in nitric acid and aqua regia. H. from 3·5 to 6·5, G. 4 to 7·5.

Linnæite α	$\text{Co}_3 \text{S}_4$	Dana, anal. 2
Linnæite β	$(\frac{8}{10} \text{Co} \frac{2}{10} \text{Cu})_3 \text{S}_4$	„ „ 1
Linnæite γ	$(\frac{2}{10} \text{Co} \frac{6}{10} \text{Ni})_3 \text{S}_4$	„ „ 3
Linnæite δ	$(\frac{3}{4} \text{Co} \frac{1}{4} \text{Ni})_3 \text{S}_4$	„ „ 5
Linnæite ϵ	$(\frac{5}{10} \text{Co} \frac{5}{10} \text{Ni})_3 \text{S}_4$	„ „ 6, 7
Linnæite ζ	$(\frac{8}{10} \text{Ni} \frac{2}{10} \text{Co})_4 \text{S}_4$	„ „ 4
Cobaltite α	Co (S As)_2	„ „ 1, 5, 6
Cobaltite β	$(\frac{5}{6} \text{Co} \frac{1}{6} \text{Fe}) (\text{S As})_2$	„ „ 2
Alloclasite α	$(\frac{8}{9} \text{Co} \frac{1}{9} \text{Fe}) (\text{S As})_2$	„ „ 3
Glaucodote	$(\frac{6}{9} \text{Co} \frac{3}{9} \text{Fe}) (\text{S As})_2$	
Alloclasite β	$\text{Co} (\frac{2}{3} \text{As} \frac{1}{3} \text{Bi})_2$	
Glaucopyrite	$(\text{Fe Co}) (\text{As S Sb})_2$	
Smaltite α	Co As_2	
Smaltite β	$(\text{Co Fe}) \text{As}_2$	Dana, anal. 2
Smaltite γ	$(\frac{2}{3} \text{Co} \frac{1}{3} \text{Fe}) \text{As}_2$	„ „ 4
Smaltite δ	$(\frac{1}{3} \text{Co} \frac{2}{3} \text{Fe}) \text{As}_2$	„ „ 3
Alloclasite γ	$\text{Co} (\frac{2}{6} \text{S}, \frac{3}{6} \text{As} \frac{1}{6} \text{Bi})_3$	
Skutterudite	Co As_3	

Our next group in like manner, is chiefly characterised by the presence of nickel.

Chloanthite Group.—Opaque, metallic lustre, readily fusible to a dark magnetic bead; green solution in nitric acid, or in aqua regia. H. 3·5 to 6·5, G. 4 to 7·5.

Millerite	Ni S	
Pentlandite	$(\frac{2}{3} \text{Fe } \frac{1}{3} \text{Ni}) \text{S}$	
Nickeline	Ni As	
Breithauptite	Ni Sb	
Arite α	Ni $(\frac{1}{3} \text{As}, \frac{2}{3} \text{Sb})$	
Arite β	Ni $(\frac{1}{2} \text{As } \frac{1}{2} \text{Sb})$	
Beyrichite	Ni ₃ S ₄	
Horbachite	$(\frac{4}{3} \text{Fe } \frac{1}{3} \text{Ni}) \text{S}_2$	
Gersdorffite α	Ni (S As) ₂	Dana, anal. 5, 3
Gersdorffite β	$(\frac{5}{3} \text{Ni } \frac{1}{3} \text{Fe}) (\text{S As})_2$	„ „ 1, 2, 8, 9
Gersdorffite γ	$(\frac{1}{4} \text{Fe } \frac{3}{4} \text{Ni}) (\frac{2}{3} \text{As } \frac{1}{3} \text{Sb})_2$	„ „ 10, 6
Chloanthite α	Ni As (Dana, near an. 8, 9, of Smaltite)	
Chloanthite β	$(\frac{4}{3} \text{Ni } \frac{2}{3} \text{Co } \frac{2}{3} \text{Fe}) \text{As}_2$	„ 5
Chloanthite γ	$(\frac{6}{3} \text{Ni } \frac{1}{3} \text{Co } \frac{1}{3} \text{Fe}) \text{As}_2$	„ 6, 10
Chloanthite δ	$(\frac{6}{3} \text{Ni } \frac{2}{3} \text{Fe}) \text{As}_2$	„ 7
Rammelsbergite	Ni As ₃	
Ullmannite α	Ni (S Sb) ₂	Dana, anal. 3, 4
Ullmannite β	Ni $(\frac{6}{10} \text{S } \frac{4}{10} \text{Sb})_2$	„ „ 5
Ullmannite γ	Ni $(\frac{1}{10} \text{As } \frac{4}{10} \text{S } \frac{5}{10} \text{Sb})_2$	„ „ 2
Ullmannite δ	Ni $(\frac{2}{10} \text{As } \frac{3}{10} \text{S } \frac{5}{10} \text{Sb})_2$	„ „ 1
Ullmannite ϵ	Ni $(\frac{4}{10} \text{As } \frac{2}{10} \text{Sb } \frac{5}{10} \text{S})_2$	(Near Nickel glance, Dana, p. 74.)
Corynite α	Ni $(\frac{2}{3} \text{S } \frac{1}{3} \text{Sb } \frac{1}{3} \text{As})_2$	
Corynite β	Ni $(\frac{5}{11} \text{As } \frac{1}{11} \text{Sb } \frac{1}{11} \text{As})_2$	
Wolfachite	Ni (S Sb As) ₂	

The three groups just described have very intimate relations to each other, which may be brought out as in the accompanying table.

MAGNETIC SECTION.—All opaque, metallic lustre, hard, heavy, readily fusible to magnetic bead, soluble in nitric acid or aqua regia. H=3·5—6·5, G=4—7·5.

	<i>Pyrites Group.</i>	<i>Smaltite Group.</i>	<i>Chloanthite Group.</i>
	Yellow solution.	Pink solution.	Green solution.
Form M X*	{	Troilite	Millerite
		Pentlandite	Pentlandite
		Nickeline
		Breithauptite
		Arite α
			Arite β

* M as usual indicates an equivalent of a metal, X is a convenient general symbol for an equivalent of what may be called the chlorous constituent.

Form $M_3 X_4$	{	Pyrrhotite .. Linnæite α .. Beyrichite		
		(<i>Dana, anal. 8</i>) Linnæite β		
		Leucopyrite .. Linnæite γ		
		Linnæite δ		
		Linnæite ϵ		
		Linnæite ζ		
Form $M_7 X_8$	Pyrrhotite			
Form $Fe S_2$	{	Pyrites	Cobaltite α	<i>Horbachite</i>
		Marcasite	Cobaltite β	Gersdorffite α
		Horbachite	Alloclasite α	Gersdorffite β
		Mispickel	Glaucodote	Gersdorffite γ
		Löllingite α	Alloclasite β	Chloanthite α
		Smaltite ϵ	Smaltite α	Chloanthite β
		Smaltite ζ	Smaltite β	Chloanthite γ
		Glaucopyrite	Smaltite γ	Chloanthite δ
			Smaltite δ	Rammelsbergite
			Glaucopyrite	Ullmannite α
				Ullmannite β
				Ullmannite γ
	Ullmannite δ			
		Ullmannite ϵ		
		Corynite α		
		Corynite β		
		Wolfachite		
Form $M X_3$	{	..	Alloclasite	
			Skutterudite	

Form $M_2 X_3$..Pacite

Passing now to pyritoids containing lead as the principal basic ingredient, we have the following—

Galena Group.—Opaque, metallic lustre, H. below 4, G. above 7; readily fusible B B, and give a malleable bead of lead on C.

Galena	Pb S	
Huascalite	$(\frac{2}{5} Pb \frac{3}{5} Zn) S$	
Clausthalite	Pb Se	
Zorgite α	$(\frac{1}{3} Pb \frac{1}{3} Cu) Se$	
Zorgite β	$(\frac{2}{3} Pb \frac{1}{3} Cu) Se$	
Zorgite γ	$(\frac{5}{8} Pb \frac{1}{8} Cu) Se$	
Lehrbachite β	$(\frac{4}{5} Pb \frac{1}{5} Hg) Se$	Dana, anal. 1
Lehrbachite γ	$(\frac{7}{8} Pb \frac{1}{8} Hg) Se$	„ „ 2
Altaite	Pb Te	
Henryite	$(\frac{3}{4} Pb \frac{1}{4} Fe) Te$	

Zinkenite Group.—Opaque, metallic lustre, gray colour, fusible, soft, B B yield brittle metallic bead on C. $H=2-4$, $G=4.5-7$.

Zinkenite	Pb S, As ₂ S ₃
Dufrenoyite	Pb S, As ₂ S ₃
Dufrenoyite	2 Pb S, As ₂ S ₃
Cosalite	2 Pb S, Bi ₂ S ₃
Boulangerite	3 Pb S, Sb ₂ S ₃
Meneghinite ..	4 Pb S, (Sb As) ₂ S ₃
Jamesonite ..	3 (Pb Fe) S, 2 Sb ₂ S ₃
Geokronite ..	5 Pb S, (Sb As) ₂ S ₃

Jordanite, Plagionite, Clayite and Epiboulangerite may perhaps find a place in this group, or in the antimonite group.

The next group is characterised by the presence of considerable proportions of Bismuth.

Bismuthinite Group.—Opaque, metallic lustre, brittle gray bead on C. $H.=2$ to 4, $G=4$ to 4.7.

Bismuthinite	Bi ₂ S ₃
Emplectite	Bi ₂ S ₃ + Cu ₂ S
Wittichenite	Bi ₂ S ₃ + 3 Cu ₂ S
Aikinite	Bi ₂ S ₃ + Cu ₂ S + 2 Pb S
Kobellite	Bi ₂ S ₃ + Pb S + 2 Pb S
Cosalite	Bi ₂ S ₃ + 2 Pb S
Frenzelite	Bi ₂ ($\frac{2}{3}$ Se $\frac{1}{3}$ S) ₃
Tetradymite	Bi ₂ Te ₃

Chiviatite, Joseite, and Wehrlite may perhaps also find a place in this group.

The next group has considerable resemblance to the foregoing, Antimony being the characteristic ingredient.

Antimonite Group.—Opaque, gray, metallic, soft, fusible, brittle bead, mostly volatile. $H=2-3$, $G=4-5$.

Antimonite	Sb ₂ S ₃
Kermesite	2 Sb ₂ S ₃ + Sb ₂ O ₃
Berthierite	Sb ₂ S ₃ + Fe S

Jordanite, Plagionite, Clayite, and Livingstonite may perhaps find a place here. Livingstonite contains some 14 p.c. of mercury, and might perhaps be placed also in the Cinnabar group.

The next group consists of arsenic and sulphur only.

Realgar Group.—Entirely volatile, non-metallic lustre, red, yellow, brown, H. 1·5—2. G. 3·4—3·6; more or less translucent.

Realgar	As S
Orpiment	As ₂ S ₃
Arsenotellurite	As ₂ S ₃ + 2 Te S
Dimorphite	As ₄ S ₃ (?)

The following group is chemically related to those forming the "Magnetic Section," but differs remarkably in physical properties.

Blende Group.—Always more or less translucent, lustre resinous or sub-metallic, rarely colourless, usually yellow red, gray, green, brown, sometimes black, not much altered by heat; H=3 to 4·5. G. from 3·5 to 4·8.

Blende	Zn S.
Wurtzite	Zn S.
Marmatite	(Zn Fe) S.
Przibramite	(Zn Cd) S.
Alabandite	Mn S.
Hauerite	Mn S ₂ .
Greenockite	Cd S.

The next group contains, as yet, one mineral only.

Molybdenite Group.—Opaque, metallic lustre, foliaceous, flexible, not reducible to a bead on charcoal.

Molybdenite	Mo S ₂
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The subdivisions of the class of "Pyritoids" suggested above will, I think, be found to harmonise very fairly with the best existing arrangements of minerals; to which they are proposed rather as additions than as substitutions. It may well be however, that I have omitted in some instances to give due weight to characters of considerable importance, besides which, it may be advisable still further to subdivide some of the groups; I would therefore invite friendly criticism from the members of the Mineralogical Society and readers of the Mineralogical Magazine.

In future papers I propose to deal with the other classes in a somewhat similar manner.