Mallet

Coon Butte

Dupl.

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A STONY METEORITE FROM COON BUTTE, ARIZONA.

By J. W. MALLET, University of Virginia.

ART. XXX.—*A Stony Meteorite from Coon Butte, Arizona;*
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I WAS told of the existence of the aërolite described in this paper by Mr. D. Moreau Barringer of Philadelphia, who found and owns the specimen, and has permitted me to examine and describe it.

Mr. Barringer and Mr. Benjamin C. Tilghman, members of the Academy of Natural Sciences of Philadelphia, have for some time been engaged in exploration at the locality known as Coon Butte in Coconino County, Arizona, whence large quantities of meteoric iron—commonly called Canyon Diablo iron—have been brought, and these gentlemen have recently sent a paper to the Philadelphia Academy on the subject of this exploration and their conclusions from the results they have thus far reached.

Mr. Barringer has sent me the following account of the circumstances under which he himself found the meteorite I have examined:

"On June 24th, 1905, while riding with Mr. S. J. Holsinger in a general northwest direction from the crater to our reservoirs in Canyon Diablo gorge, my attention was attracted by a rather curiously shaped stone lying on the surface of the thin soil which covers the level limestone plain extending for many miles in every direction in this region. The rather sharply pointed protuberance was what particularly attracted my observation and made me realize that it could not be a water-worn bowlder such as are frequently found in this region." "Upon getting off from our horses and examining the stone I at once suspected that it might prove to be an aërolite, and of course became much interested in the discovery. The greater portion of it was exposed to view, it being imbedded in the loose soil only to about an inch in depth. Two of the broken corners, as I remember, were exposed to view, and the fractures exhibited seemed to be quite fresh. I infer that these corners were broken off at the time of the fall. The locality at which it was found is typical of the region, namely a nearly bare or naked plain covered by loose soil and dotted here and there with bunches of sage brush, grease wood, etc. As I remember, the exact spot at which the stone was discovered is between a mile and a mile and a half distant from the crater in a general western direction, and about ten and a half miles in a southeast direction from Canyon Diablo station." "We made a thorough search for the fragments which had been broken off from this stone, but failed to find them. I infer that the stone struck the earth at some distance from the spot where it was found, and rebounded to this spot by reason of the force with which it struck."

Mr. Barringer thinks it highly probable that this aërolite was *seen* to fall about a year and a half before he found it, and has sent me the following statement of facts in support of this opinion.

"About the middle of January, 1904—on the 15th of the month, as nearly as the date can now be fixed—while two of our employees at Coon Butte were watching the camp (we had suspended operations during the winter), they were awakened, so they told us, by a loud hissing noise and looking northward saw that the heavens were brilliantly lighted, and while rushing out of their tent saw a meteor fall somewhere west or northwest of the butte between them and the railroad. We paid no special attention to the story, and supposed that although they might have seen a meteor fall, it had come to the earth, if it came to the earth at all, many miles distant. However on the same evening and at the same moment, a few minutes before nine o'clock, the hour being fixed by the train schedule, Dr. A. Rounsville and Dr. G. F. Manning were travelling together from Williams, Arizona, to Canyon Diablo station, Dr. Rounsville sitting next to the window on the south side of the car, and just before the train stopped they saw a brilliant light outside of the train, which Dr. Rounsville described just as our men did—i. e. as being lighter than daylight. He could see the mountains twenty miles away, and distinctly every shrub and rock for hundreds of yards from the train. As he exclaimed to Dr. Manning, who occupied the same seat, concerning this light, he caught a glimpse of a fireball dropping to the horizon in the direction of Coon Butte. The light and the fireball were both seen by Dr. Manning also. It seems from the coincidence of time almost certain that this was the same meteor as that seen by our employees at Coon Butte, the observers being about twelve miles apart. It was very near a spot at the intersection of the two lines of sight, the direction of which they of course could not determine with exactness, that I found the stony meteorite."*

The specimen as received by me was pyriform, with a roughly triangular cross-section, bounded by two approximately flat surfaces (one larger than the other) inclined at about 60° or 65° to each other and united by a third, irregularly curved convex surface. It was a good deal larger at one end than at the other. The general surface was smooth, but indented at places with the characteristic shallow pittings, like thumb prints on a lump of sculptor's modelling clay, which

*Further correspondence, sent me by Mr. Barringer, shows that there is some doubt as to the date, but the preponderance of evidence is in favor of its having been *the same* in respect to both sets of observers.

are seen on so many meteorites. One, presumably rather large, piece had been broken off from the smaller end, and two other, much smaller, fractures appeared at and near the larger, end. Measuring the mass as it lay on the larger approximately flat face, the maximum length was about $14{\cdot}5^{cm}$, maximum width about $11{\cdot}8^{cm}$ and maximum thickness about $8{\cdot}9^{cm}$. Fig. 1 is a reproduction of a photograph showing the general appearance. The weight of the specimen as it reached

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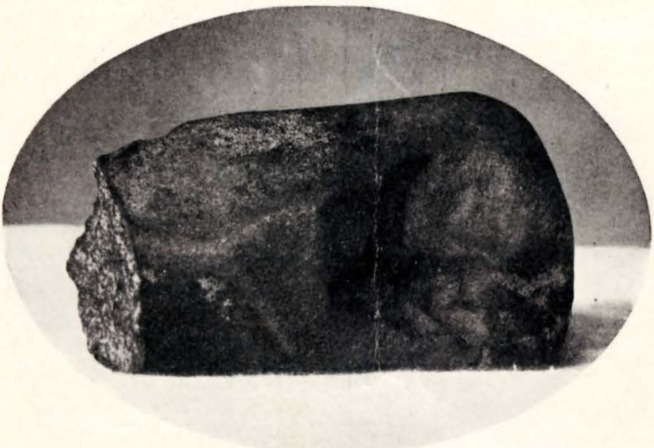

me was 2789 grams. There is an external oxidized crust, generally of dark, blackish brown color, with patches of redder brown—for the most part very thin, not exceeding $\cdot5^{mm}$ in thickness; at some points the oxidized material runs in to a depth of 7 or 8^{mm}. A surface of fracture shows a gray mass of (not very well defined) chondritic and brecciated structure, with numerous little spots of iron-stained yellowish brown color, including lustrous points of metallic iron—the general appearance like that of the Pultusk meteorites of Jan. 30, 1868 (but without the glossy black crust of these stones). There is a still closer resemblance, both of crust and fractured surface, to the meteorites from Ness Co., Kansas. From the general appearance of the surface of fracture I am inclined to class this specimen as Brezina's breccialike gray chondrite, Cgb. The specific gravity of the whole mass taken by suspension in water at 15° C. was found to be 3·471, which is sensibly less than the results of calculation from the constituent materials as found by analysis, indicating some lack of compactness in structure.

Dr. George P. Merrill, Head Curator of Geology at the U. S. National Museum, who has given much attention to the petrographic study of meteorites, very kindly undertook to have thin sections made of some fragments I sent him, to examine these under the microscope, and to secure photo-micrographs of some of them. The notes with which he has favored me are as follows, and in figs. 2, 3 and 4 the accompanying photo-micrographs are reproduced.

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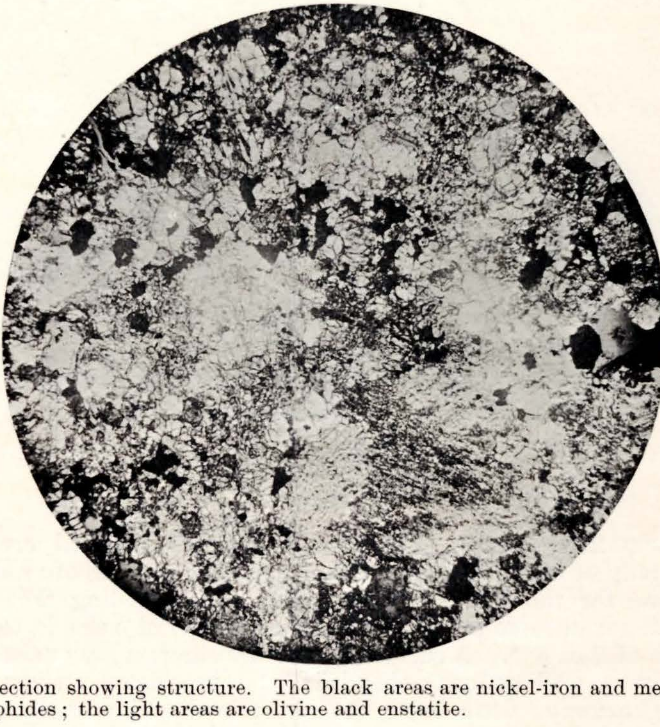

Section showing structure. The black areas are nickel-iron and metallic sulphides; the light areas are olivine and enstatite.

"Aside from its metallic constituents, the stone consists mainly of enstatite and olivine. The enstatite, which is largely in excess, occurs in granular forms, without distinct crystal outlines and also in chondrules of the usual fan-shaped radiating and granular structures (figs. 2 and 4). In the larger forms of the single crystals a condition of molecular strain is manifested by the manner in which, between crossed nicols, the dark wave sweeps over the surface. Such a condition, it may be stated, is not uncommon in stony meteorites, through its full significance seems not to have been realized.

The olivine likewise occurs in granular form and in that of chondrules with the characteristic barred or grate-like and, more rarely, porphyritic, structures. Except where stained by a recent oxidation of the ferruginous constituents, both minerals are colorless or but slightly gray.

In addition to the mineral above described is a completely colorless isotropic substance occurring, as a rule, with no crystal outlines, but rather filling interspaces as would an interstitial glass. It is sometimes quite free from enclosures or, again, includes numerous silicate granules and opaque metallic particles. Rarely does it show anything suggestive of cleavage

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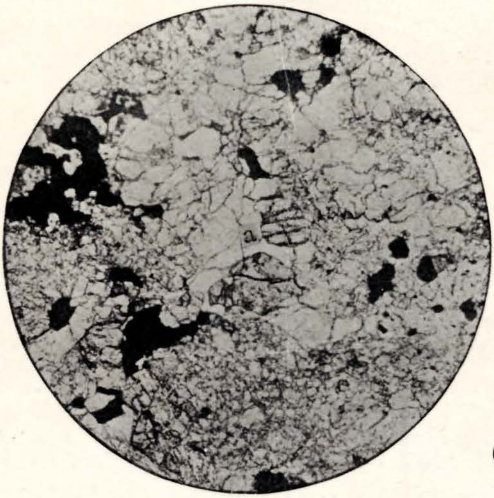

Section showing supposed maskelynite at *a*.

The supposed maskelynite has been shown to have a refractive index of 1.51 which is that of a glass intermediate in composition with albite & oligoclase. GPM

(see fig. 3 *a*). Excepting in its lack of crystallographic outlines, the mineral is similar in all respects, as far as appearance goes, to the maskelynite of the Shergotty (India) meteorite, and such I shall have to assume it to be. It is altogether too small in amount to permit a satisfactory chemical determination, though with more material a micro-chemical test might be made which would go a long way towards settling the problem.

The chondritic structure of the stone is not strongly marked, and the individual chondrules are themselves almost invariably of a fragmental nature. The one shown in fig. 4 is the most perfect exhibited in any of the slides. The structure, as a whole, is not unlike that of the Ness County, Kansas, stone, and hence, if we follow Brezina, would be placed in the group of intermediate chondrites, brecciated (Cib). As, however, I have examined this stone only in thin sections, none of which include an area of above 10^{mm} square, it is possible that further study might relegate it to the Cgb group, of which the Pultusk stone is a well known representative.

For the photo-micrographic illustrations accompanying these notes I am indebted to the U. S. Geological Survey."

The chemical analysis was found to be somewhat troublesome, particularly in regard to the distribution of the iron present in several different chemical conditions. The greater part of the metallic nickel-iron, accompanied by some schrei-

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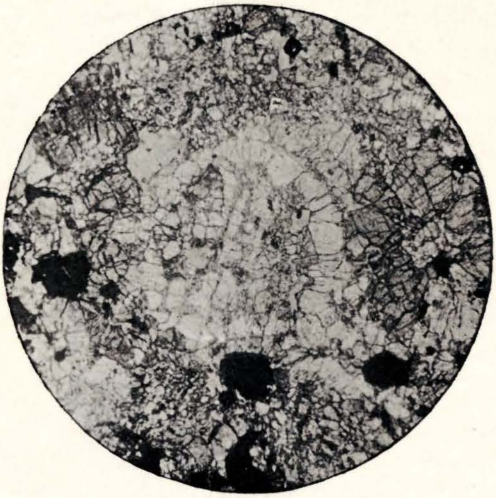

Section showing enstatite chondrule.

bersite and pyrrhotite, was separated from a pulverized sample of about fifty grams, free from crust, by means of a magnet, but it was not possible to obtain complete separation in this way, so that a small proportion of silicates had to be deducted from the magnetically separated part, and a small proportion of the constituents of the nickel-iron, schreibersite and pyrrhotite to be in like manner deducted from the siliceous part of the mass dissolved by acid. The part left by the magnet was digested with hydrochloric acid of 15 per cent strength for three days at a moderate heat, and thus a general separation of the decomposable from the undecomposable silicates was effected, but several determinations of particular constituents had to be made on individual portions. Hydrofluoric acid was used to obtain the alkalies, and the same reagent, with exclusion of air, to secure a determination of ferrous iron.

The following statement gives the general results reached, with an appended account of how they were obtained.

Enstatite	44·73
Olivine	33·48
Maskelynite (?)	6·87
Nickel-Iron	8·63
Iron rust	3·03
Schreibersite	·76
Pyrrhotite	2·14
Chromite	·08
	99·72

The minute amount of chromite was recovered from the silica of the portion undissolved by hydrochloric acid. There being but a few milligrams, no attempt was made at any analysis of it beyond fully establishing the presence of chromium.

Pyrrhotite was calculated from the amount of sulphur found, assuming the ratio S : Fe = 39 : 61. The sulphide was taken as pyrrhotite, rather than troilite, as the former is believed to occur more commonly in meteoric stones, the latter in meteoric iron. It may of course be troilite, and it may perhaps contain a little nickel.

Schreibersite was calculated from the amount of phosphorus found (partly in the magnetically separated portion, partly in the residue left by the magnet) on the assumption of the ratio, P : Fe : Ni = 15 : 56 : 29.

Iron rust was calculated from the amount of iron found in the ferric state and the amount of water driven off by heating and *collected*, assuming the composition to be that of most ordinary rust, namely, $Fe_2O_2(HO)_2$.

The nickel-iron was obtained by analysis of the magnetically collected portion, deducting mechanically adhering silicates and small amounts of sulphur and phosphorus found in this portion, and adding a small amount of nickel found in the portion left by the magnet (in excess of that accounted for as phosphide in schreibersite) and a quantity of iron from the same portion equivalent to the metallic copper thrown down from a solution of cupric sulphate.

The percentage composition of the nickel-iron, as thus obtained, is

Fe	88.81
Ni	10·72
Co	·15
Cu	trace
Sn	·01
Mn	trace
C	trace
	99·69

I was interested in again finding in iron of meteoric origin minute amounts of both copper and tin, having in former years identified both these metals as constituents of the Augusta Co., Va., and Wichita Co., Texas, meteoric irons. In the case of the Coon Butte meteoric stone none of the granules of nickel-iron exceeded ·5 or ·6^{mm} in diameter.

The feldspathic mineral supposed to be maskelynite was calculated from the alumina found, assuming (on the basis of Tschermak's analyses) that this forms 25 per cent of the mineral so named, assigning to this (on the same basis) silica in the ratio $Al_2O_3 : SiO_2 = 25 : 55$, and adding lime and the oxides of the alkaline metals as actually found. Lithium was tested for, but could not be detected. With these assumptions the percentage composition of the mineral in question is

SiO_2	55.00	assumed
Al_2O_3	25·00	assumed
CaO	14·17	
Na_2O	5·93	
K_2O	1·72	
	101·82	

As most of these constituents were found partly in the portion soluble and partly (to a larger extent) in that insoluble in hydrochloric acid, it is probable that the feldspathic mineral is attacked, though not readily, by that acid. But it is of course quite possible that some of these constituents may belong to the other silicates present. The supposition of Tschermak that maskelynite is simply a feldspar that has cooled from fusion in an amorphous state seems quite reasonable and likely.

Olivine was calculated from the remaining constituents of the portion left by the magnet and decomposed by hydrochloric acid, after deduction of the small quantities of iron, nickel and other minor constituents already disposed of as above, and also those of the maskelynite (?) to the extent indicated by the alumina, etc., found in this portion decomposed by hydrochloric acid. Thus calculated, the olivine gives the following percentage figures—

SiO_2	42·29
TiO_2	·01*
MgO	42·44
FeO	13·57
	98·31

* More exactly ·006.

This shows an excess of silica over that required for the orthosilicate of between 4 and 5 per cent, suggesting the possibility of a little free silica being present, perhaps as the asmanite (tridymite) of Maskelyne. That form of silica, it is stated, is soluble in a boiling solution of sodium carbonate in water, and as such a solution was used to take up the silica set free by the action of hydrochloric acid, it would be found and counted in with that of the olivine.

Enstatite was calculated from the results of analysis of the portion left by the magnet and not decomposed by hydrochloric acid, deducting the minute quantity of chromite and such of the constituents of the so-called maskelynite as occurred in this portion. The figures so obtained give the following percentage composition for the enstatite—

SiO_2	53·87
MgO	26·55
FeO	18·35
	98·77

showing a very fair accordance with the results of calculation from the formula of the mineral.

University of Virginia,
Feb. 3, 1906.