

- I. "On the Mineral Constituents of Meteorites." By NEVIL STORY-MASKELYNE, M.A., Professor of Mineralogy in the University of Oxford, and Keeper of the Mineral Department, British Museum. Communicated by Prof. H. J. STEPHEN SMITH. Received October 9, 1869.

(Abstract.)

*I. The Application of the Microscope to the Investigation of Meteorites.*

The difficulties in the way of the complete investigation of a meteorite resemble those we meet with in terrestrial rocks. In both the ingredient minerals are minute, and are often, especially in the case of the aërolitic rock, very imperfectly crystallized. Moreover the methods for separating them, whether mechanically or chemically, are very incomplete. With a view to obtain some more satisfactory means of dealing with these aggregates of mixed and minute minerals, I sought the aid of the microscope, by having in the first place sections of small fragments cut from the meteorites so as to be transparent.

One may learn, by a study and comparison of such sections, something concerning the changes that a meteorite has passed through; for one soon discovers that it has had a history, of which some of the facts are written in legible characters on the meteorite itself; and one finds that it is not difficult roughly to classify meteorites according to the varieties of their structure. In this way one recognizes constantly recurring minerals; but the method affords no means of determining what they are. Even the employment of polarized light, so invaluable where a crystal is examined by it of which the crystallographic orientation is at all known, fails, except in rare cases, to be a certain guide to even the system to which such minute crystals belong. It was found that the only satisfactory way of dealing with the problem was by employing the microscope chiefly as a means of selecting and assorting out of the bruised débris of a part of the meteorite the various minerals that compose it, and then investigating each separately by means of the goniometer and by analysis, and finally recurring to the microscopic sections to identify and recognize the minerals so investigated. The present memoir deals with the former part of this inquiry. Obviously the amount of each mineral thus determined, after great care and search, can only be extremely small, as only very small amounts of a meteorite can be spared for the purpose, notwithstanding that as large a surface as possible of its material requires to be searched over for instances of any one of the minerals occurring in a less than usually incomplete form. On this account one has to operate with the greatest caution in performing the analysis of such minerals; and the desirability of determining the silica with more precision than is usually the case in operations on such minute quantities of a silicate suggested to me the process, which, after several experiments in perfecting it, assumed the following form.

II. *On the Method of Analyzing Silicates that do not gelatinize with Hydrogen Chloride.*

The process is conducted in an apparatus of the following construction. A platinum retort, 30 cub. centims. in capacity, is fitted with a tubulated stopper of the same material, which reaches nearly to the bottom; a small tube entering the vertical tube of the stopper at an angle, above the neck of the retort, conveys hydrogen to its interior. The vertical tube can be closed either by a stopper of platinum or by a funnel of that metal, stopped in like manner at the top, and having a fine orifice at its lower extremity.

To the side of the retort, just below its neck, a straight delivery-tube is fixed, which in its turn fits into another platinum tube that, after taking a curve into a vertical position, is enlarged into a cylinder, which passes a considerable distance down a test-tube. The latter, into which the delivery-tube is fitted with a cork, holds 7.5 cub. centims., or 6.6 grammes of strong ammonia of the spec. gravity 0.88.

The gas-delivery tube inserted in the side of this receiver dips into some more ammonia in a second test-tube.

The pounded mineral, from 0.2 to 0.5 gramme in quantity, and a small platinum ball, are placed in the retort, and the stopper luted to it with gutta percha, and cemented air-tight in its place with caoutchouc and gutta-percha varnish. The funnel, filled with perfectly pure hydrogen fluoride, is now introduced into the tubulure of the stopper, the tap opened, and the acid allowed to run down into the retort. This acid contains about 32 per cent. of absolute hydrogen fluoride—that is to say, a funnel of this reagent contains 1.12 gramme of acid, capable of rendering gaseous 0.84 gramme of silica, and of neutralizing 0.95 gramme of ammonia. The funnel is now replaced by a little platinum stopper, and the orifice secured air-tight with gutta-percha varnish. Pure hydrogen is then allowed slowly to traverse the entire apparatus, the retort is placed in a water-bath at 100°C. for two hours, and occasionally slightly shaken to set the ball rotating. During the operation a trace only of silicium difluoride passes over.

The retort is next transferred to a paraffin-bath, and the temperature is cautiously raised. At first hydrogen fluoride passes over, and at this point of the process the flow of hydrogen requires some attention to prevent regurgitation of the ammonia. At about 132°C., in the case of the silicates mentioned in this memoir, the silica first becomes visible in fine flocks in the ammonia of the receiver, and in another minute the whole is cloudy.

In eight minutes the rise of the thermometer to 145°C. has brought over so much difluoride that the contents of the tube are semisolid, and nearly the whole of it has passed over. The temperature is then raised to 150°C., and the retort allowed to cool. The process is next repeated with a fresh charge of acid and ammonia. If no more than 0.2 gramme of silicate be taken, twice charging of the retort is sufficient; but with 0.5 gramme three or four repetitions of the process are required. In short, the operation is continued with fresh reagents till no flock of silica forms

in the receiver. Finally, 0.75 cub. centim. of sulphuric acid is introduced into the retort, and the temperature again raised to  $160^{\circ}\text{C}.$ , the stream of hydrogen being continued as before.

The several ammoniacal charges are poured into a platinum dish, together with the washings of the delivery-tube and the two test-tubes, and slowly evaporated in a water-bath, with continued stirring.

At a point in the evaporation just before the solution becomes neutral and the ammonium fluoride begins to turn acid, the entire silica in the dish will have been dissolved by the fluoride. The process is gradual, but the moment when the solution is complete is easily determined. Then, the dish being removed, potassic chloride is added in slight excess, together with absolute alcohol equal in volume to the contents of the platinum vessel. Potassium fluosilicate precipitates, which, after the lapse of twenty-four hours, is filtered, washed with a mixture of equal volumes of absolute alcohol and water, dried, and weighed. The results are accurate. In the retort are the bases in the form of sulphates, the treatment of which calls for no further remark.

### III. *The Busti Aërolite of 1852.*

This meteorite fell on the 2nd of December, 1852, about six miles south of Busti, a station halfway between Goruckpoor and Fyzabad in India, and nearly in lat.  $26^{\circ} 45' \text{ N.}$  and long.  $82^{\circ} 42' \text{ E.}$  For an account of the circumstances attending its fall I am indebted to Mr. George Osborne, at that time resident at Busti, and who presented this stone (the only specimen of the fall that he was able to procure) to the East India Company. Mr. Osborne states that the fall took place at ten minutes past ten in the morning, and was attended by an explosion louder than a thunder-clap, and lasting from three to five minutes. At Goruckpoor the report appeared to approach in a direction from N.N.W.; at Busti the sound seemed to come from the zenith, and proceed in a somewhat easterly course.

The explosion that shattered the meteorite must have occurred soon after its passing the longitude of Goruckpoor. There was no cloud in the sky at the time. The stone, which weighed about 3 lbs., was presented to the collection at the British Museum by the Secretary of State for India.

The Busti aërolite bears a great resemblance to the stone that fell on the 25th of March, 1843, at Bishopsville, South Carolina, U.S. A crust, coating the larger part of the stone, was of a dark yellowish brown, with a few yellowish-white porphyritic-looking patches at its flat end, whilst a yellowish enamel, mingled with dark grey, covered a hollow portion on one side of the stone.

It is difficult to refer these markings to the minerals underlying them, a similar crust covering both the augite and enstatite of the meteorite. They are probably due to the alterative action of the oxidized products of the nickeliferous iron on the silicates in a state of fusion during the rapid passage of the stone through the atmosphere.

The meteorite consists for the most part of the mineral enstatite; at one end, however, was imbedded a number of small chestnut-brown spherules, in which again a lens enabled me to detect minute octahedral crystals, having the lustre and colour of gold.

These two minerals seem scarcely to have been affected by the heat that fused the silicates which surround and encrust them.

#### IV. *Sulphide of Calcium* (Oldhamite).

This mineral occurs in the Busti aërolite, and sparsely in that which fell at Bishopville, imbedded in augite, or enstatite, or both of them. It has a pale chestnut-brown colour, and forms small, nearly round spherules, whose outer surface is generally coated with calcium sulphate. It cleaves with equal facility in three directions, which give normal angles, averaging  $89^{\circ} 57'$ , and are no doubt really  $90^{\circ}$ . Its system, therefore, is cubic; indeed in polarized light it is seen to be devoid of double refraction. Its specific gravity is 2.58, and its hardness 3.5 to 4. With boiling water it yields calcium polysulphides, and in acids it easily dissolves with evolution of hydrogen sulphide. Chemical analyses indicated the following as its composition:—

	I.	II.
Oldhamite { Calcium monosulphide . . . . .	89.369	90.244
{ Magnesium monosulphide . . . . .	3.246	3.264
Gypsum . . . . .	3.951	4.189
Calcium carbonate . . . . .	3.434	—
Troilite . . . . .	—	2.303
	100.000	100.000

The presence of such a sulphide in a meteorite shows that the conditions under which the ingredients of the rock took their present form are unlike those met with in our globe. Water and oxygen must have alike been absent. The existence of iron in a state of minute division, as often found in meteorites, leads to a similar conclusion. But if we bear in mind the conditions necessary for the formation of pure calcium sulphide, the evidence imported into this inquiry by the Busti aërolite seems further to point to the presence of a reducing agent during the formation of its constituent minerals; whilst the crystalline structure of the Oldhamite and of the Osbornite must certainly have been the result of fusion at an enormous temperature. The detection of hydrogen in meteoric iron by Professor Graham tends to confirm the probability of the presence of such a reducing agent.

#### V. *Osbornite*.

The golden-yellow microscopic octahedra imbedded in the Oldhamite were furnished by the analyses of that mineral to the amount of only 0.0028 gramme, and though upwards of 150 in number, were capable of being measured by the goniometer.

This microscopic mineral I wish to name Osbornite, in honour of Mr.

Osborne and in commemoration of the important service that gentleman rendered to science in preserving and transmitting to London in its entirety the stone which his zeal saved at the time of its fall.

That the octahedra of Osbornite are regular was proved by angles of even such microscopic crystals giving measurements over the edges and solid angles that accorded within 3' with those of the regular octahedron.

The crystals are brittle, and their powder retains the beautiful yellow colour of the surface, which is therefore intrinsic, and not a tarnish. The amount of them available for analysis being so minute, their chemical examination was attended with much difficulty. Boiled for a long time in the strongest hydrogen chloride, they were unchanged, and hydrogen fluoride was apparently without action on them. They passed unscathed through a fusion with potassio-sodium carbonate. When heated on a splinter of porcelain in a current of dry chlorine, the crystals glowed for a few seconds, lost their metallic lustre, and became of a honey-yellow colour, while a white sublimate formed on the walls of the tube. Exposed to the air, the altered crystals deliquesced, and assumed a pasty consistence; in water they dissolved partially, forming an alkaline solution, in which ammonium oxalate produced a precipitate. The insoluble portion was taken up for the most part by hydrogen chloride, and its solution gave a decided precipitate with the above reagent. The water through which the chlorine was allowed to escape, and the sublimate in the tube, after treatment with hydrogen chloride, were taken together, and found, on examination, to give a white precipitate with barium chloride, the filtrate from which, after the excess of barium had been removed, furnished with ammonia a precipitate resembling alumina, which, however, was insoluble in potash, and was thrown down from slightly acid solutions with sodium hyposulphite, and potassium sulphate. It was examined for titanio acid by means of magnesium wire in a slightly acid solution, but with a negative result. The only alternative left was to conclude that the substance which exhibited this deportment was either titanium or zirconium, and that the gold-like crystals were a combination of this element with calcium (perhaps a little iron) and sulphur in some remarkably stable form. That this mineral should be a compound of the sulphides of these metals merely is scarcely conceivable when its power to withstand the action of acids is considered; possibly its composition, if it could be quantitatively analyzed, would be found to be that of a compound of titanium or zirconium and calcium of the obscure kind that is known as an oxysulphide.

Mr. Sorby, who has made the zirconium and titanium group of metals the subject of special study, formed a microscopic borax bead, into which he introduced some of the oxide obtained from the Osbornite. He found it to behave as titanio acid.

The occurrence of Osbornite occasionally in the augite presently to be described, and the fact of the latter mineral lying chiefly in that part of the meteorite where the Osbornite is found, suggested the possibility of the

presence of this metal of the zirconium group in the augite itself,—an assumption confirmed by experiment. The dichroism of this augite is strongly marked, especially through the face 0 1 0, which in one position exhibits a tint resembling that of the blue anatase of Brazil, due apparently to minute scales permeating the crystal, and visible only in the microscope. These scales may possibly be the Osbornite sufficiently thin to be transparent, and may be the cause of the beautiful golden metallic reflection which characterizes the face 1 0 0 of the augite.

#### VI. *The Augitic Constituent of the Busti Aërolite.*

Associated with the spherules of Oldhamite that have been described as occurring in a nodule of this aërolite, and less plentifully distributed through the rest of its mass, is the silicate already alluded to as a variety of augite, and as containing traces of titanium or zirconium oxide. This silicate occurs in crystalline grains of a pale violet-grey colour, intimately mixed with another silicate presently to be described. When isolated, these grains present a few crystal faces, among which one as a cleavage-plane is prominent. So imperfect are the rest, that they furnished reliable measurements only with extreme difficulty. These determinations, however, together with its optical characters, proved that the mineral belongs to the oblique system. The measurements gave the following approximate values:—

		Angles found.	Angles of diopside.
0 0 1	1 0 0	About 75° 30'	73° 59'
0 0 1	1 1 0	About 81°	79° 29'
1 1 0	1 0 0	45° 54' to 47° 26'	46° 27'
1 1 0̄	1 1 0*	85° 8' to 86° 20'	87° 5'
1 0 0	1 1 1 (?)	53° 25' to 54° 15'	53° 50'
0 0 1	1 1 0	100° 8'	100° 57'

The plane containing the optic axis is perpendicular to the edge 1 0 0, 1 0 0, and the optical character in the centre of the field is negative on looking down the second mean line, which makes angles about 22° 45' and 52° 30' with the normals to the faces 0 0 1 and 1 0 0 respectively.

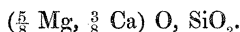
Two analyses of this mineral by the method described gave the following results:—

	I.	II.	Mean oxygen ratios.
Silicic acid . . . . .	55·389	55·594	29·928
Magnesia . . . . .	23·621	23·036	9·331
Lime . . . . .	20·02	19·942	5·709
Iron oxide . . . . .	0·78	0·309	
Soda . . . . .	0·554	[0·554]	
Lithia . . . . .	trace	[trace]	
	100·364	99·435	

Viewed as a magnesium calcium silicate, the percentage composition becomes—

Silicic acid . . . . .	56·165	56·604
Magnesia . . . . .	23·612	23·585
Lime . . . . .	20·223	19·811
	<hr/> 100·000	<hr/> 100·000

The second column gives the percentage composition according with the formula .



Such a formula does not accord with those of the ordinary varieties of augite, in which calcium is usually present in at least as high a ratio in equivalents as the magnesium. A deduction, however, of a certain amount of purely magnesian enstatite corresponding in chemical type to the augite has to be made by reason of the presence of the white mineral intercalated in layers along a direction parallel to the plane 0 0 1, and sometimes to a second plane. This white mineral is, there can be no doubt, the mineral next to be described, and its presence would modify the apparent formula of the augite as derived from analysis, increasing the magnesia.

The trace of the titanoid element in this mineral is included with the iron oxide in the above analyses.

#### VII. *On the Occurrence of Enstatite in the Busti Aërolite.*

Besides the augite already described there occurs in this meteorite another silicate which constitutes its most important ingredient. The augite is chiefly found in the nodule with the calcium sulphide, and is found more sparsely in the remaining parts. Associated with it throughout, and otherwise forming the chief mass of the stone, is a mineral which, in microscopic sections, presents the appearance of a number of more or less fissured crystals of varying transparency, some clear, some nearly opaque, and usually presenting a not very unsymmetrical polygonal outline. Those crystals are imbedded in a magma of fine-grained silicate, itself often entangled in an irregular meshwork of opaque white mineral. Amongst these ingredients, when mechanically separated, what seems to be three different minerals can be distinguished. The rarest of them is transparent and colourless, and very irregular in the form of its fragments; a second is of a greyish-white colour, translucent, and offering an even less hopeful problem to the crystallographer than that presented by the first. The third is an opaque mineral with a distinct cleavage following the faces of a prism of about  $\frac{88 \cdot 35}{91 \cdot 27}$ , and with a second imperfect cleavage perpendicular to the former. From a few fragments of the two former kinds some measurements were obtained, which conduct to the conclusion that, like the last-mentioned silicate, these minerals are enstatite. The angles 1 0 0, 1 1 0 are  $46^\circ 25'$ , and 1 0 0, 1 0 1,  $41^\circ 34'$ .

Chemical analysis confirmed the identity of these three minerals by

showing them to be enstatite under different aspects. When lime is absent it presents itself as a simply prismatic mineral, the dark-grey tabular variety. When lime is present, though to an amount less than two per cent., the crystalline structure becomes more complex. The augite may perhaps be tessellated, as it were, in the enstatite, somewhat as this latter mineral has been shown to occur intercalated to a small amount in layers of augite. I did not succeed in establishing this point, however, by an examination of microscopic sections of this mineral.

The crystalline fragments frequently show, when examined by polarized light, a composite structure, the principal sections of the different parts of the mineral being disposed at every angle of mutual inclination.

The analysis of these minerals yielded the following numbers :—

	Dark Grey Tabular Variety.		Transparent White Variety.	
	Per-centages.	Oxygen ratios.	Per-centages.	Oxygen ratios.
Silicic acid....	57·597	30·718	58·437	31·166
Magnesia .....	40·64	16·238	38·942	15·564
Lime.....	—		1·677	0·479
Iron oxide....	1·438		1·177	
Potash .....	0·394		0·332	
Soda.....	0·906		0·357	
	100·975		100·922	

Semitransparent Grey Variety.					
	Per-centages.	Oxygen ratios.	Per-centages.	Oxygen ratios.	Oxygen ratios.
	I.		II.	III.	
Silicic acid..	57·037	30·419	57·961	57·754	30·802
Magnesia ...	40·574	16·117	39·026	38·397	15·247
Lime.....	2·294	0·655	1·524	2·376	0·678
Iron oxide ..	0·867		0·154	0·423	
Potash .....	—		0·569	0·569	
Soda .....	—		0·68	0·657	
Lithia.....	—		—	0·016	
	100·772		99·914	100·192	

As in the case of the augite, the soda is probably derived from the hydrogen chloride; the iron occurs partly as metal, minutely subdivided, partly as oxide combined with the magnesium silicate. In each case the bases slightly exceed the amount required by the formula of enstatite. On comparing these with known analyses, and those which I shall shortly submit to the Society, it seems highly probable that, where the conditions under which a meteoric silicate has been formed were such that silicic acid was present in excess of that required by the formula of enstatite, this acid



remains uncombined in the form of crystallized silica with the specific gravity of a fused quartz, and that where magnesia and other bases are in excess, a basic silicate with the formula of olivine absorbs the supplementary portion of these bases. Calcium, when present, would convert into augite its equivalent ratio of what would otherwise constitute enstatite, and it is possible that this is true even when this element is distributed in small quantities throughout the mass.

No alumina, and consequently no feldspathic ingredient, has been detected in this meteorite.

### VIII. *Composition of the entire Meteorite.*

With the view of determining the different ingredient minerals present in the Busti meteorite, fragments and dust from the neighbourhood of the nodule of sulphide and augite were analyzed. The mineral was treated with hydrogen chloride, carbon disulphide, and potash, which removed 16·873 per cent., leaving a residue of 83·127 per cent.; the composition of these two portions, soluble and insoluble, is given below:—

	Soluble portion.		Insoluble portion.	
	Per-centages.	Oxygen ratios.	Per-centages.	Oxygen ratios.
Calcium sulphate. . . .	0·442			
Calcium sulphide. . . .	4·133			
Iron oxide . . . . .	0·194	....	0·891	
Silicic acid . . . . .	6·514	3·474	46·357	24·727
Lime. . . . .	0·022	0·006	12·375	3·535
Magnesia. . . . .	5·055	2·02	23·266	9·299
Potash. . . . .	0·099		0·14	
Soda. . . . .	0·118		0·455	
Lithia. . . . .	—		0·019	
	16·577		83·503	

The ratio of the silicic acid to the magnesia and lime in the latter analysis corresponds with the composition ( $\frac{3}{4}\text{Mg}\frac{1}{4}\text{Ca}$ )O, SiO<sub>2</sub>. Regarding the calcium of the white and grey varieties of enstatite to be present as augite intercalated with the enstatite, we may assert that while all the silicates of this meteorite present the typical formula MO, SiO<sub>2</sub>, three equivalents of the rock near the nodule may be treated as composed of two equivalents of augite and one of enstatite; in other parts of the stone the latter mineral predominates.

A formula for the augite with magnesium and calcium in equal proportions would no doubt more truly represent its composition; it is, however, as impossible to separate the enstatite intercalated with it as it is to remove this mineral when blended with the enstatite.

### IX. *Solubility of the Minerals of the Busti Meteorite.*

As it appears of importance to determine the degree to which these

meteoric minerals were soluble in acid, the augite and enstatite were submitted to this solvent action. Digested for several hours at 100° C. in hydrogen chloride diluted with half its volume of water, and subsequently in potash for some hours to remove the free silica, the augite and each of the three forms of enstatite proved to be acted upon, the results in all cases showing that the acid simply exercises a solvent action on the mineral, without separating it into two or more distinct silicates.

The subjoined Table gives the results of the experiments. The degree in which the acid dissolved the mineral was due to the more or less complete trituration of the material before treatment. In one case, for which the transparent variety was selected, a repetition of the process three times gave results that left no doubt as to the nature of the action of the acid.

Of the greyish-white variety of enstatite, after treatment for 20 hours with acid and 12 hours with potash, 9·414 per cent. dissolved, an analysis of which is given in column I.

Of the grey tubular variety of enstatite, after treatment with acid for 16 hours and with potash for a similar time, 7·779 per cent. dissolved, that gave on analysis numbers the approximate value of which is found in column II.

Of the white variety, after the first treatment for 20 hours with acid and subsequently with potash, 12·68 per cent. dissolved, the composition of which is given in column III. By a second treatment of the residual enstatite from this experiment, after 2 hours' trituration with acid for 30 hours and potash for 12 hours, 67·84 per cent. dissolved; and on subjecting the mineral to a third treatment in a similar way, 51·18 per cent. were dissolved in acid and potash. In the last of these experiments the ratio of the silica to the bases, neglecting the small amount of the former dissolved in the acid, is as 58·4 to 42·0, that of an analysis of an enstatite being as 58·4 to 41·6.

The solubility of the augite was determined by subjecting it to similar treatment with acid during 18 hours, and with potash for a like time, these reagents removing 7·384 per cent. of the mineral.

	I.	II.	III.
Silicic acid . . . . .	5·408	5·141	6·724
Magnesia . . . . .	2·367	1·353	4·61
Lime . . . . .	1·048	0·27	0·432
Iron oxide, &c. . . . .	0·187	0·676	0·576
Potash . . . . .	0·121	0·528	0·504
Lithia . . . . .	—	trace	trace
	9·131	7·968	12·846
Soda found . . . . .	[0·126]	[1·217]	[1·042]

#### X. *The Iron of the Busti Meteorite.*

A small pepita of the iron contained in the meteorite was analyzed.

Omitting the silicate attached to the iron, the results of the analysis were as follow :—

Iron-nickel alloy .....	98.798
Iron.....	94.949
Nickel.....	3.849
Schreibersite.....	1.202
Iron.....	0.884
Nickel.....	0.234
Phosphorus.....	0.084
	<hr/> 100.000

The quantity was far too small to encourage a search for cobalt and other metals.

Besides the nickeliferous iron, which is disseminated very sparsely, and in particles singularly unequal in size and distribution, and with which troilite is associated in very small quantity, chromite is present as a constituent of small but appreciable amount. The crystals of this mineral are distinct and brilliant, and sometimes present good angles for measurement. One gave the solid angle of a regular octahedron.

*The Manegaum Meteorite of 1843.*

This meteorite fell at Manegaum in Khandeish, India, on the 26th July, 1843. Only a small fragment was preserved, and of this a portion was given by the Asiatic Society of Bengal to the British Museum in 1862. In 1863 I described its appearance as seen in section in the microscope, and gave the particulars of its fall (*Phil. Mag.* August 1863).

From the minuteness of the specimen I had very little material to work upon. One mineral is conspicuous in the stone, namely, a primrose-coloured transparent crystalline silicate in small grains, loosely cemented by a white flocculent mineral. This greenish-yellow mineral (I.) and a fragment of the entire meteorite (II.) were analyzed, and crystalline grains of the former were measured on the goniometer. The prism angles (1) for the prism {1 1 0} were about  $\frac{88^\circ}{92^\circ}$ , and (2) for the prism {1 0 1} were  $\frac{81^\circ 52'}{98^\circ 8'}$ , for {1 0 0, 1 1 0} about  $46^\circ$ ; for {1 0 0, 1 0 1},  $49^\circ 4'$ ; and for {1 1 0, 1 0 1}  $58^\circ 39'$ .

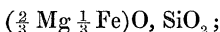
The analyses gave the following numbers :—

	I.	Oxygen ratios.	II.	Oxygen ratios.
Silicic acid.....	55.699	29.706	53.629	28.602
Magnesia .....	22.799		23.32	
Iron oxide .....	20.541	14.059	20.476	14.305
Lime .....	1.316		1.495	
Chromite .....	—		1.029	
	<hr/> 100.355		<hr/> 99.949	

The specific gravity of the granular mineral is 3·198, and its hardness 5·5.

The result of the above analyses is to show that, except for a little chromite and a little augite, with possibly in the crystallized mineral a little free silica, both that mineral and the collective silicate of the stone consist of a ferriferous enstatite.

The formula most in accordance with the analysis would be



that of the enstatite in the Breitenbach meteorite is  $\left(\frac{4}{5} \text{Mg } \frac{1}{5} \text{Fe}\right)\text{O}, \text{SiO}_2$ .

The bulk of the Busti meteorite consists of a purely magnesian enstatite; this of Manegaum is almost entirely an enstatite richer in iron than any yet examined. Both bear evidence to the white flocculent mineral which characterizes the microscopic sections of many meteorites, being composed of this now important mineral enstatite.

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In publishing the results I have obtained in the attempt, so far as this memoir goes, to treat exhaustively of the mineralogy of two important meteorites, I wish to record the obligations I am under to Dr. Flight, Assistant in my Department at the British Museum, for his valuable aid in the chemical portion of the inquiry.

## II. "On Fluoride of Silver.—Part I. By GEORGE GORE, F.R.S. Received October 5, 1869.

(Abstract.)

This communication treats of the formation, preparation, analysis, composition, common physical properties, and chemical behaviour of fluoride of silver.

The salt was prepared by treating pure silver carbonate with an excess of pure aqueous hydrofluoric acid in a platinum dish, and evaporating to dryness, with certain precautions. The salt thus obtained invariably contains a small amount of free metallic silver, and generally also traces of water and of hydrofluoric acid, unless special precautions mentioned are observed. It was analyzed by various methods: the best method of determining the amount of fluorine in it consisted in evaporating to dryness a mixture of a known weight of the salt dissolved in water, with a slight excess of pure and perfectly caustic lime in a platinum bottle, and gently igniting the residue at an incipient red heat until it ceased to lose weight. By taking proper care, the results obtained are accurate. The reaction in this method of analysis takes place according to the following equation,  $2\text{AgF} + \text{CaO} = \text{CaF}_2 + 2\text{Ag} + \text{O}$ . Sixteen parts of oxygen expelled equal thirty-eight parts of fluorine present. One of the methods employed for determining the amount of silver consisted in passing dry ammonia over the salt in a platinum boat and tube at a low red heat. The results ob-