PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. II, PP. 41–68. JULY 25, 1900.

A NEW STONY METEORITE FROM ALLEGAN, MICHIGAN, AND A NEW IRON METEORITE FROM MART, TEXAS.[1]

BY GEORGE P. MERRILL AND H. N. STOKES.

CONTENTS:

THE ALLEGAN METEORITE.

HISTORY AND PETROGRAPHY.

A LITTLE after eight o'clock on the morning of July 10, 1899, there fell on what is locally known as Thomas Hill, on the Saugatuck Road, in Allegan, Michigan, a stony meteorite, the total weight of which cannot have been far from seventy pounds, although, unfortunately, it was badly shattered in striking the ground, and its exact weight can never be known.

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[1] These meteorites have been the subject of a preliminary notice by Dr. Merrill in Science for November 24, 1899, and the Allegan stone by Mr. H. L. Ward in the American Journal of Science for December, 1899. The general and petrographic description are by G. P. Merrill, and the chemical examination is by Dr. H. N. Stokes. The chemical analyses were made in the laboratory of the U. S. Geological Survey and are published here by permission of the Director.

The main mass of the stone (see Pl. I, figs. 1, 2 and 3) weighing 62½ pounds, came into the possession of the National Museum, with an additional fragment weighing about 1½ pounds. This, with a 4-pound fragment, sold to other parties, and many small pieces stated as varying from the size of a pea to that of a hickory nut, carried away by school children and others, would readily bring the total weight to the figure mentioned.

According to Mr. Walter Price, as quoted by H. L. Ward[1] the stone came from the northwest and passed within about forty feet of where he was working, striking the ground about ten rods beyond, in sand, and burying itself to the depth of about a foot and a half. The attention of the observers, it is stated, was first attracted by a cannon-like report, followed by a rumbling sound lasting about five minutes (?), which was followed, as the stone came nearer, by a hissing sound, compared to that of an engine blowing off steam.[2] When first seen in the air the stone had the appearance of a black ball about the size of a man's fist. As it passed the observer, it is stated, "there seemed to be a blue streak behind it, about six feet long, which tapered back to a sharp point." The stone was dug up about five minutes after striking and is stated to have been too hot for handling, necessitating removal with a shovel. "The sand was hot for about two feet round where it struck." Messrs. H. Stern & Company, of Allegan, from whom the National Museum obtained the main mass of the stone, furnished corroborative evidence. They state that the sand about the hole made by the meteor was quite warm an hour after the fall, and that the stone itself was still warm when placed in their shop window, some two and a half hours later.

The general appearance of the stone is well shown in Plate I, figs. 1, 2 and 3. From a study of the mass it would appear that at the time of entering our atmosphere, and for most of its course, the point *A* (uppermost in fig. 1) was in advance,

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[1] Am. Jour. Sci., December, 1899.

[2] It is well to note that there is no evidence to show that the report was accompanied by a breaking up of the stone. But the one mass was seen to fall, and though this is somewhat angular in outline nothing indicates a fracturing after entering the earth's atmosphere and before striking the ground.

but that the broad side (lower surface in the figure) was first to strike the ground. These conclusions are based on the facts that the crust at the top *A*, where friction would have been greatest if this side had been foremost, is scarcely more than a millimeter in thickness, and, as shown by the microscope, is almost wholly glassy, enclosing only residual portions of unfused silicates; while on the other side it is from 2 to 3 mm. in thickness, blebby, and, as seen under the microscope, vesicular, and often crowded with minute silicate crystallites imperfectly secreted from the glassy base [1] (Pl. III, fig. 2). Further, the furrows on the outer surface of the crust, due to atmospheric friction, radiate in all directions from this uppermost point *A*. These furrows show somewhat indistinctly near *B* in fig. 1. That the stone struck broad side down is shown by the grass stems and earth still adhering to this surface.

A point of no inconsiderable interest in this connection lies in the fact that these grass leaves, which were welded to the surface of the stone through impact, or were even driven into the fractures caused by the same, are not charred in the least, nor is there other evidence of heat than that furnished by the black crust already referred to. The grass leaves and earthy matter adhering to the surface of the stone are shown somewhat indistinctly at *C* in Pl. I, fig. 1.

To the unaided eye this stone shows on the broken surface a quite even granular structure of gray color and, on closer inspection, abundant, beautifully spherulitic chondrules, averaging not more than one or two millimeters in diameter (Pl. II). In two cases chondrules nearly 5 mm. in diameter were observed. These are sometimes beautifully spherulitic, or again elongated and irregular in outline, and sometimes have pitted surfaces, such as are seen in compressed pebbles in conglomerates (see Pl. IV, figs. 1–7). The majority of them are dark gray in color, but some are greenish white. They are composed of both olivine and enstatite, as will be noted later. Numerous brilliant metallic points of a silver-white color indicate the presence of disseminated iron. Viewed more closely the

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[1] A similar thickening of the crust at the rear (rückseite) was noted by Tschermak on the Gopalpur meteorite (Min. Mittheil., 1872, p. 96).

stone is seen to be made up of the chondrules, iron, and dark gray silicate materials, imbedded in a light gray, ashy groundmass.

The stone is exceedingly friable, crumbling away readily between the thumb and fingers. Indeed it is pronounced by Dr. Merrill to be without exception the most friable meteorite that has come to his attention. Naturally it is beautifully fresh and free from all oxidation products.

Examined under the microscope, in thin section, the stone exhibits in a very marked degree the granular fragmental structure which sometimes characterizes chondritic meteorites, as those of Gopalpur, San Miguel, etc., and which is regarded by Tschermak and some other authorities as indicative of a tuffaceous origin. Three types of chondrules are noted: first, the ordinary enstatite chondrules showing the eccentric, fan-shaped structure, too well known to need further description (Pl. V, figs. 3 and 4); second, those composed of olivines, sometimes quite idiomorphic, developed in a black glass (Pl. V, fig. 6); and, third, those which are apparently of enstatite but almost completely structureless (Pl. V, figs. 5, 7 and 9); these last form the greenish chondrules referred to above. There are also occasional olivine chondrules showing the barred or grate structure.

As already noted, some of these chondrules are beautifully spherical and others are in the form of elongated blebs (Pl. IV, figs. 1 and 2). They are sharply differentiated in most cases from the groundmass and break away so readily as to make the preparation of satisfactory thin sections extremely difficult. When isolated they often show one or more shallow concavities, such as might be formed by the pressure of one against another, but no two were found in such contact as to produce this result (Pl. IV, fig. 1). Similar concavities have been noted by Tschermak and Makowsky in chondrules from the Tieschitz (Moravia) meteorite.[1] Many of the enstatite chondrules are distinctly fragmental in outline (Pl. IV, figs. 3–7), and none of them show a holocrystalline internal structure.

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[1] Denkschriften Kais. Akad. der Wissenschaften, Math. Nat. Classe, B. 39, 1879, p. 195.

Some of them, as separated mechanically from the groundmass, are simply blebs of enstatite slag with cavities resembling the steam cavities in terrestial rocks or in slags from smelting furnaces (Pl. IV, fig. 5). In a few cases small chondrules show little depressions on one side which are continued as holes into the interior for a third the diameter of the spherule. Pl. IV, figs. 1–7, and Pl. V, figs. 1–6, show the forms and outlines of the chondrules as seen under the microscope in thin section, or isolated. It is to be noted that in the case of a fragment, such as is shown in Pl. V, figs. 3, 4 and 5, no other portions of the same chondrule are recognizable in the slide, showing that the shattering took place prior to the consolidation of the stone. This same feature is emphasized by a study of the chondrules as picked out by hand, many of them being but fragments, with the broken surface covered by the grayish dust of the groundmass, showing that the fractures are old and not due to the breaking of the stone since it reached the earth. Some of the larger of these, showing surface fractures antedating consolidation, are shown in Pl. IV, figs. 2, 3, 4, 5, 6 and 7. The material obtained by passing the sand from the broken stone through a sieve of about 2 mm. mesh is made up in very large part of chondrules in all conditions, from mere fragments to nearly perfect spheres.

The groundmass of the stone is a confused agglomerate of olivine and enstatite particles with interspersed metallic iron, iron sulphide, and chromic iron. In no case do the silicates occur with perfect crystallographic outlines, nearly all, both olivine and enstatite, being of fragmental nature and of varying size, ranging from particles a millimeter in diameter down to the finest dust. The iron has the usual form of blebs and extremely irregularly outlined patches serving as a cement, as shown in Pl. V, figs. 6, 7, 8 and 9. By reflected light it shows up in strong contrast with the dull brassy yellow sulphide. This last is in irregular form also, sometimes associated with the iron, sometimes quite isolated. So far as observed, it never occurs as rounded blebs enclosed in the iron, as sometimes found in large masses of meteoric iron. On the other hand, the silicate minerals do thus occur. This is mentioned as having some bearing on the origin of the iron meteorites, the writer regarding them as residual masses of larger, coarse, granular forms from which the silicates have been lost through disintegration, perhaps before reaching the earth. Chromite in black specks is often associated with the sulphides, but does not in the section present good crystal outlines.

The presence of alumina and alkalies, as indicated by Dr. Stokes's analyses, caused a careful search to be made for the presence of feldspar, but none was found,[1] though it is possible that sundry minute, clear and colorless, doubly refracting particles may be thus referred. These never show twin structure, cleavage lines, nor other physical properties such as permit a definite determination. It is more probable, however, that these elements are accessory constituents of the enstatite. If such is the case, the stone, as shown by the analyses and microscopic investigation, is composed of nearly equal parts of highly ferriferous olivine and enstatite, the latter being low in magnesia in proportion as it is high in the accessory elements.

Much of the interstitial material of the groundmass is so fine and dust-like that it is impossible to determine its mineral character in the thin section. After repeated trials the device was adopted of taking some of the fragments, several grammes in weight, and after dusting them carefully with a camel's hair brush and blowing upon them to remove all external dust particles, placing them in a funnel upon a piece of silk bolting cloth and allowing a half liter or so of distilled water to trickle over them, drop by drop; the liquid was then evaporated in a porcelain dish and the resultant dust, which is believed to correctly represent the true groundmass in an unaltered condition, was collected and submitted to a microscopic examination. It was found to be composed of beautifully fresh, sharply angular splinters, mainly of enstatite, though with some olivine and black glass (Pl. III, fig. 1).

Cross sections of the thin portions of the crust (the highest

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[1] H. L. Ward (Am. Jour. Sci., Dec., 1899, p. 414) states that the stone is feldspathic, and classes it with Meunier's montrejites. I cannot agree with him in this. It is essentially nonfeldspathic and belongs more nearly to Brezina's group 29, Kugelchen chondrite (C^c).—G. P. M.

point in fig. 1, Pl. I) show a black glass, interspersed with numerous residuary particles of unfused silicates, which passes down gradually into the unchanged granular stone. Sections of the thicker blebby glass from the lower surface show air vesicles and numerous crystallites imperfectly secreted from the glassy base and too small to be seen in the figure, together with residuary, unfused particles of the original minerals (Pl. III, fig. 2).

CHEMICAL COMPOSITION.

As the nature and extent of the action of such solvents for nickel-iron as mercuric ammonium chloride on the troilite and the silicates of stony meteorites has not been satisfactorily determined, the method of magnetic separation was adopted. This, if thoroughly carried out, yields two portions, the one entirely free from metal, the other consisting of metal mixed with more or less silicate, troilite, and chromite.

About 27 grams of the pulverized material was submitted to fractional separation by an electro-magnet, the more magnetic portions being finally separated by a weak magnet. Two fractions were thus obtained, the larger being entirely free from metal, but containing some material attracted by a strong magnet. The relative proportions were:

a.	Portion free from metal, ...	72.05 percent.
b.	Portion consisting mainly of metal, .	27.95 percent.

Of each of these a complete analysis was made. By subtracting from the figures obtained for *b* the silica, oxides, and troilite the composition of the metal was deduced, while by combining them in proper proportion with the figures expressing the composition of *a* the composition of the total stony part of the meteorite was found. The usual separation of the stony part into portions soluble and insoluble in hydrochloric acid was also made, and of each a practically complete analysis was obtained.

The analysis of the non-metallic portion, *a*, gave:

	I.
SiO_2	45.60
TiO_2	.11
P_2O_5	.35
Al_2O_3	3.04
Cr_2O_3	.66
FeO	11.11
FeS	6.79
MnO	.25
NiO	trace
CaO	2.26
MgO	28.82
K_2O	.32
Na_2O	.92
Li_2O	faint trace
H_2O at 110°	.08
H_2O above 110°	.26
	100.58

No BaO or SrO could be detected. The .66 percent Cr_2O_3 corresponds to about 1.3 percent chromite. I have isolated a small amount of chromite in a state of imperfect purity by treating a large quantity of the silicate repeatedly with hydrofluoric and sulphuric acids. .1147 gram of this gave:

Cr_2O_3	50.31
Al_2O_3	9.67
FeO	28.78[1]
MgO	2.76
TiO_2	1.20

The portion *b*, containing all the metal, gave:

	II.	
Fe	75.65	82.748 percent metal.
Cu	.038	
Ni	6.51	
Co	.55	
SiO_2	8.18	17.48 percent stony.
P_2O_5	.07	
Al_2O_3	1.32	
Cr_2O_3	.21	
FeO	1.84	
FeS	.68	
CaO	.39	
MgO	4.85	
	100.228	

[1] Total iron as FeO.

The portion *b*, therefore, contains 17.48 percent stony matter, but a comparison of the ratio of SiO_2 and MgO shows that this has not the same composition as that of the main silicate portion. While 50 percent of the latter is soluble in hydrochloric acid, the former contains 39 percent soluble and 61 percent insoluble material, which may be due in part, at least, to the more magnetic properties of the enstatite. It is, therefore, erroneous to assume that the silicate accompanying the metal has the same composition as the main portion. The above data give the means of calculating approximately the amount of FeO in the magnetic portion, while the troilite is found from a sulphur determination. The relatively greater amount of chromite in the magnetic portion is also noteworthy.

For the separation of iron from nickel and cobalt, the ammonium sulphocyanate method of Zimmermann[1] was used with satisfactory results. It is necessary to add a little more sodium carbonate than is sufficient just to destroy the red color of the ferric sulphocyanate and to heat to boiling, but even then the precipitation of the iron is not absolutely complete, a small portion always remaining in solution and being removed by ammonia after destroying the sulphocyanate by nitric acid, and concentrating. The bulk of the iron is free from nickel and cobalt after one repetition of the precipitation. Like all other methods for separating iron from nickel and cobalt, this is approximative, but it avoids the tedious repetition of the acetate method and the precipitates filter well.

The separation into a soluble and an insoluble portion was effected by repeated treatments with hot dilute hydrochloric acid and alternate digestion with caustic soda. The insoluble portion, after ignition, was 49.96 percent, and the analysis of this and of the solution gave:

[1] Ann. Chem. (Liebig), 199: 10.

	III. Soluble in HCl.	IV. Insoluble in HCl.
SiO_2	17.26	28.17
TiO_2	trace	.11
P_2O_5	.35[1]	trace
Al_2O_3	.67	2.41
Cr_2O_3	.04[1]	.62
FeO	6.91	4.16
FeS	6.79	none
MnO	.09	.08
CaO	.49	1.64
MgO	17.17	11.57
K_2O	.18[1]	.14[2]
Na_2O	.08[1]	.84[2]
Li_2O	. . . .	none
	.01[1]	22[1]
	50.04	49.86

From analysis II is deduced the percentage composition of the metal, as follows:

Fe	91.42
Cu	.046
Ni	7.87
Co	.66
	99.996

From analyses I and II the composition of the total stony portion is as follows:

SiO_2	45.42
TiO_2	.10
P_2O_5	.35
Al_2O_3	3.31
Cr_2O_3	.69
FeO	11.02
FeS	6.57
MnO	.23
NiO	trace
CaO	2.24
MgO	28.60
K_2O	.30
Na_2O	.86
Li_2O	faint trace
H_2O at 110°	.07
above 110°	.24
	100.

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[1] By difference.

[2] The figures for alkalies are not to be implicitly depended on, owing to the possible partial substitution of Na_2O for K_2O during digestion with caustic soda.

and, finally, the composition of the entire sample examined is:

Fe	2109	Metallic part 23.06 percent.
Cu	.01	
Ni	1.81	
Co	.15	
SiO_2	34.95	Stony part 76.94 percent.
TiO_2	.08	
P_2O_5	.27	
Al_2O_3	2.55	
Cr_2O_3	.53	
FeO	8.47	
FeS	5.05	
MnO	.18	
NiO	trace	
CaO	1.73	
MgO	21.99	
K_2O	.23	
Na_2O	.66	
Li_2O	faint trace	
H_2O at 110°	.06	
H_2O above 110°	.19	
	100.	

Specific gravity 3.905. An average of two determinations in a picnometer flask at 27° C. by Dr. Merrill.

THE MART IRON.

HISTORY AND GENERAL FEATURES.

The second meteorite to be described, which will be known as the Mart Iron, was found early in 1898, on the farm of H. T. Vaughan, near Mart, in McLennan County, Texas.

This iron weighed originally 15¾ pounds. From it a slice weighing 456 grams was cut for the collection of the National Museum, the iron having been donated by the finder to the museum of Baylor University, at Waco, Texas. For the privilege of removing this slice we are indebted to Mr. O. C. Charlton, Curator of the museum. The original shape of the iron, as shown in Pl. VI, figs. 1 and 2, was that of an irregular oval, somewhat flattened at one side and rounded above, with two large and deep pittings on the broader surface. The original dimensions were about 8.5 by 15 by 25.5 cm. It was not seen to fall and had evidently lain in the soil some time, as the exterior was considerably oxidized and the troilite, which presumably once occupied the pits, was completely eliminated. On cutting and etching the iron gave the surface shown in fig. 1 of the plate. The small dark points are due to troilite. Sundry cracks in the iron at various points on the etched surface, shown most plainly at the upper right in fig. 1, are also filled with troilite. The blotches shown are due to the oxidation of the troilite in process of etching. Mr. Tassin, by whom the etching was done, calls attention to the perfection of the Widmannstätten figures, and particularly to the relief of the tænite bands.

As shown by this etching, the iron belongs to the octahedral variety, and is of moderately coarse crystallization. Its general appearance is so similar to that of the Hamilton County (Texas) iron described by Howell[1] as to suggest that it may be a part of the same fall. The probability is still more evident when it is considered that the two localities are not over 50 miles apart in a straight line.

The chemical evidence, as shown by a comparison of Mr. Eakins's analysis of the Hamilton iron with that of Dr. Stokes, is, however, not favorable to this view, though we believe the possible (if not probable) variation in composition in different parts of the same iron has not yet been fully worked out.

	Mart.	Hamilton Co.
Fe	89.68	86.54
Ni	9.20	12.77
Co	0.33	0.63
Cu	0.037	0.02
P	0.158	0.16
S	0.017	0.03
C		0.11
Chromite	trace	
Fe_2O_3	"	
	99.422	100.26

CHEMICAL COMPOSITION.

The samples submitted were cut from the outer portion of the meteorite, including the oxidized crust; this was carefully re-

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[1] Proc. Rochester Acad. Sci., Vol. I, 1890, pp. 87–89.

moved by scraping and filing. There was a small quantity of rust in the cracks on the cut surface, but its amount was trivial.

During the solution in aqua regia scales of schreibersite were observed. A few small black grains were left which showed crystal faces under the microscope, and which were identified as chromite by the usual reaction. A minute amount of colorless granular matter was also noted, the nature of which could not be determined.

All determinations were made in a solution of the same portion of 3.8636 grams, the residue having been brought into solution and added.

The analysis gave:

	.9659 gram	1.9318 grams
Fe	89.68	......
Ni	9.20	......
Cu	......	.037
Co	.33	......
P		.158
S		.017
Cr		trace
Total,	99.422 percent.	

The separation of iron from nickel and cobalt was effected by the Zimmerman method (see preceding section on the Allegan meteorite).

From the above data the composition of the iron may be expressed as follows:

Nickel-iron (Fe, Ni, Cu, Co)	98.31
Schreibersite	1.06
Troilite	.05
Chromite	trace
Fe_2O_3	trace
	99.42

SUPPLEMENTARY NOTE BY DR. MERRILL.

The structure of the Allegan stone is such as to bring up prominently the question of the origin of meteorites in general. It is not, however, my intention to go into or review the matter exhaustively, but rather to call attention to a few points here illustrated that have an important bearing on the subject.

As is well known, structures such as this stone possesses have been accepted by Tschermak and others as indicative of a tuffaceous origin—that is, they result not from the direct cooling of a molten magma, but from the agglomeration of already solidified particles, as is the case with volcanic tuffs. Others, of whom Dr. M. E. Wadsworth is a prominent example, regard them as the result of the hasty crystallization of an igneous magma.[1] That many meteoric stones result from the cooling and crystallization in place of igneous magmas is beyond question; yet there is an almost equal certainty that others are of tuffaceous origin, though the nature of the evidence is not such as to be fully appreciable except by petrographers.

In 1888 I described a meteorite from the San Emigdio range of California,[2] and announced my conclusion in favor of a tuffaceous origin. Nevertheless, as the stone was badly weathered there has always been a question in my mind as to how much of the apparent fragmental appearance was due to weathering and how much was original. The absolutely fresh character of the Allegan stone, which is of a surprisingly similar nature, gives me an opportunity to reconsider the subject, and as it happens, to confirm the views first expressed.

The general structure of the Allegan stone can, I believe, be accounted for only by regarding it as an agglomerate of chondrules imbedded in a fragmental groundmass or matrix, the materials for which were derived from the trituration of other chondrules.

One fact which, in my mind, has always mitigated against the theory which would account for the peculiar structure of a meteorite of this type on the assumption of hasty crystallization, has been the complete absence of a glassy base in any but the chondritic portions. Obviously, if the stone is a product of crystallization in mass the chrondrules are products of the earliest crystallization, and should, judged by the standard of terrestrial petrography, be the most highly crystalline, while the base in which they are imbedded might be glassy or crystalline, accord-

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[1] For a very clear exposition of Dr. Wadsworth's views see his Lithographic Studies, pp. 106–117.

[2] Proc. U. S. Nat. Museum, Vol. XI, 1888, pp. 161–167.

ing to conditions. In reality the reverse is the case, the chondrules being more or less glassy, or at least imperfectly crystalline, as in the barred and fan-shaped forms, while the groundmass of the rock is of crystalline particles, and of particles of the chondrules themselves. So far as I have observed there is no true glassy base in meteorites of this type.

That certain conditions of crystallization will give rise to the spherulitic forms of the enstatite is undoubted, but from a study of the crust of the Allegan stone it appears that when meteoric material is fused and allowed to re-crystallize, even so rapidly as must have been the case in this crust, it is not spherulitic, but takes the form of crystallites in a glassy base, as among terrestrial rocks. It is evident that time is not the only factor that should be considered.

The subject of the spherules in liparite has been pretty well worked out by Cross and Iddings,[1] and while it is easy to conceive of the abrupt transition from a wholly or partly crystalline spherule to a glassy base, as sometimes seen in spherulites of obsidian, it will, in the present state of knowledge, puzzle any petrographer to account for an equally sharp transition from a glassy spherule (chondrule) to a base composed wholly of crystalline particles, shown in many meteorites. Even could we account for such anomalies of crystallization as are above noted, the presence of plainly fragmental chondrules—chondrules which were fragments at the time of the final consolidation of the stone—remains to be explained. The forms shown in Pl. IV were all carefully picked from the rock. That they are original fragments, *i. e.*, not due to fracturing in place, is shown by the dull and sometimes abraded character of the surface of fracture, and further by the fact that in no case was the remainder of the chondrule represented by one of these pieces found in the vicinity. Fig. 6 of this plate is one of the most striking illustrations of this nature, being that of a portion of an oval enstatite chondrule some 8 mm. in greatest diameter, imbedded in a fine granular groundmass. The flat surface of fracture is dull and lusterless, and the fracture is, I believe, unquestionably an old one. Fig. 7 shows a side view of the

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[1] Bull. Phil. Soc. Washington, Vol. XI, 1891.

same chondrule. In other cases, as in figs. 3 and 4 of the same plate, the fractures are old and show abraded surfaces. Figs. 2 and 5 are plainly those of fragments of elongated chondrules that have been broken across. Figs. 3, 4, 5 and 9, Pl. V, are evidently sections of just such fragments, and in fig. 4 the splintering fracture along a cleavage plane of the enstatite (below in the figure) is plainly evident under the microscope. With reference to such forms as that shown in fig. 6, Pl. V, one can assume that after the olivines had become imperfectly secreted the magma was resolved into spherical drops which cooled too rapidly for further crystallization, while in the enstatite forms crystallization may have been in some cases prior to the assumption of the globular form and in others subsequent thereto. Such forms seem to lend support to the theory of Sorby[1] that "some at least of the constituent particles of meteorites were originally detached glassy globules, like fiery rain." It is possible to conceive that these chondrules, first as blebs of molten matter and then as consolidated particles, may have been triturated in the deep throat of some volcano. The spherical form, however, I do not regard as due to trituration, like volcanic lapilli, as formerly held by some writers, but rather to a previous molten condition. Be this as it may, consolidation must obviously have taken place before the mass was shot forth into space. The manner in which the metallic portions are wrapped about or even injected into the silicate particles and the chondrules (see figs. 6, 7, 8 and 9, Pl. V) suggests the possible reduction of the iron—or at least a remelting in an atmosphere from which oxygen was largely excluded—after the stony portion assumed its present form.

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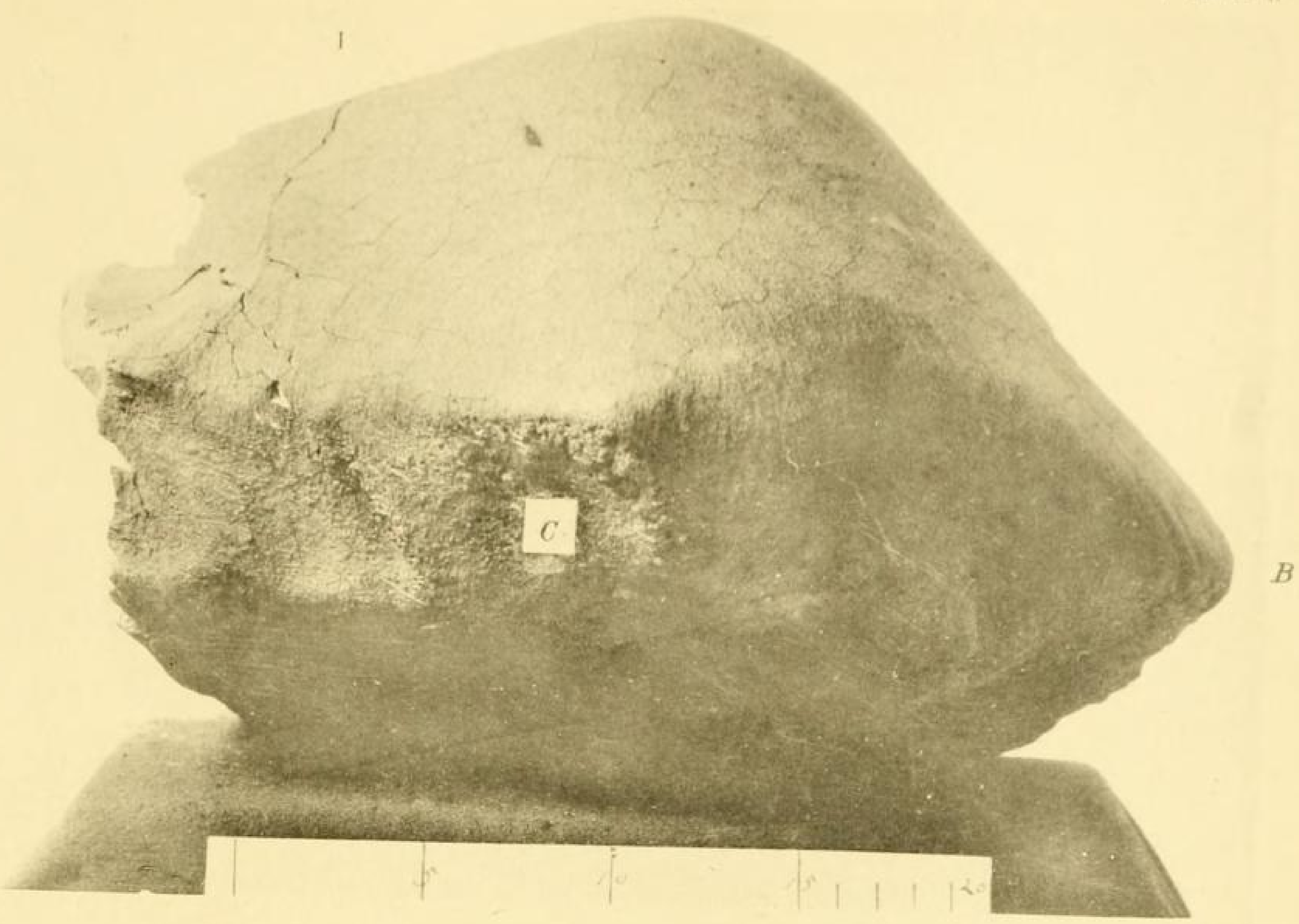
[1] Nature (London), Vol. 15, April 5, 1877.

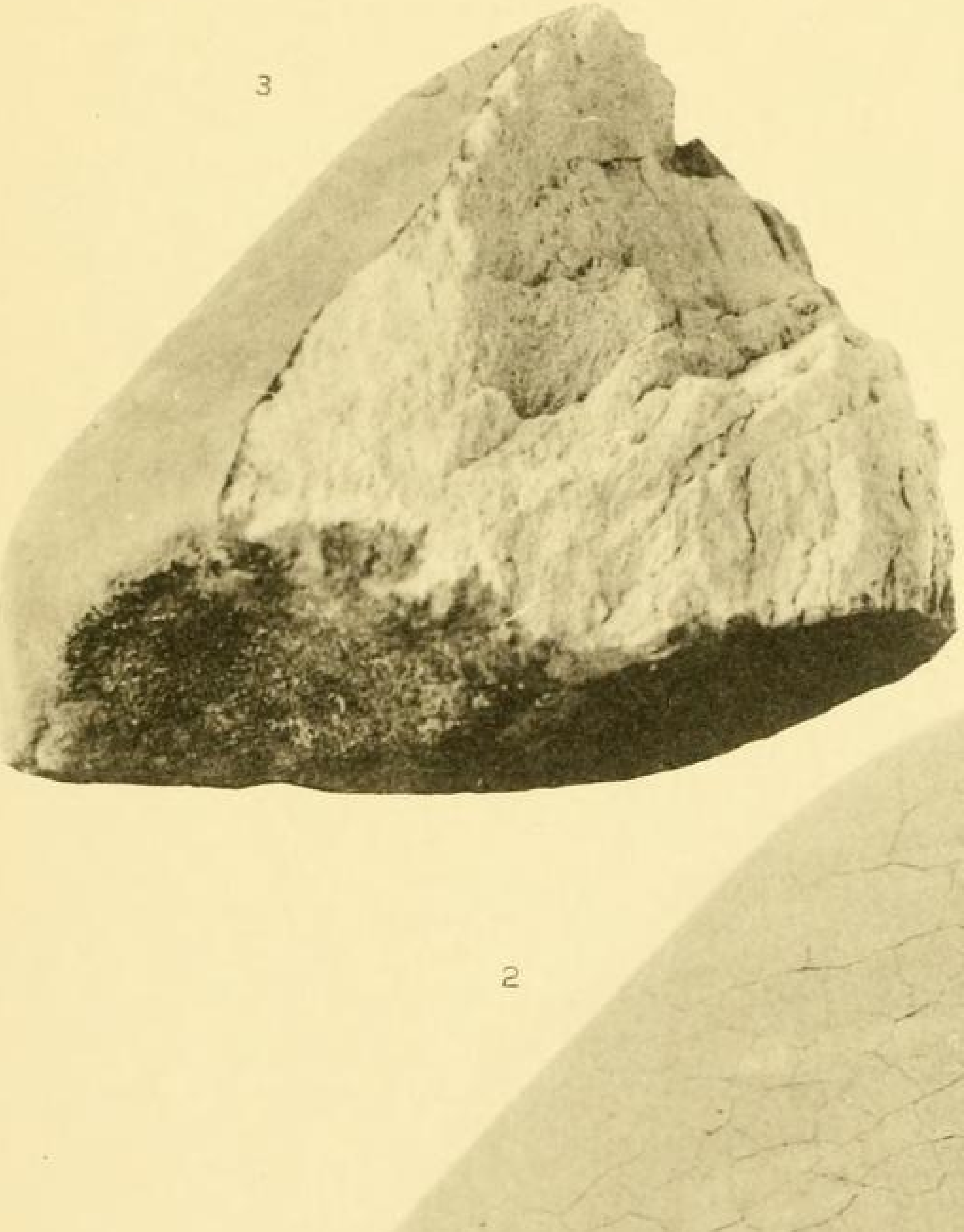
PLATE I.

Figs. 1, 2, and 3. Allegan meteorite, as received at the National Museum. Fig. 3 on reduced scale and introduced to show outline of cross-section.

1



3

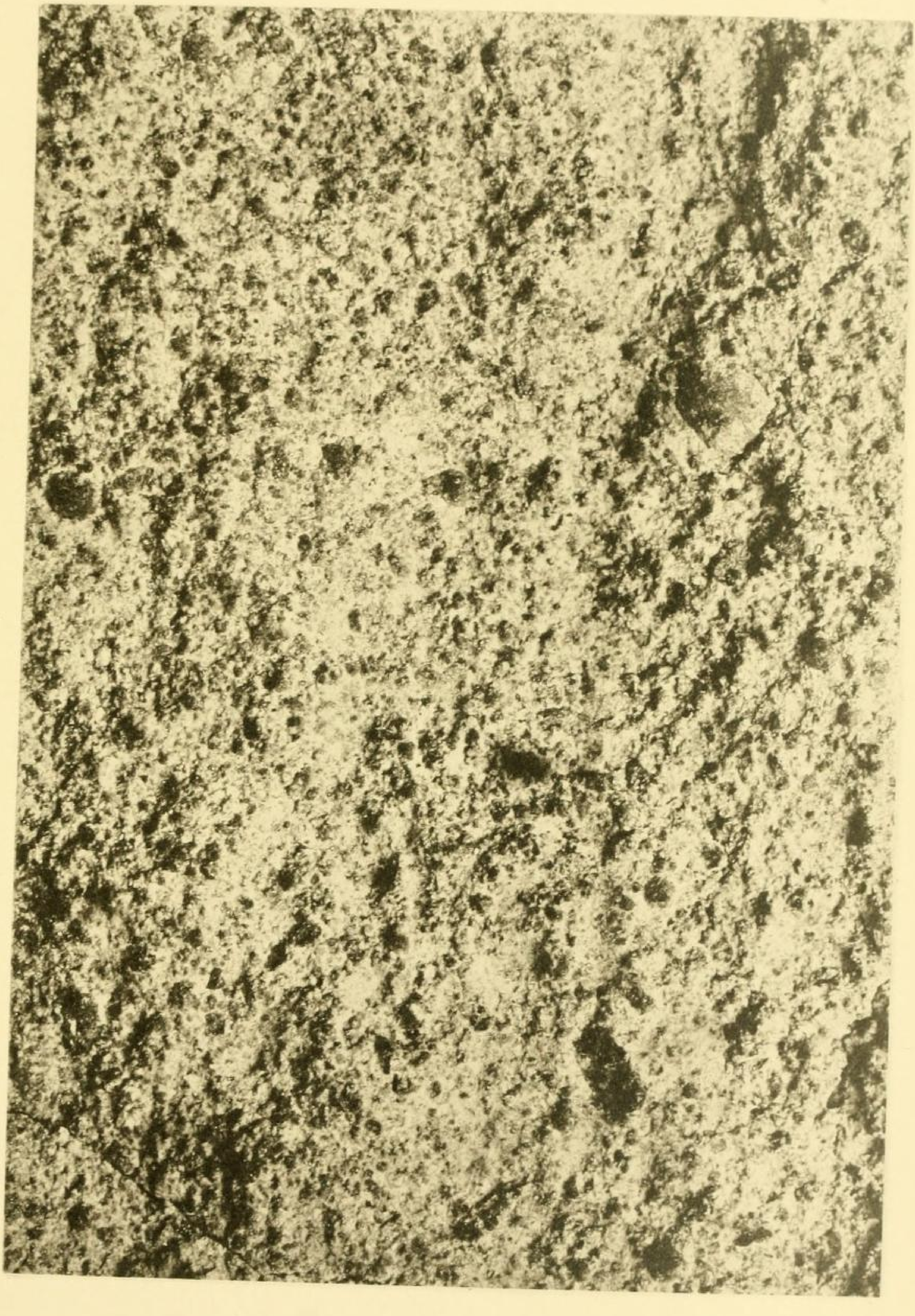


2

THE ALLEGAN METEORITE.

PLATE II.

Broken surface of Allegan meteorite, magnified about five diameters.



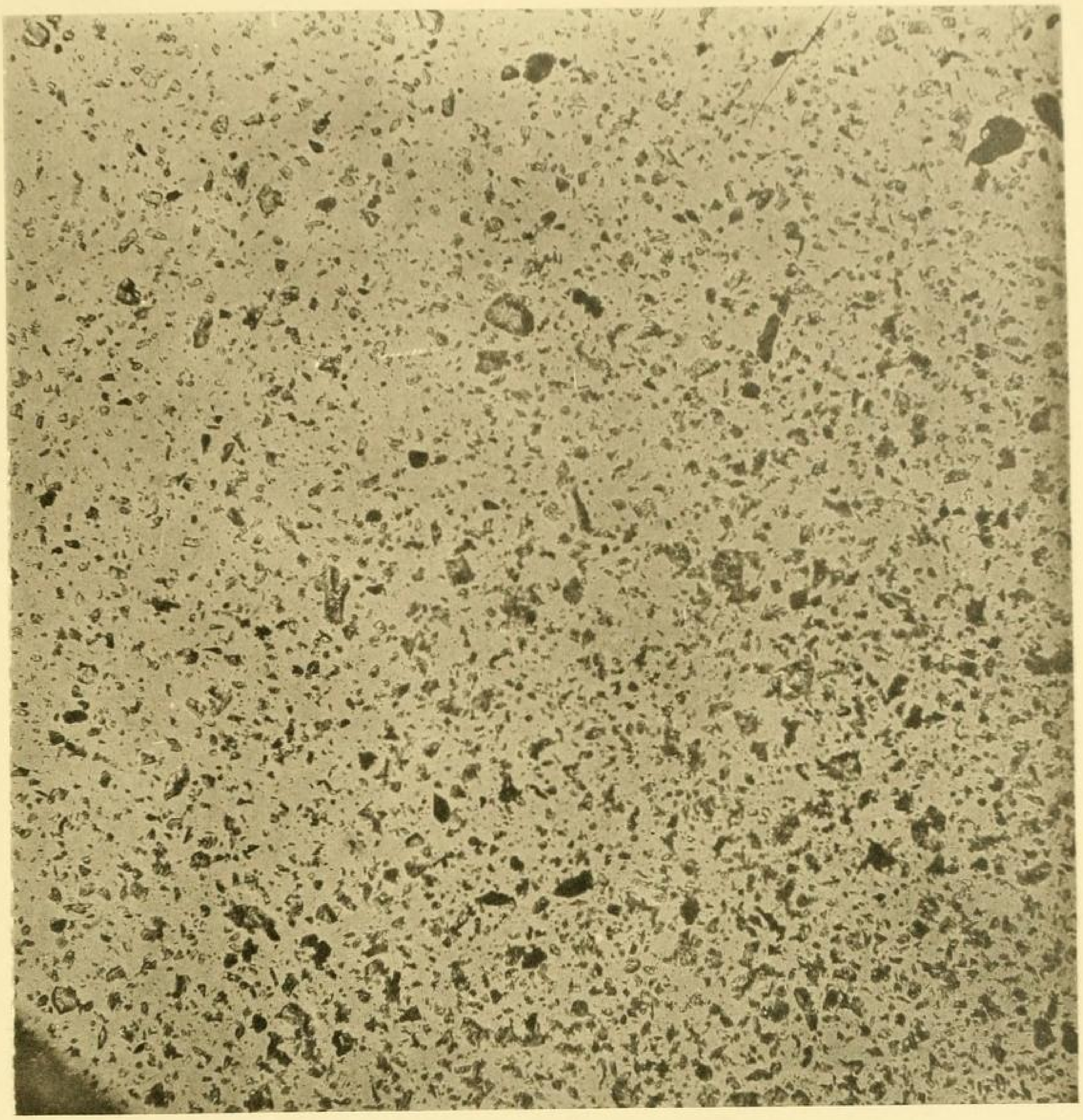
The Allegan Meteorite.

PLATE III.

Fig. 1. Fragmental particles washed out of Allegan meteorite.

2. Cross-section of thick crust from under surface of Allegan meteorite. The oval colorless areas are air vesicles; the angular areas, residual particles of unfused silicates. Actual thickness of crust, 3 mm.

1



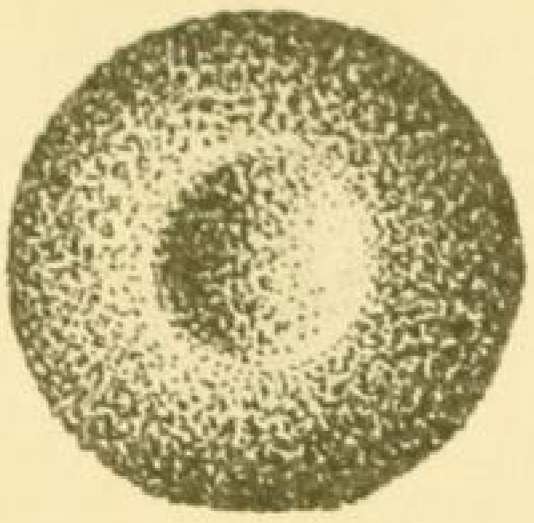
2

THE ALLEGAN METEORITE.

PLATE IV.

Fig. 1. Indented chondrule. Allegan meteorite.

2–7 inclusive. Fragmental chondrules showing old surfaces of fracture, indicating that the chondrules were fragments at the time of the consolidation of the stone in its present form. Actual sizes : fig. 1, 2 mm.; figs. 2, 3 and 4, about 3 mm.; fig. 5, 4 mm. in length ; figs. 6 and 7, 8 mm.



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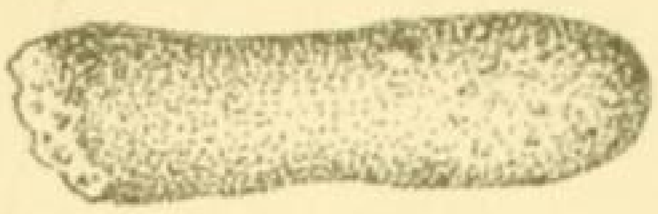

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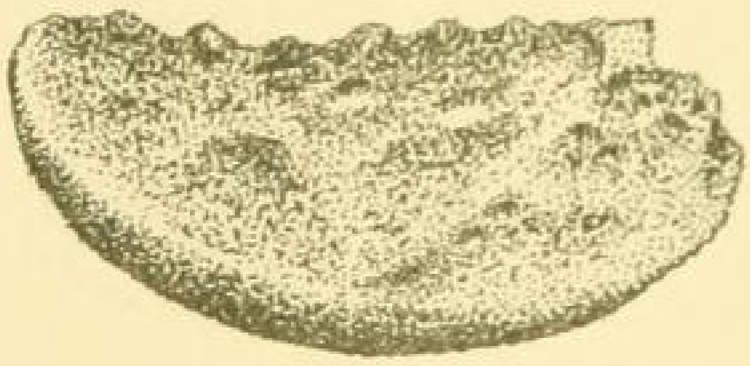

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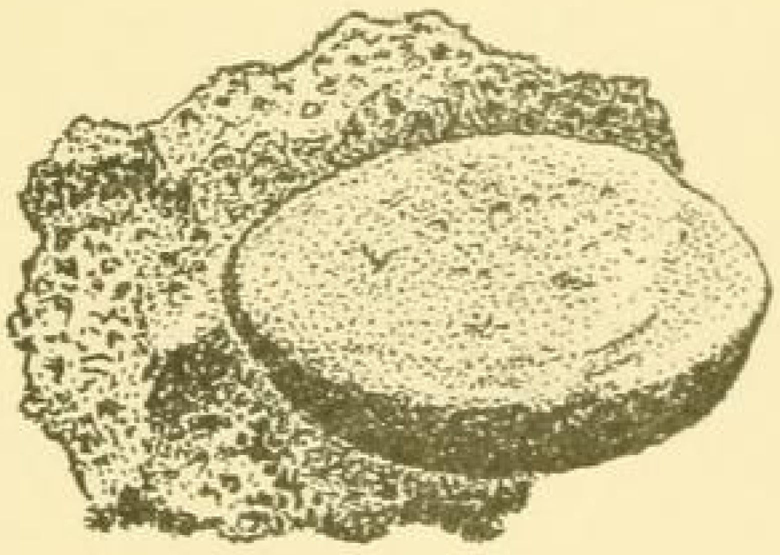

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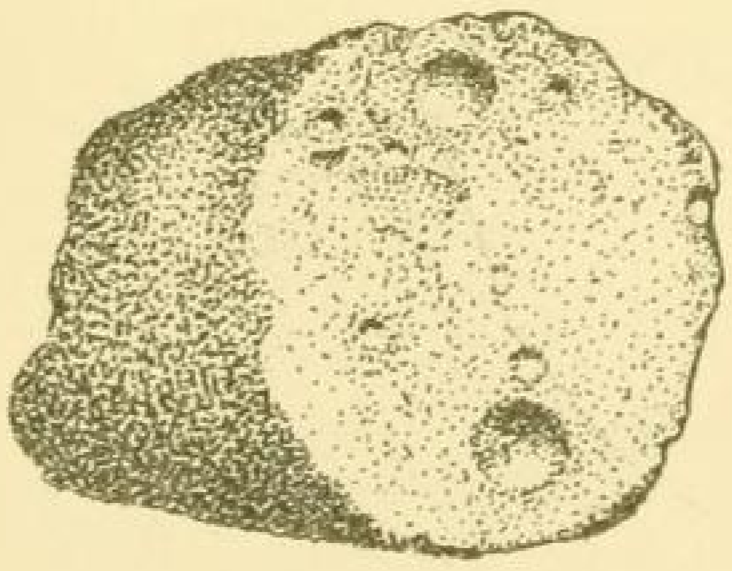

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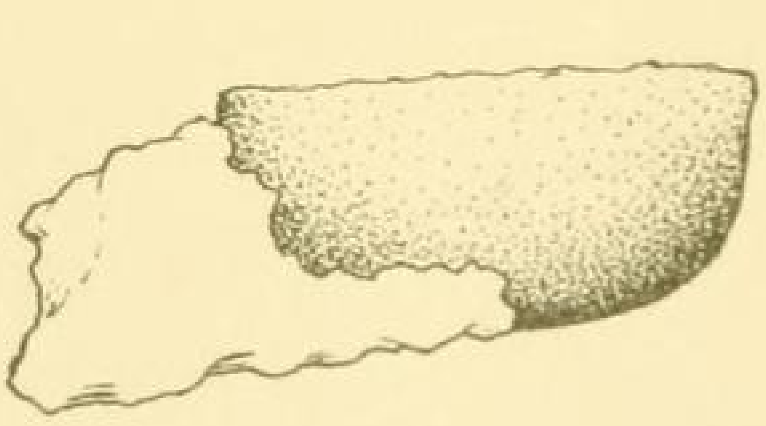


7

THE ALLEGAN METEORITE.

Heliotype Co. Boston

PLATE V.

Allegan meteorite. All greatly magnified.

Figs. 1 and 2. Clear colorless olivines in groundmass.

3. Radiating enstatite with clear olivines and iron (black).

4 and 5. Fragmental chondrules of nearly amorphous enstatite.

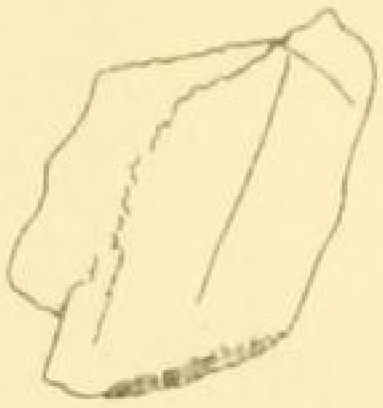
6. Chondrule composed of olivines imperfectly secreted from a black glass. The clear colorless portions in close contact represent olivines, the black areas, iron.

7. Imperfectly crystalline enstatite chondrule in contact with a fragment of a nearly amorphous one of the same mineral nature.

8. Iron, drawn to show the very irregular nature of the masses.

9. Nearly amorphous enstatite chondrule in contact with metallic iron.

1



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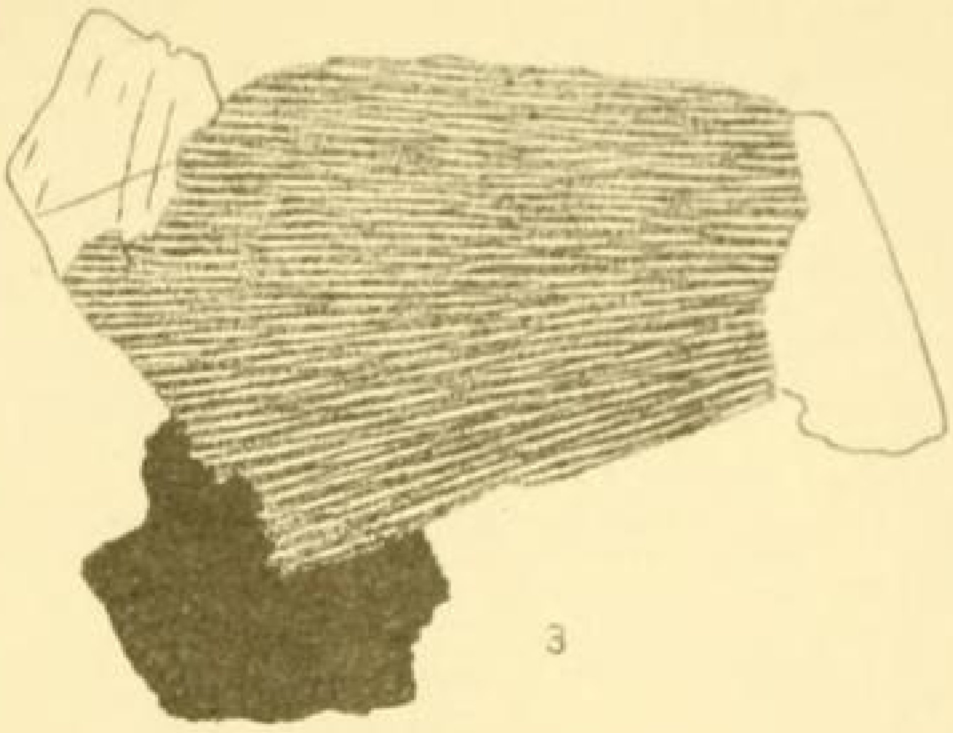

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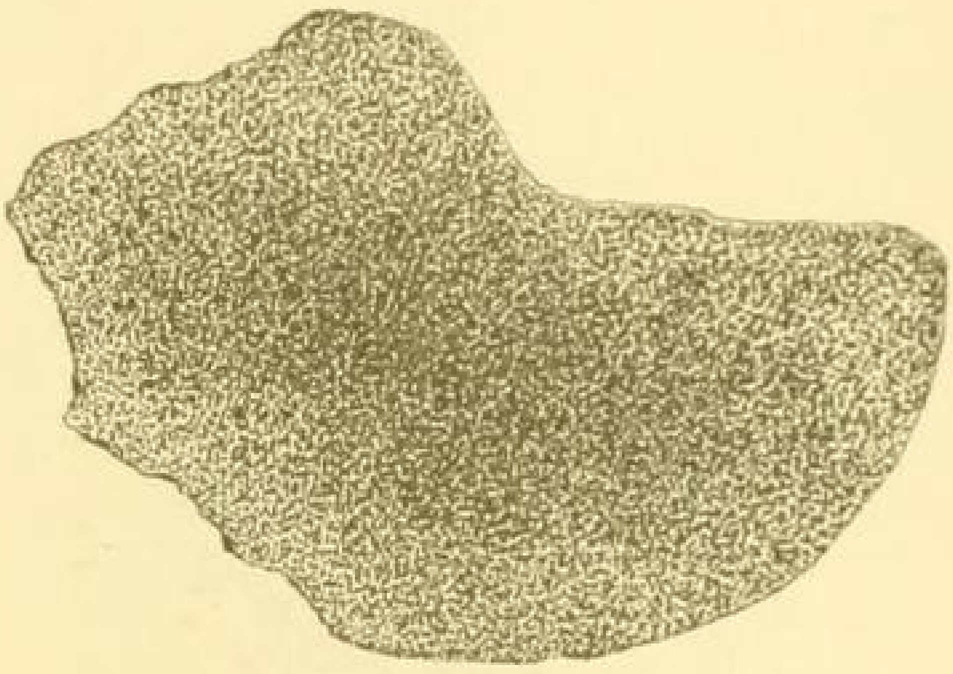

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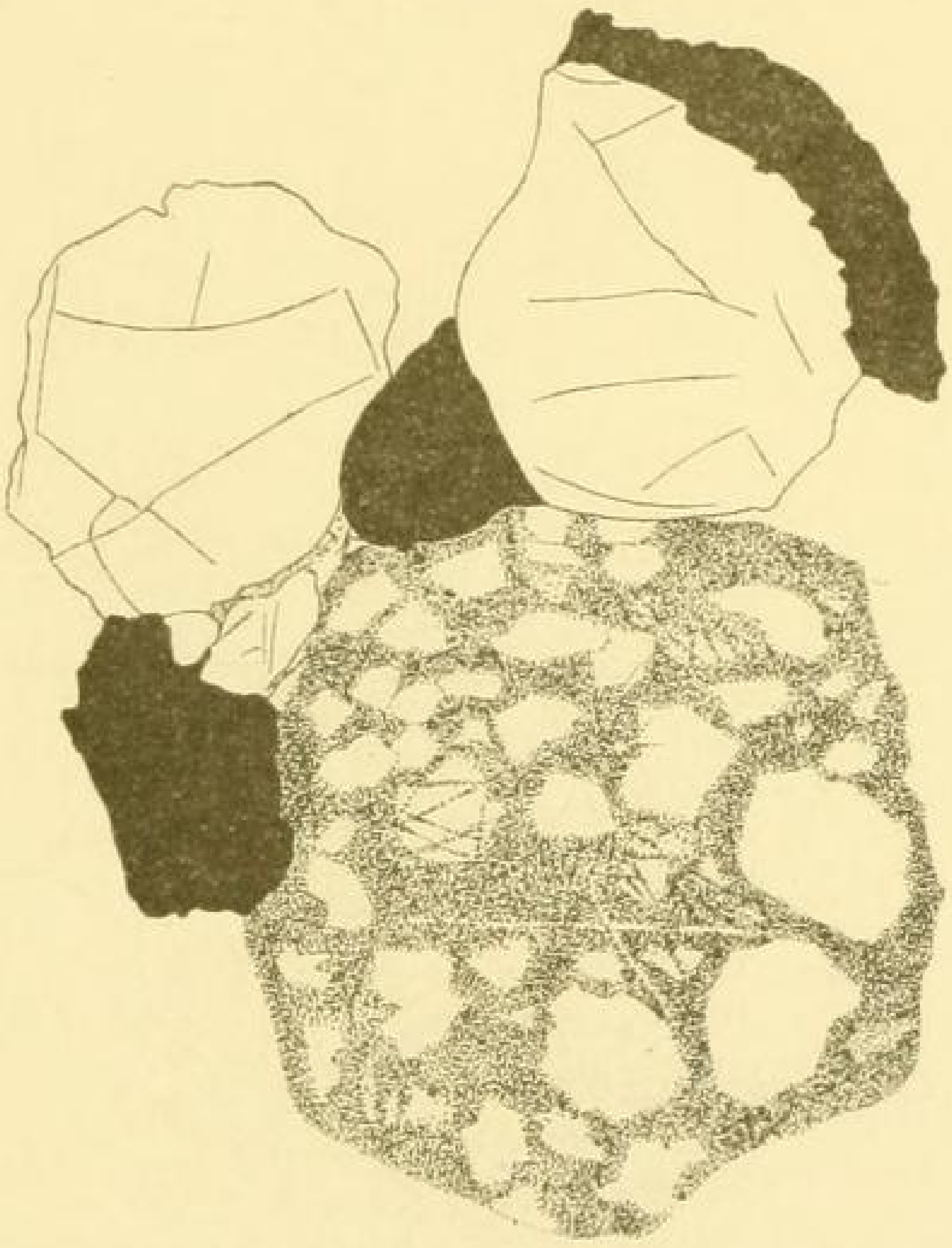

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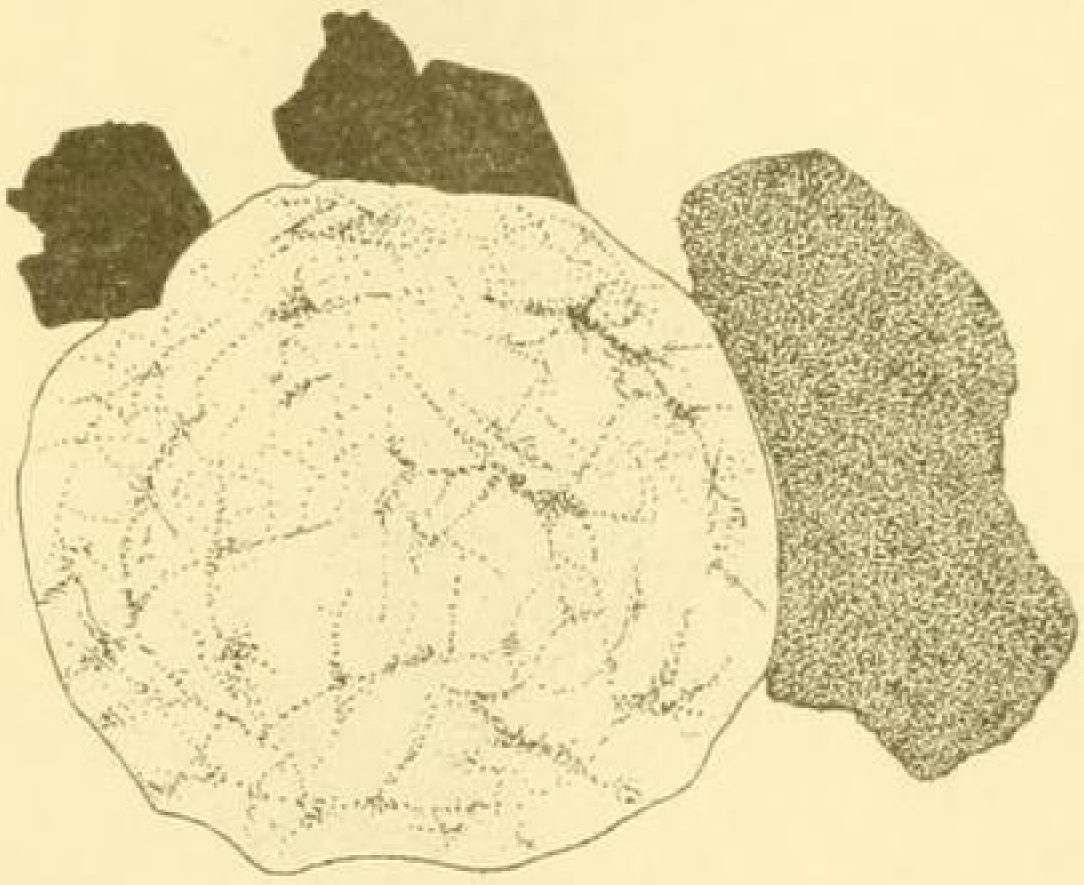

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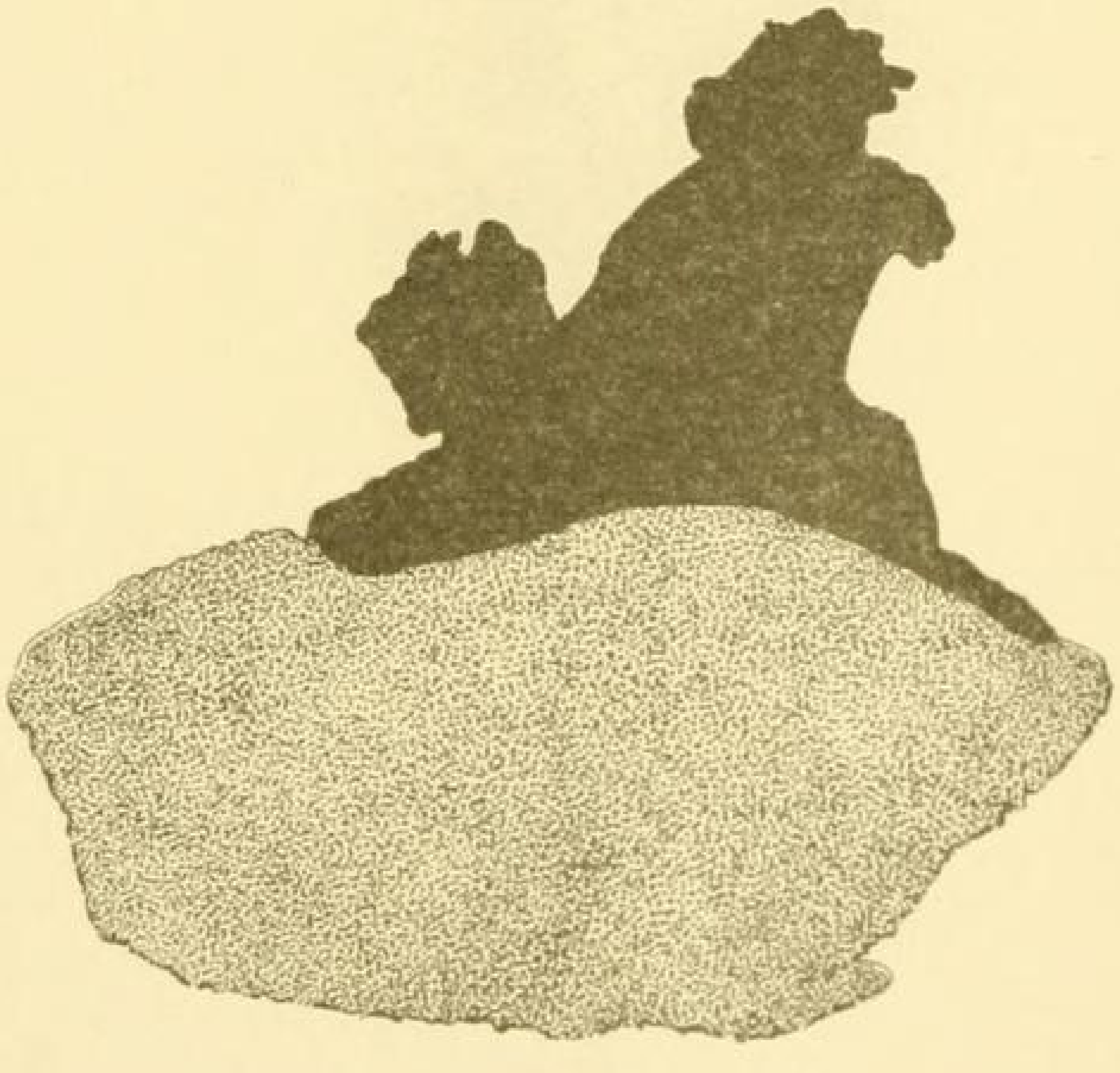


9

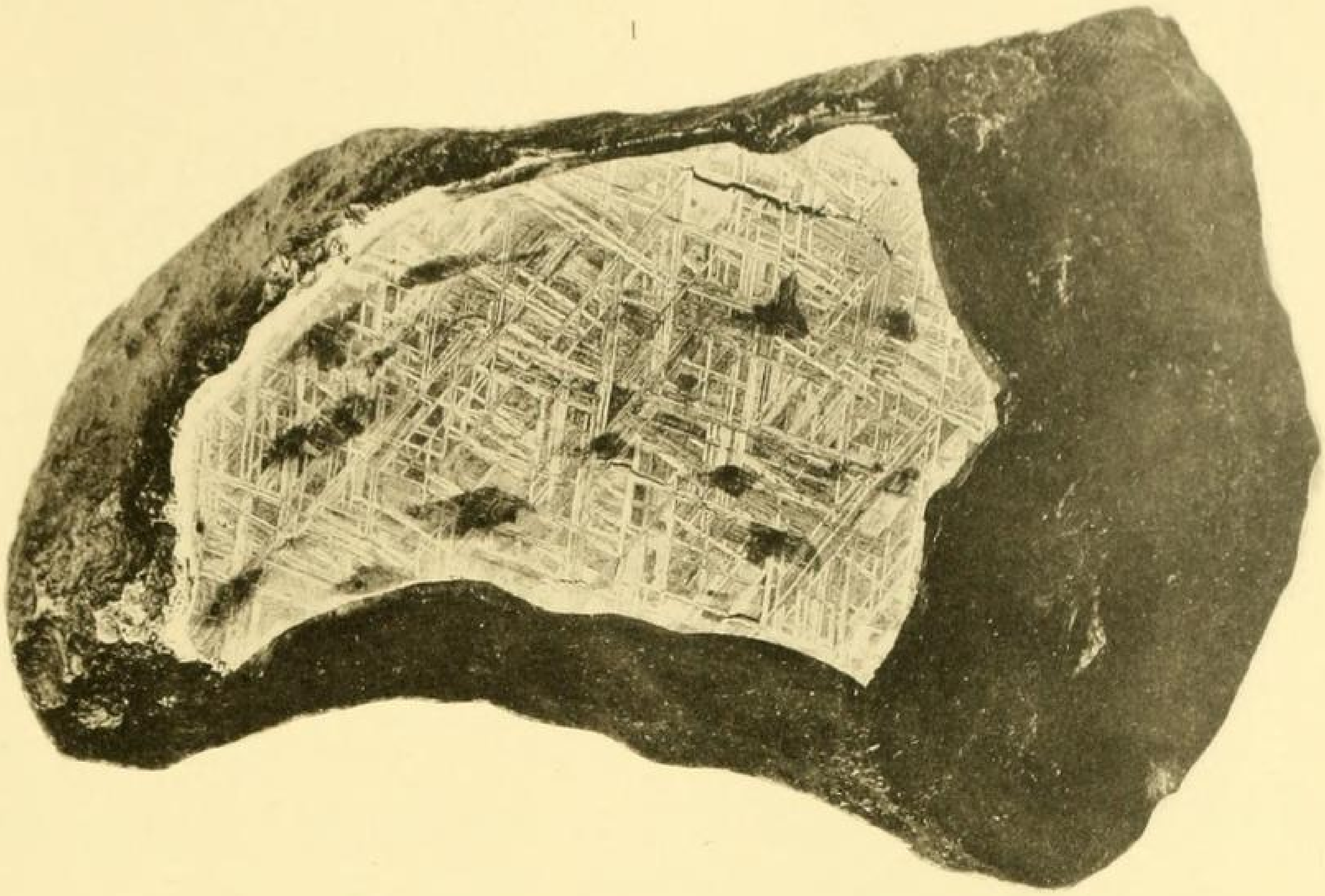
THE ALLEGAN METEORITE.

Heliotype Co. Boston.

PLATE VI.

Figs. 1 and 2. The Mart Iron.

1



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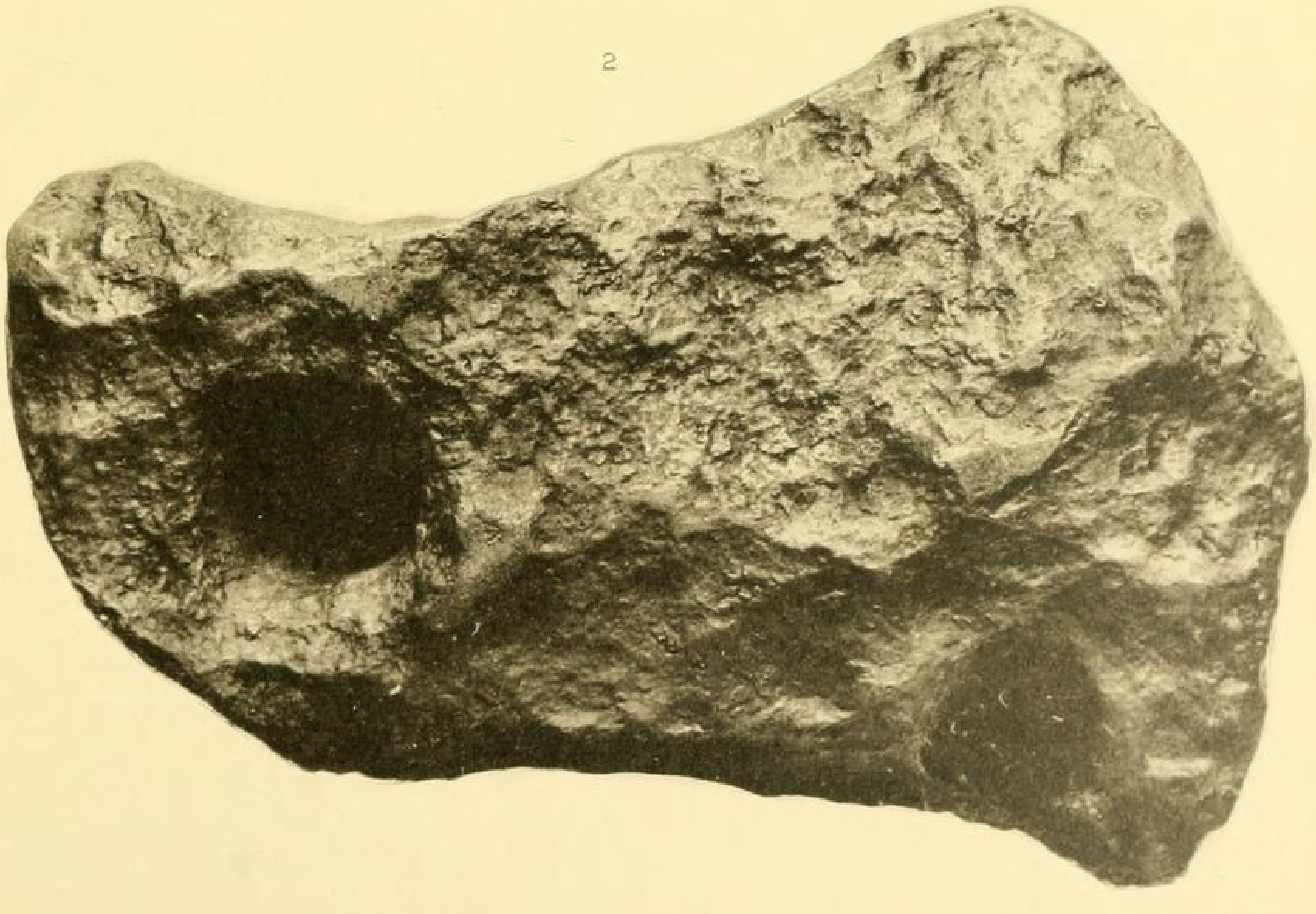

THE MART IRON.