The Meteoric Stones of Baroti, Punjab, India, and Wittekrantz, South Africa.[1]

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The Meteoric Stone of Baroti, Punjab, India.

Fall of the Stone.

In 1912 Mr. N. B. Kinnear, Curator of the Bombay Natural History Society's Museum, brought to me at the British Museum, for identification, a specimen of a supposed meteorite which had been sent to the Bombay Natural History Society by the late General W. Osborn.

General Osborn stated that, in November, 1910, on arrival at his usual winter quarters in the hill station of Kotheir in the Punjab, he visited his friend, the Rajah of Bilaspur, who presented him with a fragment, weighing about a quarter of a pound, of a meteorite which had fallen in daylight at the village of Baroti, in the Bilaspur (Simla) district, one day during the month of September, 1910.[2] General Osborn afterwards visited the locality and was able to procure from the natives a piece of the meteorite weighing $4\frac{1}{4}$ lb., together with several smaller fragments. In a letter to Mr. Kinnear, he supplied the following account of the fall of the stone, as given to him by the natives in answer to inquiries which he made in the villages:—

'At about ten o'clock in the morning, the villagers at Baroti, a village in the Bilaspur (Simla) district, were at work about their fields when

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

[2] According to a brief account of the meteorite of Baroti by G. Cotter in Rec. Geol. Surv. India, 1912, vol. xlii, p. 273, the stone fell at about 10 a.m. on September 15, 1910.

they were alarmed by a rushing noise overhead. Looking up they saw a meteor approaching them at a great velocity, accompanied by a cloud of light-coloured smoke. The meteorite struck the earth about four hundred yards from their village. On going to the spot they found that it had landed with great force on a sheet of ordinary dark sandstone rock, the face of which, at the point of impact, was broken up for a space of about two feet in diameter, and to a depth of more than an inch. The meteorite itself was broken in pieces on its contact with the rock. The villagers gathered up these fragments, some of which they took to the Rajah of Bilaspur, others they kept themselves, either as curiosities, or probably as objects of superstitious reverence.'

On a second visit to his winter quarters in Kotheir, in March, 1912, General Osborn succeeded in obtaining from the men of Baroti two additional small fragments of the meteorite.

Through the kindness of Mr. Kinnear a fragment weighing 858 grams, and smaller pieces (50 and 25 grams) for analysis, have been presented to the British Museum by the Bombay Natural History Society.

Physical Characters.

The piece weighing 858 grams is a fragment of a stone which was probably three or four times as large. It is half covered with the usual dull black crust, and is sharply pointed at one end, where three fairly flat, crusted surfaces meet. The broken, uncrusted surface is white and shows no sign of brecciation or veining. On close examination, it is seen to be spangled over with small grains of silver-white nickeliferous iron and with bronzy-yellow troilite. Otherwise it is fairly uniform in appearance and only with difficulty can a few chondrules be distinguished. The material is somewhat friable. The specific gravity of the stone was found to be 3·54.

Mineral Composition.

Examined in thin-slices under the microscope, the meteorite is seen to consist of a finely granular aggregate of colourless bronzite and olivine, in which are distributed numerous small particles of nickel-iron and troilite, and a few chondrules not sharply separated from the matrix. With a high power a fair amount of colourless interstitial felspathic material can be detected. It consists of an acid felspar near to oligoclase, as the refraction is about equal to that of the Canada balsam, and, though most particles extinguished uniformly, a few showed faint twinstriations and one gave symmetrical extinctions about the twin-lamellae of 8°. Of the chondrules, some consist of olivine (polysomatic), but most are of radial fibrous bronzite or of alternating bars of bronzite giving straight extinction and of 'clino-bronzite' giving extinctions generally higher than 20°: in some cases the interspaces between the eccentrically radiating bronzite are filled with the felspathic material.

Method of Chemical Analysis.

In order to avoid the tedious separation of the metallic iron by means of ammonio-mercuric chloride, the following simple method of analysis was adopted. It is probable that an analysis made by this method, when conducted with all care, will give results little less accurate than those obtained by the more complex method involving so many processes in which loss or inaccuracies may occur.

A fragment of the stone, free from crust and as fresh as possible, from 10 to 15 or even 20 grams in weight, is broken up and ground to powder so far as the lumps of metallic iron will allow. The material thus obtained is then separated into attracted and unattracted portions by means of a magnetic comb. After the separation of the coarser grains of metallic iron, the unattracted portion is re-ground and the separation with the magnet repeated several times, so as to extract practically all the metallic iron. In this way the attracted material may contain a considerable amount (from 20 to 30 per cent.) of adhering unattracted material, but it is less disadvantageous that this should be the case than that any appreciable amount of metallic iron should be left with the main mass of unattracted material. The attracted and unattracted portions are then treated as follows:—

(1) *Attracted portion.*—As the material consists of lumps of metallic iron of varying sizes, with adhering non-metallic material, it is inadmissible to separate it into different portions for different determinations; it must be treated as a whole. It is digested on the water-bath with hydrochloric acid of specific gravity 1·06, to which a few cubic centimetres of nitric acid are added. After half-an-hour's digestion the liquid is poured off from the insoluble residue, which is again digested with acid, the operation being repeated until the liquid is no longer coloured by iron. The residue is collected and washed, and is then digested with carbonate of soda to remove the silica liberated from the soluble silicate. This silica is added to that obtained by the evaporation

of the main solution of the iron. After the separation of silica from the main solution, the filtrate is collected in a graduated flask and portions are set aside for the determination of sulphur and phosphorus. In the remainder, the iron, nickel, lime, magnesia, &c., are determined by the usual methods. For the separation of nickel, precipitation of the iron with ammonia, repeated four or even five times, was used.

The total iron obtained in the analysis is due mainly to the metallic iron, but also partly to the troilite and the soluble silicate. To obtain the percentage of metallic iron, therefore, from the total iron there must be deducted an amount sufficient to form sulphide of iron with the sulphur, and an amount corresponding to the ferrous iron in the soluble silicate. The latter may be calculated as the amount sufficient to form an orthosilicate with the silica and magnesia, or, better, may be determined by analysing the soluble silicate in the unattracted material.

(2) *Unattracted portion.*—To the unattracted portion is added the insoluble residue obtained in the analysis of the attracted portion, and the whole is thoroughly mixed.[1] The finely powdered homogeneous material thus obtained can be analysed by the usual methods of rock analysis, and separate portions may be taken for the determination of sulphur, phosphorus, alkalis, chromic oxide, ferrous iron, &c. A portion may also be taken for the determination of the composition of the soluble silicate, or simply for the determination of the proportion of magnesium to iron in it. The small fractional percentage of nickel, which may be obtained in the analysis, is taken as due to nickeliferous iron not removed by the magnet. An amount of iron corresponding to the nickel (as determined by the analysis of the attracted portion) must, therefore, be estimated as metal. In the analysis of the Baroti meteorite no nickel was found in the unattracted material, although two portions were tested; in the analysis of the Wittekrantz stone, only a very small fractional percentage was obtained.

[1] In the analyses of the Baroti and Wittekrantz stones this was not done, and the bulk-analyses were calculated on the assumption that the material adhering to the nickel-iron had the same composition as the main mass of the unattracted portion. The relative amounts of sulphur obtained in the analyses of the attracted and unattracted portions suggest the approximate correctness of this assumption; but any variations would have only a slight effect upon the individual numbers in the bulk-analysis, since the total weight of the unattracted material is more than twenty times as great as that of the adhering material.

Results of the Chemical Analysis of the Baroti Meteorite.

The weight of the attracted portion was 1·4692 gram, that of the unattracted portion 11·3459.

Analysis of the attracted portion.

Fe	70·38
Ni	6·52
Co	0·24
SiO_2	3·42
FeO	2·20[1]
CaO	0·38
MgO	3·45
FeS {S	0·34
FeS {Fe	0·59
Insoluble	11·89
	99·41

Analysis of the unattracted portion.

SiO_2	43·53
TiO_2	0·18
Al_2O_3	2·63
Fe_2O_3	0·49
Cr_2O_3	0·20
FeO	15·35
MnO	trace
CaO	1·96
MgO	27·12
SrO	nil
BaO	nil
Na_2O	1·00
K_2O	0·05
P_2O_5	0·28
H_2O	0·19
FeS {Fe	4·74
FeS {S	2·71
	100·43

The weights taken in the analysis of the unattracted portion were, for main analysis 1·0057 gram, for sulphur 0·6746, for alkalis 0·5100, for phosphorus 0·8250, for ferrous iron 0·6974, for water and chromium 0·4157 gram.

A partial analysis of the soluble silicate, made on 6·0206 grams of the unattracted material, in order to determine the ratio of magnesium to iron, gave the following result, after deducting 12·98 per cent. of FeS and 0·87 per cent. of Fe_2O_3 as determined in the analysis of the unattracted material:—

SiO_2	31·40
FeO	20·49
MgO	32·12

These numbers indicate that the composition of the olivine may be approximately represented by the formula $3Mg_2SiO_4 . Fe_2SiO_4$.

[1] As determined from the analysis of the soluble part of the unattracted material.

Bulk-analysis, i.e. the combined result of the analyses of the attracted and unattracted material:—

		Atomic and molecular ratios.
Fe	8·13	0·1452
Ni	0·75	0·0127
Co	0·03	0·0004
FeS { Fe	4·32	0·0772
FeS { S	2·47	0·0772
SiO_2	39·68	0·6613
TiO_2	0·16	0·0020
Al_2O_3	2·40	0·0235
Fe_2O_3	0·44	0·0027
Cr_2O_3	0·18	0·0012
FeO	13·99	0·1943
MnO	trace	—
CaO	1·79	0·0320
MgO	24·71	0·6177
Na_2O	0·91	0·0147
K_2O	0·04	0·0004
P_2O_5	0·25	0·0017
H_2O	0·17	0·0094
	100·42	

Mineral composition of the Baroti meteorite, as calculated from the bulk-analysis and the known composition of the olivine ($3Mg_2SiO_4 . Fe_2SiO_4$):—

Molecular ratios.		Percentages.		
147	$Na_2O . Al_2O_3 . 6SiO_2$	7·70	10·25	Felspar
4	$K_2O . Al_2O_3 . 6SiO_2$	0·22		
84	$CaO . Al_2O_3 . 2SiO_2$	2·33		
27	$FeO . Fe_2O_3$	...	0·63	Magnetite
20	$FeO . TiO_2$	...	0·31	Ilmenite
12	$FeO . Cr_2O_3$	...	0·27	Chromite
$\frac{17}{3}$	$\{3Ca_32(PO_4) . CaO\}$	...	0·56	Apatite[1] ?
179	$CaSiO_3$	2·08	30·38	Bronzite
534	$FeSiO_3$	7·03		
2127	$MgSiO_3$	21·27		
675	Fe_2SiO_4	13·77	42·12	Olivine
2025	Mg_2SiO_4	28·35		
772	FeS	...	6·79	Troilite
1452	Fe	8·13	8·91	Nickel-iron
127	Ni	0·75		
4	Co	0·03		
94	H_2O	...	0·17	Water
			100·39	

[1] The phosphorus has been attributed to apatite rather than to schreibersite since it was found only in the unattracted material.

The Meteoric Stone of Wittekrantz, South Africa.

Fall of the Stone.

In 1898 a small fragment of a stony meteorite which fell at Wittekrantz, Beaufort West, Cape Colony, was presented to the South African Museum, Cape Town, by Dr. C. E. Piers. In answer to the inquiries made by Dr. G. S. Corstorphine, accounts of the fall were obtained from Mr. J. S. Parker, of Wittekrantz, and Mr. W. F. Savage, who witnessed the event. Mr. J. S. Parker's graphic description of the fall, as given in a letter to Dr. Corstorphine dated April 27, 1900, is as follows:—

'On the 9th of December, 1880, at about 8 a.m., I heard a most unusual noise and saw high in the air a dense stripe of smoke, and as the smoke travelled along, reports came from it like the quick firing of a rifle. The aerolite was travelling in an easterly direction, and at a great pace, for it was very soon out of hearing—only the smoke being visible. I concluded that at each report a piece of the aerolite must have sprung from the main body, as two pieces struck the ground near my house. The one we have got, but the other struck the ground about 200 yards from my dwelling-house. Before it reached the earth, it made a noise like a stone from a sling, only much louder, and that made us notice where it struck ground, which it did with such force as to bruise one end. When picked up it was so hot that it could not be touched with the naked hand and was carried to the house on a flat stone. Mr. Savage and Dr. Stewart were at my place on the morning this happened, and both saw the stone.'

The stone here described as actually seen to fall was presented by Mr. Parker to the South African Museum in 1900, and is referred to by Dr. Corstorphine in the Report of the South African Museum for that year.[1]

Mr. W. F. Savage, in a letter to Miss M. Wilman dated November 14, 1902, gives the following account:—

'The exact date I forget, but it was about eight in the morning. I and Mr. James Parker's brother Jack were busy with a purchase of some wool in front of one of the Kraals at the farm Wittekrantz, when the heat became very intense, and then we heard a rumbling noise proceeding from the direction of the Krantz, and then we heard a rattle as of musketry and the whizzing of bullets, and one particularly large one appeared to be coming our way . . . and passed us with a terrible whiz and fell to earth about 200 yards off. Shortly after, a Kaffir boy who

[1] Report of the South African Museum for 1900, Cape Town, 1901, p. 10.

saw it fall by the dust it threw up, ran across and picked it up. He could not pick it up at first for the heat; however, he managed to bring it to the house, and it was even then warm. . . . It fell on a flat stone, and simply crushed the spot it fell on to powder. The moment almost after the missile passed us the air became normally cool again.'

In a letter to Mr. W. L. Sclater, dated March 28, 1900, Dr. C. E. Piers stated how he obtained the small piece of the meteorite which he presented to the South African Museum in 1898:—

'It was presented to me some time between June, 1882, and April, 1885, when I resided at Wagenaar's Kraal in the Nieuweveld, by Mrs. Parker, the wife of — Parker, of the farm Wittekrantz, District of Beaufort West. She informed me that the meteorite in question was brought to her at the homestead by a Kaffir herdman, who was throwing it from hand to hand, it still being too hot to hold in one hand, and that he said he had seen it strike the ground near the homestead, I understood some three or four hundred yards away, and as his master was out he had brought it to his mistress. Mrs. Parker informed me that some pieces had also fallen in an adjoining farm.'

It seems probable from these accounts that two stones at least fell near the farm of Wittekrantz, one of which was seen by Mr. James S. Parker, and is the large stone presented by him to the South African Museum, while the other was the one seen by Mr. Savage, a fragment of which afterwards came into the possession of Dr. Piers.

Both specimens were sent by Dr. Corstorphine to the British Museum for examination. The larger one, after a cast had been made of it, was returned to the South African Museum. The smaller one was retained for investigation, the results of which are given in this paper.

Physical Characters.

The large stone presented by Mr. Parker weighed 4lb. 7oz. From the cast preserved in the British Museum, it appears to be a fairly complete stone, covered by the usual fused black crust, except on the edges and corners, where it appears to have been rubbed away to a large extent. The small specimen (113·5 grams) is a broken fragment of a larger stone: only small patches of fused crust remain on the unbroken surface. On the fractured surface the stone is seen to be grey and compact, and shows numerous small particles of nickeliferous iron. Troilite is not so obvious, but can be seen in thin veins and patches with a lens. One or two fairly sharply defined chondrules are also visible.

The specific gravity of the stone was found to be 3·49.

Mineral Composition.

Under the microscope in thin-slices the meteorite is seen to be very similar in character to the Baroti stone. Small patches of nickeliferous iron and troilite (in less amount) are seen scattered through a matrix consisting of confusedly arranged grains of olivine and enstatite, with a few chondrules of irregular shape and not sharply defined from the rest of the matrix. These chondrules, like those of Baroti, consist mainly of fibrous bronzite. The colourless interstitial material differs from that in the Baroti stone by being for the most part isotropic, and having an index of refraction less than that of Canada balsam.

Chemical Composition.

The analysis was made by the same method as in the case of the Baroti meteorite, excepting that no separate determination was made of the composition of the soluble part of the unattracted material. A fragment weighing about 10 grams was taken. After being powdered and separated with the magnetic comb, this yielded 1·1959 gram of attracted and 8·7383 grams of unattracted material.

Analysis of the attracted portion.	
Fe	59·49
Ni	5·82
Co	0·13
SiO_2	5·46
FeO	3·17
CaO	0·20
MgO	5·37
FeS { Fe	0·79
FeS { S	0·45
Insoluble	18·64
	99·52

Analysis of the unattracted portion.	
SiO_2	44·64
TiO_2	0·19
Al_2O_3	2·76
Fe_2O_3	0·52
Cr_2O_3	0·39
FeO	15·76
MnO	0·16
CaO	2·31
MgO	27·58
Na_2O	1·26
K_2O	0·15
P_2O_5	0·17
H_2O	0·18
{ Fe	0·50
{ Ni	0·05
{ Fe	2·39
{ S	1·37
	100·38

From the percentages of FeO, MgO, and SiO_2 in the analysis of the attracted portion, the composition of the olivine approximates to that of the olivine in the Baroti stone, viz. $3Mg_2SiO_4 . Fe_2SiO_4$.

The weights taken in the analysis of the unattracted portion were, for main analysis 1·0539 gram, for sulphur and phosphorus 0·7325, for alkalis 0·5382, for ferrous iron 0·7337, for chromium 0·9540, for water 1·0061 gram.

Bulk-analysis of the Wittekrantz meteorite (combined result of the analyses of the attracted and unattracted material):—

		Atomic and molecular ratios.
Fe	7·65	0·1366
Ni	0·75	0·0127
Co	0·02	0·0003
FeS Fe	2·20	0·0393
FeS S	1·26	0·0393
SiO_2	41·12	0·6853
TiO_2	0·17	0·0021
Al_2O_3	2·54	0·0249
Fe_2O_3	0·48	0·0030
Cr_2O_3	0·36	0·0023
FeO	14·51	0·2015
MnO	0·15	0·0021
CaO	2·12	0·0380
MgO	25·40	0·6350
Na_2O	1·16	0·0187
K_2O	0·14	0·0015
P_2O_5	0·16	0·0011
H_2O	0·16	0·0089
	100·35	

Mineral composition of the Wittekrantz meteorite as calculated from the result of the bulk analysis and the known composition of the olivine ($3Mg_2SiO_4 . Fe_2SiO_4$) is as follows:—

Molecular ratios.		Percentages.		
187	$Na_2O.Al_2O_3.6SiO_2$	9.81	11.95	Felspar
15	$K_2O.Al_2O_3.6SiO_2$	0.83		
47	$CaO.Al_2O_3.2SiO_2$	1.31		
30	$FeO.Fe_2O_3$	...	0.70	Magnetite
21	$FeO.TiO_2$	...	0.32	Ilmenite
23	$FeO.Cr_2O_3$	...	0.52	Chromite
$\frac{11}{3}$	$\{3Ca_32(PO_4).CaO\}$	...	0.37	Apatite[1]?
296	$CaSiO_3$	3.43	26.89	Bronzite
421	$FeSiO_3$	5.56		
1790	$MgSiO_3$	17.90		
760	Fe_2SiO_4	15.50	47.42	Olivine
2280	Mg_2SiO_4	31.92		
393	FeS	...	3.46	Troilite
1366	Fe	7.65	8.42	Nickel-iron
127	Ni	0.75		
3	Co	0.02		
89	H_2O	...	0.16	Water
			100.21	

The most interesting result of the investigation of these two meteoric stones is the demonstration of the close similarity in chemical and mineral composition presented by meteorites, one of which fell in South Africa in 1880 and the other in India in 1910.

As seen in the following table, these meteorites are also very closely related to the recently described[2] chondritic stone which fell at St. Michel, Finland, on July 12, 1910:—

	Baroti.	Wittekrantz.	St. Michel.
Nickel-iron	8.91	8.42	8.71
Troilite	6.79	3.46	6.11
Olivine	42.12	47.42	43.22
Bronzite	30.38	26.89	26.25
Felspar	10.25	11.95	14.63

How far this similarity extends to other chondritic meteoric stones is discussed in the following paper.

[1] See footnote, p. 27.

[2] L. H. Borgström, Bull. Comm. Géol. Finlande, 1912, No. 34.

On the remarkable similarity in chemical and mineral composition of chondritic meteoric stones.[1]

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[Read November 11, 1913.]

THE observation of the striking similarity both in chemical and mineral composition of the Baroti, Wittekrantz, and St. Michel meteorites (see the preceding paper) suggested the idea of testing how far such a close relationship applied to other chondritic meteoric stones.

The practical identity in chemical composition of different meteoric stones has been often pointed out. For example, A. E. Nordenskiöld[2] showed in the case of the stones of Erxleben, Lixna, Blansko, Ohaba, Pillistfer, Dundrum, Hessle, Orvinio, and Ställdalen that the percentage chemical compositions differed very slightly if the proportions of the metals, silicon, &c., were considered instead of the oxides. The general resemblance of chondritic stones is also very obvious in thin-sections examined under the microscope; for the most part only some of the so-called crystalline chondrites,[3] such as Hvittis, Pillistfer, Daniel's Kuil, Cléguérec, and Khairpur, distinguishing themselves at all markedly from the rest. It is this close resemblance which has rendered the possible recognition of any periodicity of falls of similar meteorites difficult.[4]

It is the object of the present note to bring into prominence these imilarities, since they appears to have been rather obscured than otherwise by the somewhat too elaborate schemes of classification which have been devised. The Tschermak-Brezina classification, which has

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

[2] A. E. Nordenskiöld, Geol. Fören. Förh. Stockholm, 1878, vol. iv, p. 56; abstract in Neues Jahrb. Min., 1879, p. 77.

[3] 'Ck' of Brezina's Classification.

[4] See G. Tschermak, Sitz.-Ber. Akad. Wien, 1907, vol. cxvi, p. 1430, and L. Fletcher, 'An Introduction to the Study of Meteorites,' 10th edit., 1908, p. 46.

been generally adopted, is based in the case of chondritic stones almost solely upon physical and structural variations, some of which are of a quite trivial character. A classification of terrestrial rocks upon similar lines would not bear contemplation, when the present embarrassing superfluity of specific rock-names is considered. Even when a terrestrial rock classification is applied to meteorites we find that its effect is to some extent to disguise rather than to emphasize similarities. This is the case with the interesting attempt which O. C. Farrington[1] has made to classify meteoric stones on the same principles as those used for the quantitative classification of igneous terrestrial rocks.[2] The difficulties, however, involved in the chemical analysis of meteoric stones, especially in respect to the apportioning of the total iron between the metallic iron, the troilite, the silicates, &c., are so great, and the methods generally employed of separating the metallic iron by means of copper chloride, mercuric chloride, or iodine are so tedious, that only in the hands of expert and very patient analysts can fairly accurate results be expected. A critical examination of the analyses quoted by Farrington shows in fact that the variations, apart from those of the nickel-iron, by which according to the quantitative system the chondritic stones are divided into groups, are in many cases simply due to errors of analysis involved in the determination of the iron according to its different conditions as to oxidation, &c. Where the percentage of ferrous oxide is higher than the average it will often be found that the iron is low and vice versa. That the amount of metallic iron has been underestimated in the case of the meteoric stones of Ergheo, Mauerkirchen, Long Island, Stavropol, and Zavid is rendered highly probable by merely a cursory examination of the specimens of these meteorites in the British Museum Collection, for they all show quite normally fair amounts of metallic iron upon polished surfaces, whereas the percentages recorded in the analyses are so small as to be either insufficient or very little more than sufficient to form troilite with the sulphur. For such reasons it appears much more probable that where, as is sometimes the case, different analyses of the same stone bring it into different groups, this result is due rather to analytical vagaries than to actual variations in different parts of the stone. What material, for example, could be more homogeneous in appearance than that of the Alfianello stone, yet in the

[1] O. C. Farrington, 'Analyses of Stone Meteorites,' Field Mus. of Natural History, Chicago, 1911, Publication 151, Geol. Ser., vol. iii, No. 9, pp. 195–229.

[2] W. Cross and others, '*Quantitative Classification of* Igneous Rocks,' Chicago, 1903.

quantitative classification it falls into two different groups, and could be placed in two more according to the data of two other analyses which have been published.[1]

Objection has been made to the quantitative classification of terrestrial rocks that in some cases it tends to separate far apart rocks which are mineralogically very similar. That it has the same tendency to disguise similarities in the case of meteorites, however, appears to be due not so much to faults in this system as to imperfections in the analytical material to which it has been applied.

Instead of considering the individual percentages of the bulk analyses as is done in the quantitative classification, I have sought to compare the mineral composition of a number of meteoric stones for which this has been determined by analyses of the soluble and insoluble silicates. The results obtained in the case of forty-one chondritic stones are given in the accompanying table (pp. 36, 37).

The table shows the remarkable similarity, if not specific identity, as regards chemical and mineral composition of these particular stones. In the case of these meteorites, when allowance is made for some variation in the amount of nickel-iron, not only are the amounts of the soluble and insoluble silicates remarkably constant, but their actual chemical composition varies very slightly, the proportion of magnesium to iron atoms in the olivine being generally about **3 : 1**, and in the bronzite **4 : 1**.

In two columns of the table are given the symbols and names of the stones in the Brezina and quantitative classifications respectively as quoted from Farrington's paper. From these it is evident that the structural and physical variations on which the Brezina classification is based have little or no connexion with changes in the chemical and mineral composition; and that in the quantitative classification the groups Estacadose, Parnallose, Pultuskose, Farmingtonose, Castaliose, and Kernouvose are practically identical. Into these groups, changes in the chemical composition relating mainly to the relative amounts of iron and ferrous oxide would bring most of the members of the Traviose and Wacondose groups, including Ergheo and the other stones referred to on p. 34, in the analyses of which too little iron is recorded. These groups account for most of the chondritic meteoric stones of which we have what have been regarded as accurate analyses.

These considerations, therefore, lead to the conclusion that almost all of the chondritic meteoric stones at present known are, apart from some

[1] See C. Friedheim, Sitz.-Ber. Berlin. Akad., 1888, p. 345.

CHEMICAL AND MINERAL COMPOSITION OF CHONDRITIC METEORIC STONES.

No.	Name of Meteorite.	Date of Fall.	Specific Gravity.	Percentage of Nickel-iron.	Ratio of Fe to Ni in Nickel-iron.	Percentage of Troilite.	Percentage of Olivine.	Ratio of Mg to Fe Atoms in Olivine.	Percentage of Insoluble Silicates (Bronzite and Felspar).	Ratio of Mg to Fe Atoms in Bronzite.	Percentage of Felspar (when determined).
1	Ausson	Dec. 9, 1858	3·54	10	9	4	45	3	37	4	8
2	Bachmut	Feb. 15, 1814	3·56	6	4	6	43	2	41	4	10
3	Baldohn	April 10, 1890	3·79	18	—	6	37	3	38	4	—
4	Baroti	Sept. 15, 1910	3·54	9	11	7	42	3	40	4	10
5	Beaver Creek	May 26, 1893	—	17	10	5	37	$3\frac{1}{2}$	40	5	—
6	Cape Girardeau	Aug. 14, 1846	3·67	18	11	6	35	3	41	5	—
7	Carcote	(Known since 1888)	3·47	10	10	6	40	$2\frac{1}{2}$	41	4	—
8	Chantonnay	Aug. 5, 1812	—	8	6	6	42	3	41	4	—
9	Cléguérec (Kernouvé)	May 22, 1869	3·75	20	12	6	35	3	40	4	—
10	Dhurmsala	July 14, 1860	3·40	8	$4\frac{1}{2}$	6	48	4	34	4	—
11	Estacado	(Found in 1902)	3·63	14	9	4	41	2	42	4	—
12	Farmington	June 25, 1890	—	8	7	5	46	3	41	3	—
13	Hessle	Jan. 1, 1869	3·74	19	8	5	42	3	33	4	10
14	Honolulu	Sept. 27, 1825	—	4	2	6	48	2	38	$4\frac{1}{2}$	7
15	Khetri	Jan. 19, 1867	3·68	18	—	5	35	3	42	4	—
16	Lesves	April 13, 1896	3·57	8	8	6	46	$2\frac{1}{2}$	38	3	—
17	Linn County	Feb. 25, 1847	—	$10\frac{1}{2}$	9	6	42	3	41	3	—
18	Lixna	July 12, 1820	3·73	15	8	6	39	$2\frac{1}{2}$	38	5	6
19	Lundsgård	April 3, 1889	3·61	12	5	6	41	3	39	4	—
20	Makariwa	(Found in 1879)	—	5	4	6	49	3	39	3	—
21	Meuselbach	May 19, 1897	3·47	8	7	8	39	$2\frac{1}{2}$	38	4	—
22	Mezö-Madaras	Sept. 4, 1852	—	10	5	6	42	3	40	3	—
23	Modoc	Sept. 2, 1905	3·54	5	10	4	46	3	44	4	14
24	Muddoor	Sept. 21, 1865	—	9	7	4	44	3	41	3	—
25	Nerft	April 12, 1864	—	6	4	$5\frac{1}{2}$	46	$2\frac{1}{2}$	39	4	10
26	Rakovka	Nov. 20, 1878	3·58	7	4	6	44	3	41	4	—
27	Richmond	June 4, 1828	3·37	8	7	4	46	4	42	3	—
28	St. Christophe	Nov. 5, 1841	—	9	4	7	43	3	40	4	8
29	St. Denis-Westrem	June 7, 1855	—	8	6	5	46	$2\frac{1}{2}$	39	4	13
30	St. Michel	July 12, 1910	3·56	9	11	6	43	3	41	4	15
31	Searsmont	May 21, 1871	3·70	15	10	3	43	3	39	3	—
32	Sevrukovo	May 11, 1874	3·50	16	8	5	48	4	31	4	—
33	Shelburne	Aug. 13, 1904	3·50	8	10	5	45	3	41	4	13
34	Tennasilm	June 28, 1872	3·53	7	5	6	44	2	42	4	—
35	Tjabé	Sept. 19, 1869	—	14	10	6	40	3	40	5	—
36	Tourinnes-la-Grosse	Dec. 7, 1863	3·61	12	5	6	41	3	39	4	—
37	Utah	(Found in 1869)	3·66	17	11	5	40	3	36	5	—
38	Utrecht	June 2, 1843	3·61	9	—	5	43	3	42	3	—
39	Winnebago County	May 2, 1890	3·80	19	14	6	36	4	38	$4\frac{1}{2}$	—
40	Wittekrantz	Dec. 9, 1880	3·49	$8\frac{1}{2}$	10	$3\frac{1}{2}$	47	3	39	4	12
41	Zomba	June 25, 1899	3·54	$8\frac{1}{2}$	7	5	42	3	44	4	9

No.	Symbol in Brezina's Classification.	Name in Quantitative Classification.	Analyst.	Reference.
1	Cc	Pultuskose	A. A. Damour	C. R. Acad. Sci. Paris, 1859, **49**, 31
2	Cw	Castaliose	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 18
3	Cc	—	E. Johanson	Neues Jahrb. Min., 1892, i, 104
4	Cw or Ro	—	G. T. Prior	Mineral. Mag., 1913, **17**, 22
5	Cck	Pultuskose	W. F. Hillebrand	Amer. Journ. Sci., 1894, **47**, 430
6	Cc	Farmingtonose	S. L. Penfield	Amer. Journ. Sci., 1886, **32**, 230
7	Ck	Parnallose	W. Will	Neues Jahrb. Min., 1889, ii, 177
8	Cgb	—	C. Rammelsberg	Zeits. Deutsch. Geol. Ges., 1870, **22**, 889
9	Cka	Kernouvose	F. Pisani	C. R. Acad. Sci. Paris, 1869, **68**, 1489
10	Ci	Pultuskose	S. Haughton	Proc. Roy. Soc. London, 1866, **15**, 214
11	Ckb	Estacadose	J. M. Davison	Amer. Journ. Sci., 1906, **22**, 59
12	Csa	Farmingtonose	L. G. Eakins	Amer. Journ. Sci., 1892, **43**, 66
13	Cc	Pultuskose	G. Lindström	K. Svenska Vet. Akad. Handl., 1870, **8**, No. 9
14	Cwa	—	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 1
15	Cgb	Pultuskose	D. Waldie	Journ. Asiatic Soc. Bengal, 1869, **38**, 2, 252
16	Cw	Parnallose	A. F. Renard	Bull. Acad. Roy. Belg., 1896, **31**, 654
17	Cwa	—	C. Rammelsberg	Monatsber. Akad. Berlin, 1870, **70**, 457
18	Cga	Pultuskose	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 1
19	Cw	Parnallose	O. Nordenskjöld	Geol. Fören. Förh., 1891, **13**, 470
20	Cgb	—	L. Fletcher	Mineral. Mag., 1894, **10**, 287
21	Ccka	Estacadose	G. Linck	Ann. Naturhist. Mus. Wien, 1899, **13**, 103
22	Cgb	Estacadose	C. Rammelsberg	Zeits. Deutsch. Geol. Ges., 1871, **23**, 734
23	Cwa	Castaliose	W. Tassin	Amer. Journ. Sci., 1906, **21**, 359
24	Cc	—	F. Crook	Inaug.-Diss., Göttingen, 1868, 33
25	Cia	Estacadose	A. Kuhlberg	Ann. Phys. Chem. (Pogg.), 1869, **136**, 448
26	Ci	Parnallose	P. Grigoriew	Zeits. Deutsch. Geol. Ges., 1880, **32**, 417
27	Cck	Pultuskose	C. Rammelsberg	Monatsber. Akad. Berlin, 1870, **70**, 440
28	Cg	Pultuskose	A. Lacroix	Bull. Soc. Sci. Nat. Ouest France, 1906, **6**, 81
29	Cca	Pultuskose	C. Klement	Bull. Mus. Hist. Nat. Belg., 1886, **4**, 280
30	Cw or Ro	Estacadose	L. H. Borgström	Bull. Comm. Géol. Finl., 1912, No. 34
31	Cc	Pultuskose	J. L. Smith	Amer. Journ. Sci., 1871, **2**, 200
32	Cs	—	A. Eberhard	Archiv Naturk. Dorpat, 1882, **9**, 115
33	Cg	Pultuskose	L. H. Borgström	Trans. Roy. Astron. Soc. Canada, 1904
34	Cca	—	G. Schilling	Archiv Naturk. Dorpat, 1882, **9**, 95
35	Ck	—	E. H. Baumhauer	Archiv. Néerl., 1871, **6**, 305
36	Cw	Parnallose	F. Pisani	C. R. Acad. Sci. Paris, 1864, **58**, 169
37	Cgb	Pultuskose	S. L. Penfield	Amer. Journ. Sci., 1886, **32**, 228
38	Cca	Farmingtonose	E. H. Baumhauer	Ann. Phys. Chem. (Pogg.), 1845, **66**, 465
39	Ccb	—	L. G. Eakins	Amer. Journ. Sci., 1890, **40**, 319
40	Ci	—	G. T. Prior	Mineral. Mag., 1913, **17**, 28
41	—	—	L. Fletcher	Mineral. Mag., 1901, **13**, 1

variation in the amount of nickel-iron, practically identical in chemical and mineral composition, the identity extending in the main even to the chemical composition of the olivine and pyroxene.

The type to which most chondritic meteoric stones approximate has in round numbers the following percentage mineral composition :—

Nickeliferous Iron (in which Fe : Ni is about 10) ...	9
Troilite	6
Olivine (in which Mg : Fe = 3)	44
Bronzite (in which Mg : Fe = 4)	30
Felspar (Oligoclase)	10
Chromite, &c.	1
	100

How far this may be too wide a generalization can only be definitely shown by analyses of chondritic stones not hitherto examined and by new accurate analyses to replace many of the older ones; and for this purpose analyses made with all care by the simple time-saving method described in a previous paper (p. 24) might suffice.