THE MINERALOGICAL MAGAZINE

AND

JOURNAL OF

THE MINERALOGICAL SOCIETY.

No. 90. September, 1920. Vol. XIX.

The classification of Meteorites.[1]

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[Read January 20, 1920.]

THE first broad grouping of meteorites was into irons and stones according as they consisted mainly of nickeliferous iron or of silicates. These were the two main divisions of the first really serviceable classification as applied by Gustav Rose in 1862–4 to the collection of meteorites in the University Museum of Berlin. In this classification the division of meteoric irons included as separate groups the pallasites and the mesosiderites, in which nickel-iron and silicates are present in about equal amounts; and the meteoric stones were for the first time split up into chondrites, or stones containing those curious rounded grains (chondrules) peculiar to meteorites, and non-chondritic stones, which were divided according to mineralogical composition into the groups of eucrites, howardites, &c., still largely recognized.

At about the same time (1863) Maskelyne used for the British Museum Collection the threefold division of meteorites into siderites or meteoric irons, consisting mainly of nickeliferous iron, siderolites, consisting of metal and silicates in about equal amounts, and aerolites or meteoric stones, consisting mainly of silicates.

In Tschermak's modification of the Rose classification, published in 1883, the siderolites were kept, as by Maskelyne, distinct from the irons, the irons themselves were for the first time separated into the groups of

[1] Communicated by permission of the Trustees of the British Museum.

octahedrites, &c., according to the structure revealed by etching, and the chondrites were subdivided into groups according to their colour (white, intermediate, grey, and black) and structure.

Since that time the Rose-Tschermak classification was gradually modified by Brezina into the system now most commonly used. In this classification a return was made to the twofold division of Rose into irons and stones, part of the siderolites of Maskelyne, consisting mainly of the pallasites, being attached to the irons under the name of lithosiderites, and the other part, consisting mainly of the mesosiderites, to the stones under the name of siderolites. The reasons for such a separation appear to be rather insufficient, and the restricted meaning given to the word siderolite leads to confusion. Other modifications introduced by Brezina are also open to criticism as no improvement on the Tschermak classification. For example, Tschermak had rightly distinguished between the chladnite (Bishopville), consisting mainly of a pure non-ferriferous enstatite, and the diogenites (Shalka, &c.), consisting of a highly ferriferous 'bronzite' (hypersthene), but Brezina, calling the pyroxenes indiscriminately 'bronzite', united the two groups under the name chladnite. Again, whereas Tschermak had defined the howardites as consisting of 'bronzite' (hypersthene), augite, and anorthite, and had shown that much of what had been described as olivine in these meteorites is really bronzite (hypersthene), Brezina once more made olivine an essential constituent. In the case of the chondrites, also, the ureilites are wrongly included amongst them, and the introduction of subdivisions based upon brecciation and the presence of veins is a quite unnecessary complication and over-elaboration only tending to defeat the ends of classification.

Previous to the complete development of the Rose-Tschermak-Brezina system, other classifications had been brought forward by C. U. Sheperd, A. Daubrée, and S. Meunier, but these have met with little acceptation.

In all these classifications, the division into groups is based either on mineralogical composition as in the case of the non-chondritic stones, or on structure as in the case of the irons, while in the case of the chondrites it depends to a large extent upon such unimportant characters as colour, brecciation, and veining. In none of them is any consideration paid to the chemical composition of the nickeliferous iron nor much to that of the silicates. The only attempt at a chemical classification of meteoric stones has been that of O. C. Farrington [1] on the lines of the American

[1] O. C. Farrington, Analyses of stone meteorites. Field Museum of Nat. Hist., 1911, Pub. 151, Geol. Ser., vol. 3, no. 9, p. 195.

quantitative classification of terrestrial rocks, and besides being open to the same objections as have been brought against that classification, it is vitiated by the unreliable character of many of the analyses on which it is based.

In a paper published in this Journal[1] the author pointed out the significance for classificatory purposes of the chemical composition, in the first place of the nickeliferous iron, and in the second place of the magnesium silicates of meteorites.

With respect to these constituents individual meteorites show wide variations:—

(1) in the amount of nickel in the nickeliferous iron.

(2) in the amount of ferrous oxide in the magnesium silicates.

In the case of the meteoric irons, as pointed out by Farrington,[2] the variation in the amount of nickel has an intimate relation to the structure as revealed by the etching of polished surfaces.

Irons in which the ratio of iron to nickel is well above fourteen or below about six belong to the group of ataxites, and have a granular to compact structure showing no definite figures on etching. Irons in which the ratio of iron to nickel lies between these limits, however, exhibit variations in structure which depend apparently upon the relative amounts of two constituent alloys of nickel and iron, *kamacite*, of which the composition has been represented by the formula $Fe_{14}Ni$, and *taenite*, which is much richer in nickel. Irons consisting almost solely of kamacite are known as hexahedrites or cubic irons, since they have a cubic cleavage, and show on etching fine lamellae (Neumann lines) due to twinning of a cube on an octahedron face. Irons less poor in nickel (Fe : Ni = about 6–13) belong to by far the largest group called octahedrites, since on etching they exhibit a structure (Widmanstätten figures) in which plates of kamacite, bordered by narrow seams of taenite, are arranged parallel to the faces of an octahedron, with interstices filled with plessite, which is probably an intimate mixture of kamacite and taenite. The most reliable analyses indicate that the coarser the structure, i.e. the wider the plates of kamacite, the poorer in nickel is the iron, though the greater or less amount of plessite may modify to some extent this relation. The ordinary classification of meteoric irons

[1] G. T. Prior, On the genetic relationship and classification of meteorites. Mineralogical Mag., 1916, vol. 18, pp. 26–44.

[2] O. C. Farrington, Analyses of iron meteorites, compiled and classified. Field Columbian Museum, 1907, Pub. 120, Geol. Ser., vol. 3, no. 5, pp. 59-110. See also F. Berwerth, Ein natürliches System der Eisenmeteoriten. Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Klasse, 1914, vol. 123, Abt. 1, p. 1.

into hexahedrites, octahedrites, and ataxites has for its basis, therefore, a grouping according to the percentage of nickel.

Turning now to the meteoric stones, it is found that the amount of nickel in the nickel-iron they contain shows similar variations to those in the meteoric irons, and in addition the magnesium silicates differ widely in the amounts of ferrous oxide in their chemical composition.

As shown by the author, these two variations, viz. of the amount of nickel in the nickel-iron and of ferrous oxide in the magnesium silicates in a meteorite, are not independent. The relation between them is such that for any meteoric stone *the richer in nickel is the nickel-iron, the richer in ferrous oxide are the magnesium silicates*, or, in other words, the ratio of magnesia to ferrous oxide in the magnesium silicates varies directly with the ratio of iron to nickel in the nickel-iron.

The explanation advanced by the writer to account for this relationship is that meteorites have separated from a single magma which has passed through successive stages of progressive oxidation.[1] In the earliest stage represented by any meteorites at present known, viz. by the Bishopville and Daniel's Kuil types, although silicon and magnesium were completely oxidized, calcium and chromium were still partially in the form of sulphides, and the iron had suffered practically no oxidation whatever. These meteorites, therefore, contain such minerals as oldhamite (sulphide of calcium) and daubreelite (sulphide of chromium and iron), and magnesium silicates free from ferrous oxide, while the nickel-iron in them is comparatively poor in nickel. In the later stages, on the other hand, owing to the progressive oxidation, there took place, at the expense of the nickeliferous iron, an increasing production of oxide of iron, which in the resulting meteorites entered more and more into the composition of the magnesium silicates, while the residual nickel-iron became richer and richer in nickel, since little or no oxidation of nickel would occur so long as any iron remained unoxidized.[2]

A classification, therefore, of meteorites (both irons and stones) based upon the proportion of iron to nickel in the nickel-iron, and consequently also on the proportion of MgO to FeO in the magnesium silicates, is a natural one.

Such a grouping of meteorites showing their mutual relations is exhibited in the following table, which is a modified form of one previously published.[3]

[1] See also W. Wahl, Beiträge zur Chemie der Meteoriten. Zeits. Anorg. Chemie, 1910, vol. 69, p. 67.

[2] See W. Wahl, loc. cit., p. 70.

[3] G. T. Prior, Mineralog. Mag., 1916, vol. 18, p. 42.

TABULAR CLASSIFICATION OF METEORITES.

Class ↓		Group →	1	2	3	4
		Nickel-iron →	Fe : Ni = 13 and over.	Fe : Ni = 13–8.	Fe : Ni = 8–2.	—
		Magnesium silicates →	Enstatite (and Clino-enstatite). MgO : FeO very high to ∞.	Bronzite (and Clino-bronzite) and Olivine. MgO : FeO over 4.	Hypersthene (and Clinohypersthene) and Olivine. MgO : FeO = 4–2.	Pyroxene (mostly monoclinic) and Olivine. MgO : FeO less than 2.
		Felspar →	Oligoclase.	Oligoclase.	Oligoclase.	Anorthite.
IRONS.	1	SIDERITES → Mainly nickel-iron.	Nickel-poor Ataxites. Hexahedrites. Coarsest Octahedrites. Coarse Octahedrites.	Medium Octahedrites to Finest Octahedrites.	Some Finest Octahedrites? Nickel-rich Ataxites.	Oktibbeha County?
STONY-IRONS.	2	SIDEROLITES[1] → Nickel-iron in large amount.		Most Pallasites. Siderophyre. Lodranite. Mesosiderites.[2]	A few Pallasites.	
STONES (AEROLITES).	3	CHONDRITES → Nickel-iron generally in decreasing amount from left to right.	*Enstatite-chondrites.* Daniel's Kuil (Hvittis) type.	*Bronzite-olivine-chondrites.* Kroonstad type.	*Hypersthene-olivine-chondrites.* Baroti and Soko-Banja types.	
	4	ACHONDRITES → (Non-chondritic stones). Nickel-iron in small amount or absent.	*Enstatite-achondrites.* Aubrites (Aubres, Bishopville, and Bustee).	*Clinobronzite[3]-olivine-achondrites.* Ureilites.	*Hypersthene-olivine-achondrites.* Amphoterites (& Rodites). *Hypersthene-achondrites.* Diogenites (Shalka, &c.). *Olivine-achondrites.* Chassignite.	*Calcium-rich Achondrites.* Angrite, Nakhlite. Eucrites, Shergottite, Howardites. Mesosiderites.[2]

[1] As defined by Maskelyne, including both the lithosiderites and siderolites of Brezina.

[2] As seen in the vacant compartments, the stony-irons (Class 2) and the calcium-rich achondrites (Group 4) fit less perfectly than the rest into the general scheme, and mesosiderites appear to be related to both, for as regards iron and olivine they belong to Group 2, and as regards pyroxene and felspar to Group 4.

[3] See p. 56.

In this scheme, meteorites are divided into four classes, viz. Irons, Stony-irons, Chondritic Stones, and Non-chondritic Stones, and each of these classes is divided into four groups, each group having certain characters common to, or varying within the same limits for, all four classes.

The chief alterations from the table previously published are as follows: (1) For the sake of simplification the groups 3 and 4 of the earlier table are merged into one (Group 3); (2) in order to avoid confusion, the name *aubrite*[1] is given to the group of enstatite-achondrites, which includes the bustites (Aubres and Bustee) and the original chladnite (Bishopville) of Tschermak's classification, but not the chladnites of Brezina (Shalka, &c.);[2] (3) Tschermak's name of diogenite is again taken for the so-called 'bronzite' stones, the hypersthene-achondrites, Shalka, Manegaum, and Ibbenbühren; (4) the stony-irons are separated from the achondrites as a separate class; (5) the order of the classes is reversed.

The names enstatite, bronzite, and hypersthene, used in the table, are defined roughly by the ratio[3] of MgO to FeO at the head of the column. The limits are about the same as those originally proposed by Des Cloizeaux, viz. for bronzite, from 6 to 10 per cent. of FeO.[4] In view of the significance of the ratio of MgO to FeO in the magnesium silicates it seems advisable to revive these terms for meteorites, instead of referring all rhombic pyroxenes indiscriminately to bronzite as is done in the Brezina classification, or to enstatite and bronzite only as in that of Tschermak.

As regards the monoclinic pyroxenes, those which occur in meteorites, with few exceptions, are very poor in lime and alumina as compared with terrestrial augites, and thus in chemical composition approximate to or are identical with the orthorhombic forms. It is proposed, therefore, to extend the use of the very satisfactory self-explanatory terms, clinoenstatite, clinobronzite, and clinohypersthene, so as to cover not only the twinned monoclinic pyroxenes of the chondrites to which Wahl restricted the terms, but also the monoclinic pyroxenes of small optic axial angle of his 'enstatite-augite' series.[5] Varieties of the latter series, when the chemical

[1] From Aubres, the meteorite of earliest date of fall of the group.

[2] See p. 52.

[3] The ratio is really a little higher, since the olivines in the chondrites are generally rather richer in ferrous oxide than the pyroxenes.

[4] A. Des Cloizeaux, Ann. Chim. Phys., 1864, ser. 4, vol. 1, 515.

[5] W. Wahl, Die Enstatitaugite. Min. Petr. Mitt., 1907, vol. 26, p. 1. The name enstatite-augite conveys essentially the same idea as the name clinoenstatite.

composition has been accurately determined, might still be distinguished by the compound names, enstatite-diopside, hedenbergite-hypersthene, &c., which Wahl has applied to them. These names, however, in some cases, depend upon rather slight differences in the percentage of lime and are misleading as to the crystal-system they suggest. It is proposed, therefore, as preferable and sufficient, to distinguish clinoenstatites, &c., which contain appreciable (though still relatively small) amounts of lime as calcareous or as calc-clinoenstatites, &c.

For the olivines of meteorites equally suitable terms to enstatite, bronzite, and hypersthene for the pyroxenes are not available. In the meteorites of Group 1, if olivines were present (as is generally not the case) one would expect to find the pure magnesium olivine forsterite, and this olivine is said to occur in the Tucson iron; the olivine of chassignite (with MgO : FeO about 2) at the lower limit of Group 3 is near to hyalosiderite; and that of Nakhla in Group 4 (with MgO : FeO = $\frac{1}{2}$) is close to hortonolite.

The classification outlined in the table, when arranged in more usual (linear) form, with definitions rather more elastic and, wherever possible, in conformity with those of the Brezina classification, is as follows :—

Linear Classification of Meteorites.

I. Meteoric Irons or Siderites.

Consisting chiefly of nickel-iron, and enclosing sulphide of iron (troilite), phosphide of iron and nickel (schreibersite), sulphide of iron and chromium (daubreelite), carbide of iron (cohenite), graphite, &c. According to structure they have been divided into the following groups, which, as previously shown, also depend upon the proportion of iron to nickel in the nickel-iron :—

(1) Hexahedrites or Cubic Irons (H).[1]

These irons have a cleavage parallel to the faces of a cube and on etching show fine lines (Neumann lines) due to twinning of a cube on an octahedron face. They are poor in nickel, with a ratio of Fe to Ni higher than 13, for they consist almost wholly of kamacite, to which the

[1] If symbols are considered necessary and convenient, those of the Brezina classification may be used for the different groups, with the following additional ones, viz. Au for Aubrite, Cen for Enstatite-chondrite, Cbr for Bronzite-chondrite, Chy for Hypersthene-chondrite, and Di for Diogenite.

formula $Fe_{14}Ni$ has been attributed. The presence of orientated schreibersite needles (rhabdite) and daubreelite are characteristic features of the non-brecciated hexahedrites.

(2) Octahedrites or Octahedral Irons (O).

These irons on etching show Widmanstätten figures, in which lamellae or plates of kamacite bordered with narrow seams of taenite are arranged parallel to the faces of an octahedron, with interstices filled with plessite, which is probably an intimate mixture of kamacite and taenite. According to the thickness of the plates they were divided by Brezina into :—

Coarse	*Coarsest Octahedrites*	with lamellae	over	2–5 mm.	in thickness	(Ogg)
	Coarse	,,	,,	1·5 to 2 mm.	,,	(Og)
Medium		,,	,,	0·5 to 1 mm.	,,	(Om)
Fine	*Fine*	,,	,,	0·15 to 0·4 mm.	,,	(Of)
	Finest	,,	,,	0·1 mm.	,,	(Off)

but three divisions only (as indicated by the brackets) into coarse, medium, and fine octahedrites would perhaps be sufficient. Some members of these groups have a brecciated structure.

Octahedrites are mostly richer in nickel than hexahedrites, the ratio of Fe to Ni decreasing from the coarsest to the finest, viz. according to the most reliable analyses, from about 13 in the coarsest to about 6 in the finest. They generally contain more troilite than the hexahedrites. The presence of cohenite and graphite is especially characteristic of the groups of coarsest and coarse octahedrites, in some members of which (e.g. Cañon Diablo) diamond has been found. The medium octahedrites form by far the largest group of meteoric irons.

(3) Ataxites or Massive Irons (D).

These irons have a granular to compact structure and show on etching neither Neumann lines nor Widmanstätten figures. They have been divided into :—

(a) *Nickel-poor Ataxites*, in most of which the ratio of Fe to Ni is over 16, and thus beyond the limit of the hexahedrites.

(b) *Nickel-rich Ataxites*, in which the ratio of Fe to Ni varies from about 6 to 2, and thus beyond the limit of the finest octahedrites.

In a few ataxites, in which analyses indicate a ratio of Fe to Ni within the limits of the octahedrites, the massive character may be attributed to the obliteration of the original octahedral structure by subsequent heating.

II. Meteoric Stony-irons or Siderolites.[1]

Consisting mainly of nickel-iron and silicates, both in large proportion.

(1) PALLASITES or Olivine-'stony-irons' (P).

Consisting of olivine crystals, generally rounded or broken, in a network or mesh of nickel-iron. In most pallasites the iron is poor in nickel, with a ratio of Fe to Ni of over 9, and the olivine is correspondingly poor in ferrous oxide, with a ratio of MgO to FeO of 6–8, but Eagle Station and Mount Vernon are exceptional with a ratio of Fe to Ni of 5–6 and a ratio of MgO to FeO correspondingly as low as 4.

(2) SIDEROPHYRE or Bronzite-asmanite-'stony-iron' (Si).

Consisting of nickel-iron poor in nickel (Fe : Ni = about 9) as in the pallasites, bronzite correspondingly poor in ferrous oxide (MgO : FeO = about 5), and asmanite (tridymite), all in large amount. Steinbach (Rittersgrün, Breitenbach) is the only representative.

(3) LODRANITE or Bronzite-olivine-'stony-iron' (Lo).

Consisting of a granular aggregate of olivine, poor in ferrous oxide (MgO : FeO = about 7) as in the pallasites, and bronzite poor in ferrous oxide (MgO : FeO = about 5) as in siderophyre, enclosed in a mesh of iron correspondingly poor in nickel (Fe : Ni = about 10) as in pallasites.

Lodran is the only representative, but the ureilites (see p. 62) are closely related.

(4) MESOSIDERITES[2] or Hypersthene-anorthite-'stony-irons' (M).

Consisting of nickel-iron enclosing patches of stony matter composed of hypersthene (and clinohypersthene) and anorthite: olivine is also present, but generally as separately enclosed crystals, often of fairly large size. The iron is poor in nickel (Fe : Ni = 10–13) and the olivine correspondingly poor in ferrous oxide (MgO : FeO = 6–10) as in the pallasites, but the pyroxene, rich in ferrous oxide (MgO : FeO about 2), and the felspar (anorthite) are of somewhat the same composition as in the eucrites and howardites. The group is apparently the result of a mixture of two types.[3]

[1] This term is here used as originally by Maskelyne and not in the restricted sense of Brezina (see p. 52).

[2] Under this name are included both the groups mesosiderite and grahamite of the Brezina classification, since, as shown by the writer (Mineralogical Magazine, 1918, vol. 18, pp. 151-172), no distinction can be drawn between the two as regards the amount of felspar.

[3] See Mineralogical Magazine, loc. cit., p. 171.

III. Meteoric Stones or Aerolites.

Consisting mainly of silicates, generally with interspersed particles of nickel-iron and troilite. According as they contain chondrules or not, they have been divided into chondritic stones, or chondrites, and non-chondritic stones, or achondrites.

A. Chondrites.

Containing chondrules: felspar when present is generally oligoclase.

When the chemical composition has not been accurately determined, stones containing chondrules may be described (as in the Brezina classification), according to colour, as white, intermediate, grey, or black; according to structure, as brecciated, veined, spherical (when the chondrules are well formed and for the most part break away from the matrix), and crystalline (when the groundmass is more crystalline than tufaceous); and as carbonaceous when they are impregnated with carbonaceous matter. These terms, however, should be used as qualifications only and not as group-distinctions, since they do not appear to have any very direct relation to the chemical composition. When the latter[1] has been determined, chondrites can be divided into the following groups:—

(1) Enstatite-chondrites (Cen). Daniel's Kuil and Hvittis type.

Consisting essentially of crystalline nearly pure non-ferriferous enstatite, with nickel-iron in large amount up to 25 per cent. and poor in nickel (Fe : Ni = about 13), troilite, and some oligoclase. Characteristic accessory constituents are oldhamite and daubreelite. Chondrules are few and imperfect.

To this group belong Hvittis, the so-called 'enstatite-anorthite[2]-chondrite' (Cek) of the Brezina classification, and some of the crystalline chondrites (Ck), viz. Pillistfer, Daniel's Kuil, and Khairpur.

(2) Bronzite-chondrites or strictly Bronzite-olivine-chondrites (Cbr). Kroonstad type.

Consisting essentially of bronzite (with clinobronzite) and olivine, in approximately equal amounts, with some oligoclase, forming a crystalline to tufaceous aggregate which encloses chondrules (composed of the same minerals with in some cases isotropic material) and grains of nickel-iron

[1] Or more simply either the ratio of MgO to FeO in the insoluble silicate or the ratio of Fe to Ni in the nickel-iron (see G. T. Prior, A method for the quick determination of the approximate amount and composition of the nickeliferous iron in meteorites. Mineralogical Magazine, 1919, vol. 18, p. 349).

[2] Really oligoclase.

and troilite. The nickel-iron is less poor in nickel (Fe : Ni in Kroonstad = 11) than in the enstatite-chondrites, and is less in amount, though this is generally over 10 per cent. The ratio of MgO to FeO in the ferro-magnesium minerals in the type meteorite is about 5. To this group belong most of the crystalline chondrites (Ck) not included in Group 1, and also many grey (Cg) and spherical (Cc) chondrites of the Brezina classification; and the qualifications according to colour and structure, as white, crystalline, spherical, &c., can be applied to the individual members.

(3) HYPERSTHENE-CHONDRITES or strictly Hypersthene-olivine-chondrites (Chy). Baroti and Soko-Banja types.

Of similar mineral composition and structure to the preceding group, except that the iron is richer in nickel (Fe : Ni varying from about 7 to 3) and generally in less amount, and the ferromagnesium minerals are correspondingly richer in ferrous oxide (MgO : FeO varying from about 4 to $2\frac{1}{2}$). In Baroti Fe : Ni = $6\frac{1}{2}$, in Soko-Banja 3.

To this group belong perhaps all white (Cw) and intermediate (Ci) chondrites, and also the rest of the grey and spherical chondrites of the Brezina classification not included in Group 2; and as in that group the qualifications according to colour and structure can be applied to the individual members.

B. ACHONDRITES.

Of crystalline-granular structure and containing little or no nickel-iron and no chondrules.

They can be divided into (a) calcium-poor, and (b) calcium-rich achondrites.

(a) *Calcium-poor achondrites in which felspar when present is generally oligoclase.*

In chemical and mineral composition they correspond to the chondrites and include :—

(1) AUBRITES or Enstatite-achondrites (Au). Aubres, Bishopville, and Bustee.

Consisting almost wholly of crystalline granular enstatite (and clino-enstatite) poor in lime and practically free from ferrous oxide, with accessory oligoclase (most plentiful in Bishopville). Aubres and Bustee are brecciated, and Bustee is distinguished from the other two meteorites by containing nodules which are rich in oldhamite and in a diopside (enstatite-diopside of Wahl) very rich in lime, but like the enstatite practically free from ferrous oxide. Nickel-iron is in very small amount and is poor in nickel.

Except for the lack of chondrules and nickel-iron these meteorites, in mineral and chemical composition, are closely related to the enstatite-chondrites.

(2) UREILITES or Clinobronzite-olivine-achondrites (U). Novo-Urei, Goalpara, and Dyalpur.

Consisting of detached crystals (or crystal aggregates) of olivine and a calc-clinobronzite (diopside-enstatite of Wahl) enclosed in a fine mesh of nickel-iron and carbonaceous matter including diamond. The nickel-iron is in small amount and poor in nickel, and the ferromagnesium minerals are correspondingly poor in ferrous oxide (MgO : FeO for the clinobronzite = 8–12, and for the olivine 4–5). These meteorites are closely related to Lodran, from which they differ mainly in containing much less nickel-iron. In mineral and chemical composition they correspond to the bronzite-chondrites, though the ferromagnesium minerals have a somewhat higher ratio of MgO to FeO.

(3) AMPHOTERITES or Hypersthene-olivine-achondrites (Am), including the brecciated Rodites (Ro) of the Brezina classification.

Consisting of a crystalline granular aggregate of hypersthene and olivine (hyalosiderite) with a little nickel-iron. The nickel-iron is very rich in nickel (Fe : Ni = about 2) and the ferromagnesium silicates are correspondingly rich in ferrous oxide (MgO : FeO = about 2). In mineral and chemical composition they correspond to the hypersthene-chondrites, though the ferromagnesium minerals have a somewhat lower ratio of MgO to FeO.

(4) DIOGENITES or Hypersthene-achondrites (Di). Shalka, Manegaum, and Ibbenbühren.

Consisting mainly of hypersthene rich in ferrous oxide (MgO : FeO = 2–3), with little or no nickel-iron.

(5) CHASSIGNITE or Olivine-achondrite (Cha). Chassigny.

Consisting mainly of olivine (hyalosiderite) rich in ferrous oxide (MgO : FeO = about 2) with little or no nickel-iron.

(b) *Calcium-rich achondrites in which felspar when present is generally anorthite.*

They appear to bear little relation to the chondrites, being much richer in lime and ferrous oxide and in some cases also in alumina. They fall into two main divisions, one (including groups 1 and 1 a) poor in felspar and therefore in alumina, and with pyroxenes rich in lime, the other (including groups 2, 2 a, 2 b) rich in anorthite, and, therefore, in lime and alumina, but with pyroxenes poor in lime and alumina.

(1) ANGRITE or Augite-achondrite (An). Angra dos Reis.

Consisting almost wholly of purple calcium-rich titaniferous augite, rich in ferrous oxide (MgO : FeO = about 2), with a little olivine and troilite.

(1 a) NAKHLITE or Diopside-olivine-achondrite (Nk). Nakhla.

Consisting mainly of a crystalline granular aggregate of green calcium-rich hedenbergite-diopside and brown olivine near to hortonolite. Both diopside and olivine are extremely rich in ferrous oxide, the ratio of MgO to FeO of the pyroxene being about $1\frac{1}{2}$, and of the olivine $\frac{1}{2}$. The interstitial felspar in this meteorite is nearer to oligoclase than to anorthite.

(2) EUCRITES or Clinohypersthene-anorthite-achondrites (Eu).

Consisting mainly of calc-clinohypersthene (hedenbergite-hypersthene of Wahl) and anorthite, and in structure doleritic (ophitic) to basaltic. The clinohypersthene is very rich in ferrous oxide (MgO : FeO = about $\frac{1}{2}$), but poor in lime and alumina as compared with most terrestrial augites.

(2 a) SHERGHOTTITE or Clinohypersthene-maskelynite-achondrite (She). Sherghotty.

Consisting of a somewhat similar calc-clinohypersthene (diopside-hypersthene of Wahl) to that in the eucrites, associated, however, with laths of isotropic maskelynite instead of anorthite.

(2 b) HOWARDITES or Hypersthene-clinohypersthene-anorthite-achondrites (Ho).

Consisting essentially of hypersthene, clinohypersthene, and anorthite. The ferromagnesium silicates are rich in ferrous oxide (MgO : FeO = 1–2). These meteorites are generally brecciated. Olivine, the presence of which in the Brezina classification is considered as essential, is either absent or present only as an accessory constituent, for the mineral often described as olivine is hypersthene, as shown by Tschermak [1] and Wahl [2] in the case of Luotolacs, &c. Some of the fragments in these brecciated meteorites consist of an ophitic aggregate of calc-clinohypersthene and anorthite like the eucrites, others (as in Petersburg) of a more gabbro-like aggregate of a rose-coloured pyroxene and felspar. The above definition of the group corresponds to that of the Tschermak classification of 1883 and not to that of Brezina. The eucrite group might be extended to include the howardites as brecciated varieties.

[1] G. Tschermak, Mikrosk. Beschaff. der Meteoriten, 1885, p. 8.

[2] W. Wahl, loc. cit., p. 84.