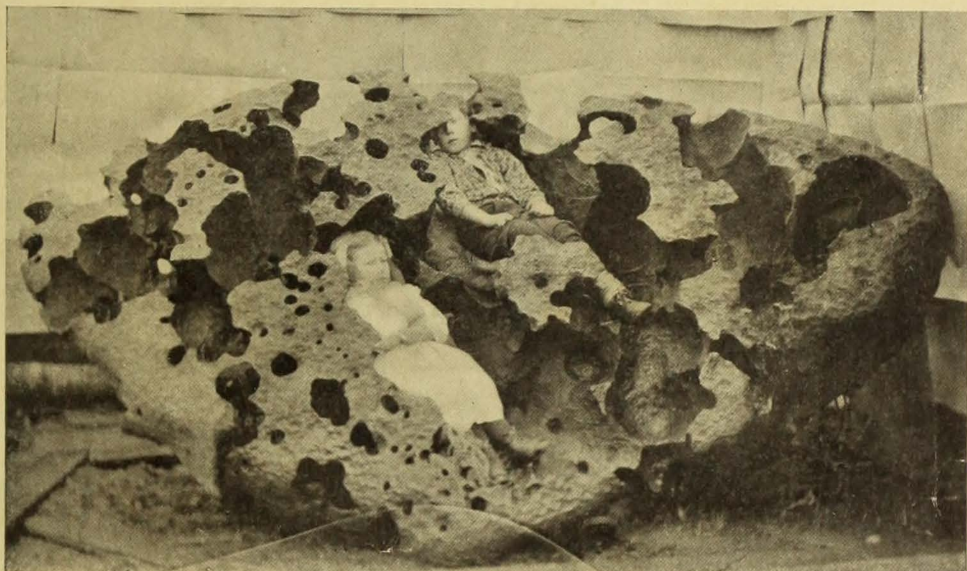
AMERICAN MUSEUM OF NATURAL HISTORY

The Foyer Collection of Meteorites



By EDMUND OTIS HOVEY, Ph. D.
Associate Curator of Geology

GUIDE LEAFLET NO. 26

DECEMBER, 1907

American Museum of Natural History

Seventy-seventh Street and Central Park West, New York City

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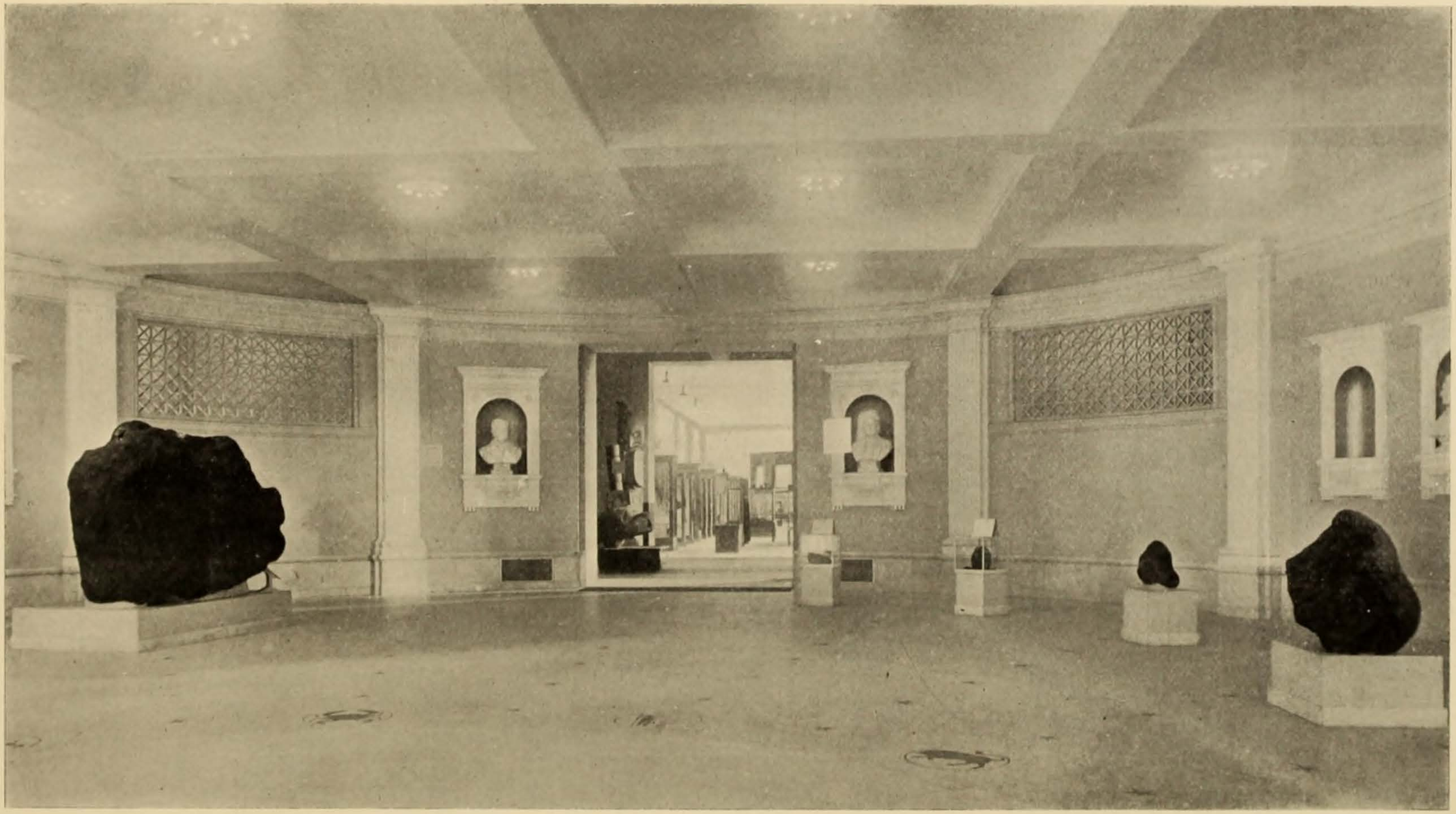

WESTERN HALF OF FOYER.

Showing the following Meteorites: Ahnighito, Brenham, Forest City, The Dog, The Woman.

THE METEORITES

IN THE FOYER OF THE

American Museum

OF

NATURAL HISTORY

By EDMUND OTIS HOVEY, Ph. D.

ASSOCIATE CURATOR OF GEOLOGY

NO. 26

OF THE

GUIDE LEAFLET SERIES

OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

EDMUND OTIS HOVEY, EDITOR

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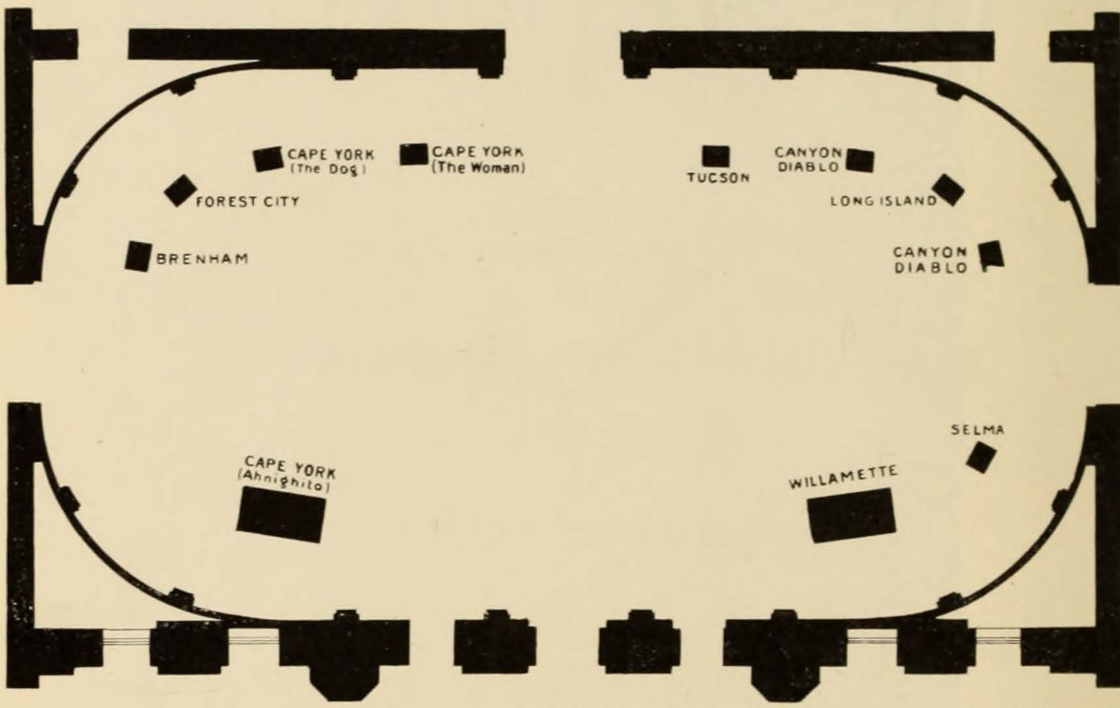
NORTH



THE FOYER. NO. 104.

First (Ground) Floor, Central Section of Building.

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THE METEORITES IN THE FOYER OF THE AMERICAN MUSEUM OF NATURAL HISTORY.[1]

By Edmund Otis Hovey, Ph. D.

Associate Curator of Geology.

Introduction.

SCARCELY a century ago the scientific and even the popular world scoffed at the idea that masses of matter could possibly come from outer space (or "heaven") and strike the surface of the earth,— in other words that stones could fall from the sky. Even at the present time, although it is well known that occasionally masses of metal and stone — "meteorites" — do fall from the sky, there is much misinformation current in regard to their character and the conditions under which they have come to the earth.

Livy, Plutarch and other early historians mention several stones which had been seen to fall from the sky. Among these were a stone which fell in Phrygia and was kept there for centuries until it was removed to Rome about 204 B. C. with imposing ceremonies; a shower of stones that fell in the Alban Mountains near Rome about 652 B. C., and a stone that fell in Thrace in the fifth century B. C. and was known to Pliny five hundred years later. The image of the goddess Diana which was preserved at Ephesus is said to have "fallen down from Jupiter" and was probably a meteorite, and idol known as the Venus of Cyprus seems likewise to have had the same origin. Stones which have fallen from the sky have been regarded as being of miraculous origin and have been worshiped by many primitive peoples. They have been viewed with awe too by tribes and nations which could not be considered primitive, including some in India, China and Japan.

Arguments which form strange reading at the present day were advanced by eminent scientists against the idea that any bodies could come to the earth from space, and French scientists were particularly

[1] *Guide Leaflet No. 26* of the American Museum series.

vehement in their denial of such origin. Even the famous chemist Lavoisier was one of a committee of three who presented to the French Academy in 1772 a report upon a stone, the fall of which was said to have occurred at Lucé four years previously. They recorded their opinion that the stone was an ordinary one which had been struck by lightning. It was, nevertheless, a true meteorite.

Early in the year 1794 Professor Chladni, a renowned German physicist, published a thesis in which he collated many accounts of bodies which had been said to have fallen from the sky, discussed the nature of the bodies themselves and expressed the conviction that bodies could and did come to our earth from space. Chladni devoted particular attention to the iron-and-stone mass known as the "Medwedewa" meteorite and the iron mass known as Campo del Cielo. The former of these was first described by the traveler Pallas, who saw it in the year 1772 at the city of Krasnojarsk, Siberia. The latter was found by Indians in the interior of Argentina, South America, and was first visited in the year 1783 by Don Michael Rubin de Celis, who calculated the weight of the mass to be 30,000 pounds.

As if in direct confirmation of Chladni's theory, a shower of stones fell at Siena, Italy, on June 16, 1794, and the occurrence is thus described in connection with the account of an eruption of Vesuvius by Sir William Hamilton[1]:

"I must here mention a very extraordinary circumstance indeed, that happened near Sienna in the Tuscan state, about 18 hours after the commencement of the late eruption at Vesuvius on the 15th of June, though that phenomenon may have no relation to the eruption; and which was communicated to me in the following words by the Earl of Bristol, bishop of Derry, in a letter dated from Sienna, July 12th, 1794: 'In the midst of a most violent thunder-storm, about a dozen stones of various weights and dimensions fell at the feet of different people, men, women, and children; the stones are of a quality not found in any part of the Siennese territory; they fell about 18 hours after the enormous eruption of Vesuvius, which circumstance leaves a choice of difficulties in the solution of this extraordinary phenomenon: either these stones have been generated in this igneous mass of clouds, which produced such unusual thunder, or, which is equally incredible, they were thrown from Vesuvius at a distance of at least 250

[1] Philosophical Transactions of the Royal Society of London. Abr. ed., 1809, vol. XVII, p. 503.

miles; judge then of its parabola. The philosophers here incline to the first solution. I wish much, Sir, to know your sentiments. My first objection was to the fact itself; but of this there are so many eye-witnesses, it seems impossible to withstand their evidence, and now I am reduced to a perfect scepticism.' His lordship was pleased to send me a piece of one of the largest stones, which when entire weighed upwards of 5 lb.; I have seen another that has been sent to Naples entire, and weighs about 1 lb. The outside of every stone that has been found, and has been ascertained to have fallen from the cloud near Sienna, is evidently freshly vitrified, and is black, having every sign of having passed through an extreme heat; when broken, the inside is of a light grey color mixed with black spots, and some shining particles, which the learned here have decided to be pyrites, and therefore it cannot be a lava, or they would have been decomposed."

Scientists, however, are often hard to convince, and some of that day contended that the Siena stone had been formed in the air by condensation of the particles of dust in an eruption cloud from Vesuvius, in spite of the fact that Siena is 250 miles distant from the volcano and that the largest stone of the shower weighed 7½ pounds, while several weighed more than 1 pound each. Even the 56-pound stone which fell December 13, 1795, at Wold Cottage near Scarborough, Yorkshire, England, almost at the feet of a laborer, did not dislodge this theory from the mind of Edward King, its originator.

The cloud theory was completely disproved at Krakhut near Benares, India, on December 19, 1798, when, directly after the passage of a ball of fire through the air, a heavy explosion or a series of explosions was heard and many stones[1] fell from a sky which had been perfectly cloudless for a week before the event and remained so for many days afterward. Even these facts, however, did not fully convince the scientists of France and it required the occurrence of the meteoritic shower of L'Aigle, France, April 26, 1803, for final proof.[2] L'Aigle is easily accessible from Paris and M. Biot, a noted physicist was sent at once to investigate the matter. Biot learned that on the day mentioned a violent explosion occurred in a practically clear sky in the vicinity of

[1] Represented in the general meteorite collection, Morgan Hall, No. 404 of the fourth floor of this building, by a small fragment one fourth of an ounce (8 grammes) in weight.

[2] A fragment of L'Aigle weighing 5 ounces (157 grammes) is in the general collection.

L'Aigle which was heard over an area seventy five miles in diameter directly after a swiftly moving fire-ball had been seen to pass through the air. The explosion, or series of explosions, was immediately followed by the fall of two or three thousand stones within an elliptical area about $6\frac{1}{4}$ miles long and $2\frac{1}{2}$ miles wide. The largest of the stones weighed 20 pounds, the next largest $3\frac{1}{2}$ pounds, but most of the fragments were very small. The occurrence at L'Aigle proved the correctness of another of Chladni's theories, which was that "fire balls" in the sky were nothing more or less than meteorites in flight.

The oldest still existing meteorite of the fall of which we have an exact record is that of Ensisheim, in Elsass, Germany.[1] An ancient document states:

"On the sixteenth of November, 1492, a singular miracle happened: for between 11 and 12 in the forenoon, with a loud crash of thunder and a prolonged noise heard afar off, there fell in the town of Ensisheim a stone weighing 260 pounds. It was seen by a child to strike the ground in a field near the canton called Gisguad, where it made a hole more than five feet deep. It was taken to the church as being a miraculous object. The noise was heard so distinctly at Lucerne, Villing, and many other places, that in each of them it was thought that some houses had fallen. King Maximilian, who was then at Ensisheim, had the stone carried to the castle; after breaking off two pieces, one for the Duke Sigismund of Austria and the other for himself, he forbade further damage, and ordered that the stone be suspended in the parish church." [2]

Within the past century many stones and some masses of iron have been seen to fall from the sky and afterwards have been collected and are now in cabinets, while several hundred specimens have been found which are so much like the positively known meteorites that they have been classed with them and are jealously guarded in collections.

Classification.

Meteorites are generally divided into three classes according to their mineral composition:

1. "Siderites," or iron meteorites, which consist essentially of an alloy of iron and nickel;

[1] A fragment of this meteorite weighing about four ounces (129 grammes) is in the general meteorite collection.

[2] Fletcher. An Introduction to the study of Meteorites. P. 19. 1888.

9 AHNIGHITO, THE GREAT CAPE YORK METEORITE.

Weight, more than 36.5 tons. The largest and heaviest meteorite known.

2. "Siderolites," or iron-stone meteorites, which are formed of a nickel-iron sponge, or mesh, containing stony matter in the interstices;
3. "Aërolites," or stone meteorites, which are made up mainly of stony matter, but almost always contain grains of nickel-iron scattered through their mass.

The line of demarcation between these classes is not always sharp, and there are many subordinate kinds of aërolites.

Countless numbers of meteoritic bodies, mostly of minute size, must exist within the boundaries of the solar system, since from fifteen to twenty millions of them enter the earth's atmosphere every day. Almost all of these are dissipated in our atmosphere through heat produced by friction with the air, so that the only evidence of their presence is a trail of light across the sky. This usually is visible only at night, and is familiar to all as a shooting star or meteor. Shooting stars are to be seen almost every evening, but they are particularly abundant during August and November. Sometimes the November shower of meteors has been so pronounced that the sky has seemed fairly to radiate lines of fire, an effect far surpassing in brilliance the most ambitious artificial fire works. Not one in a hundred million of these shooting stars, however, reaches the earth in a recognizable mass; in fact, there are records of only about 685 known meteorites which are represented in museums and private cabinets.

The weight of known meteorites varies between wide limits. The lightest independent mass is a stone meteorite weighing about one sixth of an ounce called Mühlau from the town in the vicinity of Innsbruck, Austria, near which it was found in 1877; the heaviest mass known is Ahnighito, of the Foyer collection, an iron meteorite weighing more than thirty-six and one half tons which came from Cape York, Greenland. Some showers of meteorites have furnished even smaller individuals than Mühlau. Forest City, well represented in the Foyer collection, has been found in fragments weighing one twentieth of an ounce. Pultusk is a famous fall and the smallest of the "Pultusk peas," as the material is called, weigh less than one thirtieth of an ounce each, while Hessle fell in a veritable rain of meteoritic dust, the smallest particles of which weigh about one four hundred twenty-fifth of an ounce and could never have been found had they not fallen on an ice-covered lake, where they were readily seen and recognized.

Meteoritic masses are almost certainly extremely cold during their existence in outer space, but when they come into the earth's atmosphere friction with the air raises the temperature of the surface to the melting point, producing a great amount of dazzling light as well as superficial heat. In spite of this surface fusion, it is highly probable that the duration of the aërial flight of a meteorite is so short that in many cases the interior does not become even warm.[1]

The rapid heating of the exterior and the differences of temperature between different parts of a meteorite often lead to its rupture before it reaches the ground. This is particularly the case with stone meteorites, the iron meteorites being tough enough usually to withstand the fracturing agencies. Most of the meteorites which have burst have furnished only two or three fragments, so far as known, but a few have furnished many, while there have been found 700 pieces of Hessle, 1000 pieces of Forest City, several thousand each of Knyahinya and L'Aigle, and about one hundred thousand each of Mocs and Pultusk. The name "stone shower" has been appropriately given to the falls comprising many individuals. "Iron showers" from bursting siderites are much rarer than the stone showers, only six are known to have occurred, among which Canyon Diablo leads, several thousands of fragments of this famous fall having been found.

The breaking up of a meteorite is accompanied by an explosion or series of explosions, and often these are startling in their sharpness and intensity, when they occur near the earth. Forest City, 268 pounds of which have been found, just before falling burst in a series of explosions which were heard over an area two hundred miles in diameter. There were three distinct detonations connected with the fall near Butsura, Bengal, which were heard at Goruckpur sixty miles away, although the meteorite was a small one, less than fifty pounds of it having been found. The occurrences at Krakhut, L'Aigle and Ensisheim have already been mentioned.

Chemical Composition.

Some forty one elements, four of which are gases, are said to occur in meteorites, but several of these may be regarded as doubtful. The

[1] See also page 18.

most abundant have been arranged by Dr. O. C. Farrington[1] in the following order of importance:

1. Iron	3. Silicon	5. Nickle	7. Calcium
2. Oxygen	4. Magnesium	6. Sulphur	8. Aluminum

The other elements of particular importance in this connection are carbon, chlorine, chromium, cobalt, copper, hydrogen, manganese, nitrogen, phosphorus, potassium and sodium.

Mineral Constituents.

Seven elements have been found in meteorites in the elemental or uncombined state. They are iron, nickel, cobalt and copper in the form of alloys, carbon, hydrogen and nitrogen. With these exceptions, the constituents of meteorites are chemical compounds and all but six of the whole list have their exact equivalents in minerals which are found in the crust of the earth.

According to most authorities the constituents of meteorites may be divided into essential and accessory components as follows[2]:

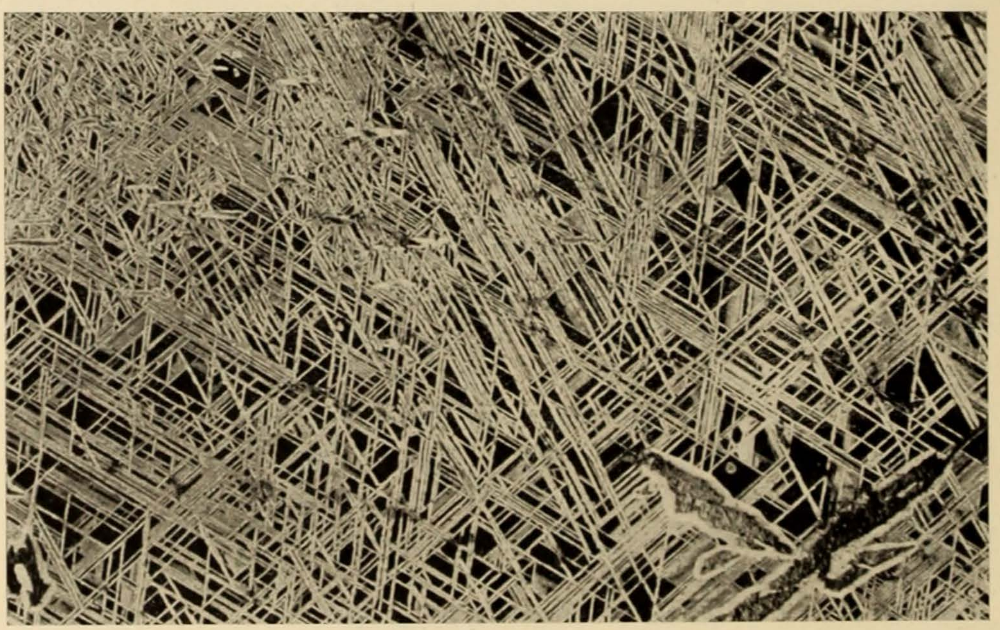
Essential.	*Accessory.*
Nickel-iron	*Schreibersite
Olivine (chrysolite)	Diamond
Pyroxenes (Orthorhombic)	Graphite (Cliftonite)
Pyroxenes (Monoclinic)	Hydro-carbons.
Feldspar (Plagioclase)	Cohenite
*Maskelynite.	*Moissanite
	*Troilite
	Pyrrhotite
	*Daubréelite
	*Oldhamite
	Tridymite
	Chromite
	Magnetite
	Osbornite
	Lawrencite
	Glass

[1] Journal of Geology. Vol. IX, p. 394. 1901.

[2] E. Cohen. Meteoritenkunde I, p. 322. 1894. The asterisk indicates the minerals which are peculiar to meteorites and are not known to occur in the earth's crust.

Essential Constituents.

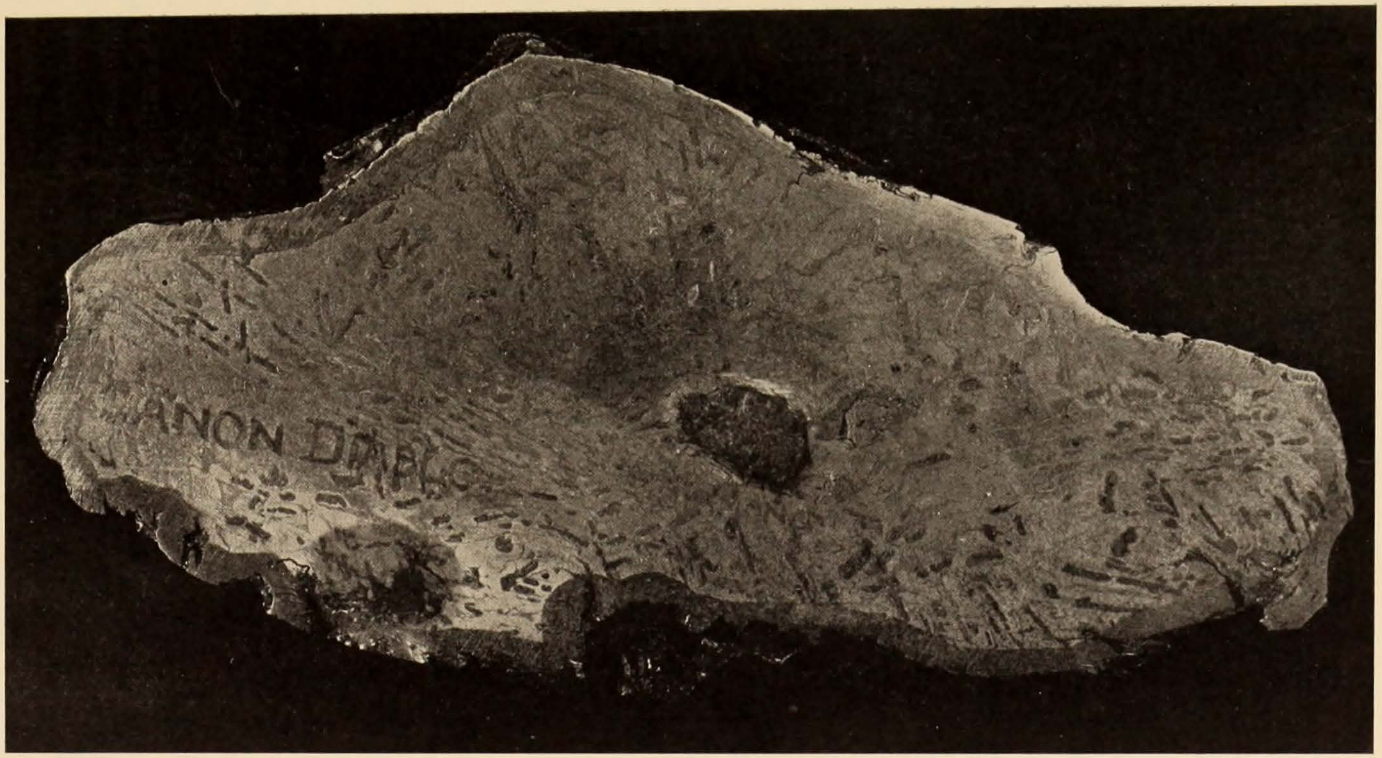
The iron of meteorites is always alloyed with from 6 to 20 per cent of nickel. This "nickel-iron," as it is commonly called, is usually crystalline in texture, and when it is cut, polished and "etched" a beautiful network of lines is brought out, indicating plates which lie in positions determined by the crystalline character of the mass. This network of lines constitutes what are called the Widmanstätten figures, from the name of their discoverer. When these figures are strongly developed, the meteoritic origin of the iron cannot be questioned, but their absence does not necessarily disprove such an origin. Native iron of terrestrial



WIDMANSTÄTTEN LINES, OR FIGURES.
Carleton Iron Meteorite. Natural size. In this iron the plates are very thin.

origin is extremely rare and has been found almost exclusively at Disco Island and immediate vicinity on the west coast of Greenland. The Disco, or Ovifak, iron contains less nickel than meteoritic iron, while other terrestrial nickel-irons (*i. e.* awaruite and josephinite) contain much more. Small quantities of metallic cobalt are also alloyed with the nickel and a little copper is sometimes found in the same association.

Next to nickel-iron the mineral olivine, or chrysolite, is the most important constituent. This is a silicate of magnesium, always con-



15 CANYON DIABLO. ETCHED SECTION SHOWING WIDMANSTÄTTEN LINES.

A diamond was found in the black spot in this section.

taining some iron, which occurs in all the siderolites and most of the aërolites, sometimes comprising a considerable portion of their mass. It is a dark yellowish-green to black, glassy mineral usually occurring as rounded or angular grains, but sometimes as crystals. It is prominent in a slice of Brenham in the Foyer collection, where it forms glassy grains in a mesh of nickel-iron. Olivine is the gem, peridot.

The minerals belonging to the group known as orthorhombic pyroxenes are next to olivine in point of abundance. Chemical analyses show that all gradations are present from the colorless enstatite to the almost black hypersthene members of the group. The monoclinic pyroxenes, which are important constituents of terrestrial igneous rocks, are represented in meteorites by only two forms, an iron-alumina pyroxene like common augite and one nearly free from iron and without alumina which is to be compared with diopside. The augite-like mineral is brown to green in color and occurs usually in grains or splinters rarely in crystals. It has been found in many meteorites, but diopside has been identified only once with certainty.

The great feldspar series has been identified in meteorites in four of its forms, namely: anorthite, albite, oligoclase and labradorite. Of these, anorthite has been found forming a large part (35 per cent.) of some meteorites and measurable crystals have been obtained, but in most cases where feldspar occurs in a meteorite, it has been possible to go no farther than to identify it as belonging to the plagioclase section of the mineral group.

Maskelynite is a transparent, colorless, glassy mineral. In chemical composition it is related to the terrestrial species leucite, but it is a distinct form and thus far is known only from meteorites. It is not known to occur in any of the meteorites displayed in the Foyer.

Accessory Constituents.

Schreibersite is a phosphide of iron, nickel and cobalt which is probably peculiar to meteorites. It is tin-white in color, changing to bronze-yellow or steel gray on exposure to the air. In structure it is granular, flaky, crystalline or needle-like. Next to nickel-iron schreibersite is the most generally disseminated constituent of siderites and forms some of the shining lines to be seen on etched sections.

Carbon occurs in at least three forms in meteorites, as the diamond, as graphite (cliftonite) and as hydrocarbons. Diamonds were first found in Canyon Diablo in 1891. They are extremely minute in size but recognizable crystals have been obtained. Graphite (cliftonite) occurs usually in nodules and only in siderites in particles that are large enough for easy examination. The material is very fine. The cliftonite form of graphite is considered by most authorities to be a pseudomorph after diamond.

Hydrocarbons of several kinds have been found in meteorites. According to Cohen[1] they may be grouped into three classes: (1) compounds of carbon and hydrogen alone; (2) compounds of carbon, hydrogen and oxygen; (3) compounds of carbon, hydrogen and sulphur. None of the meteorites in the Foyer collection is known to contain any hydrocarbon, but the fact that any meteorite should contain such substances is of great scientific interest. It is pretty clear that they belong to the pre-terrestrial history of the masses; hence, since they are readily combustible or volatile, the meteorites that contain them cannot have been heated to high temperatures, at any rate, subsequent to the formation of the compounds. This is an additional argument in support of the statement already made that the heating of meteorites during aërial flight is, in many instances at least, only superficial. Furthermore, the existence of hydrocarbon compounds in meteorites, where no life can have existed, shows that organisms are not absolutely necessary to the formation of such compounds in the earth's crust.

Cohenite, which is a carbide of iron, nickel and cobalt, is tin-white in color and looks like schreibersite. It is much rarer, however, and occurs in isolated crystals. The only terrestrial occurrence of cohenite is in the basaltic iron of Greenland. Moissanite, the natural carbide of aluminum corresponding to the artificial carborundum, has thus far been found only in Canyon Diablo, where it occurs in microscopic crystals. It is the latest discovery among the constituents of meteorites, having been found in 1905 by Henri Moissan.

As far as investigations have been carried, heating develops the fact that meteorites contain gases condensed within them, either by occlusion in the same way that platinum and zinc absorb hydrogen or by some form of chemical union. According to Cohen[2] the following gases have

[1] Meteoritenkunde. Heft I, p. 159.
[2] Meteoritenkunde. Heft I, p. 169

been found: hydrogen, carbon dioxide, carbon monoxide, nitrogen and marsh gas (light carburetted hydrogen).

Troilite is common in meteorites and constitutes brass- or bronze-yellow nodules, plates and rods which are to be seen in nearly every section, particularly of siderites. The mineral is usually considered to be the simple sulphide of iron, FeS, but its exact chemical composition and crystalline structure are still matters of investigation and dispute. Canyon Diablo and Willamette contain, or contained, much troilite in the shape of rods, and the fusion and dissipation of this mineral during the aërial flight of the masses gave rise to some of the holes which penetrate them, and the same statement is true of many other meteorites. Pyrrhotite, the magnetic sulphide of iron, $Fe_{11}\ S_{12}$, occurs in stone meteorites and chiefly in the form of grains. Daubréelite is likewise a sulphide of iron, but it differs from those just mentioned through containing much chromium, giving the chemical formula FeS, $Cr_2\ S_3$. The mineral is peculiar to siderites and siderolites and has never been found in the stone meteorites or in the earth's crust. It occurs in Canyon Diablo, where it may be seen surrounding nodules of troilite as a black shell with metallic luster.

Oldhamite, a sulphide of calcium, CaS; tridymite, a form of silica, SiO_2; chromite, an oxide of iron and chromium, $FeCr_2\ O_4$; magnetite, the magnetic oxide of iron, $Fe_3\ O_4$; osbornite, another sulphide or oxysulphide of calcium, and lawrencite a chloride of iron, $Fe\ Cl_2$, occur sparingly in some meteorites. Lawrencite manifests itself rather disagreeably through alteration to the ferric chloride, which oozes out of the masses of iron and stands in acrid yellow drops on the surface or runs in streaks to the bottom. Glass like the volcanic glass of terrestrial rocks seems never to be absent from the interior of stone meteorites, but from the nature of the case it is not found in iron meteorites.

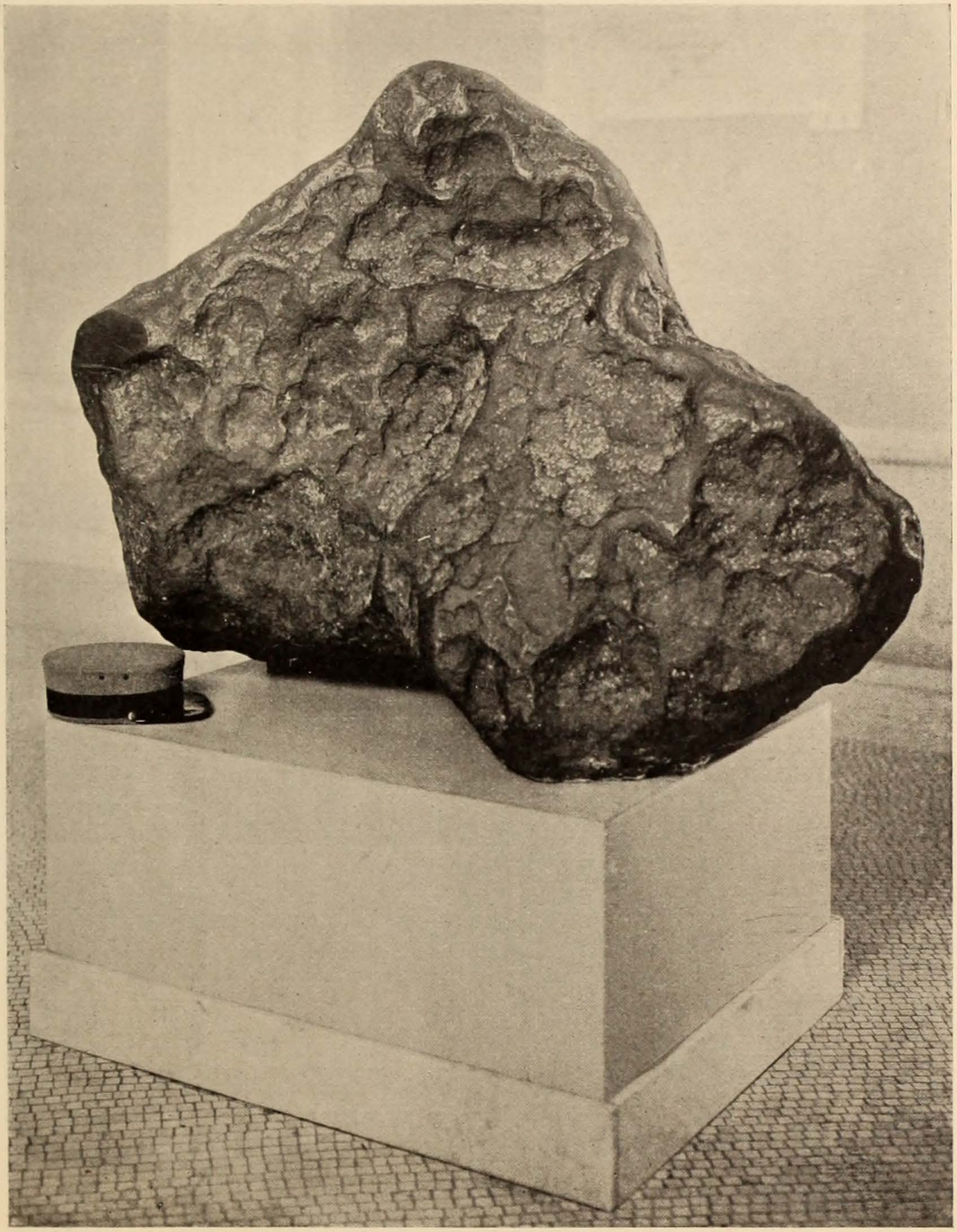
Surface Characteristics.

The surface of a newly-fallen meteorite always consists of a thin veneer or crust which differs in marked degree from the interior of the mass. In the case of the siderites, this seems to be a polish due to melting and friction, together with partial oxidation. Some iron meteorites which are known to have lain long in the ground likewise show a crust which is somewhat similar in appearance, but it is due to slow oxidation or "rusting" in the ground and is called the rust crust. Almost without exception the aërolites are covered with a crust, the appearance of which varies according to the mineral composition of the mass. The crust is almost always black and is usually dull, but sometimes it has high luster. A few meteorites possess a dark-gray crust, and some show crust only in patches.

The crust of the stone meteorites is glassy in character on account of its being composed of silicates which have been cooled rapidly from fusion. This glass, like glasses of volcanic origin, does not long resist the atmospheric agents of decay, hence it is usually missing from those aërolites which have lain long in the earth or it is much decomposed, as may be seen by examining Long Island and Selma in the Foyer collection. The crust varies in thickness on different parts of a meteorite and often shows ridges and furrows which are due to friction with the air. Frequently the ridges or furrows radiate from one or more centers in such manner as to show which side of the mass was forward during its flight through the air. So quickly is the crust formed that even the smallest members of a meteorite shower usually possess a complete crust. In the case of angular fragments the crust on the different sides can usually be distinguished as "primary" or "secondary" according to whether it was a part of the original exterior of the mass or was formed upon the new surfaces exposed by the bursting of the meteorite.

Another common surface characteristic of meteorites is an abundance of shallow depressions or pittings, which on account of their form have been called "thumb marks," or piëzoglyphs. These pittings are so shallow and superficial in character that exposure to the atmosphere obscures or obliterates them in a comparatively short time. The rusting of an iron meteorite may produce similar shallow depressions, as will be seen from an examination of the surfaces of the great hollows in Willamette. The true piëzoglyphs doubtless owe their origin to several different causes, the most potent of which are unequal softening of a mass due to varying chemical composition and rapidly changing pressure and consequent erosion during flight through the atmosphere.

Without going more deeply into the subject in general we may now turn our attention to the Foyer collection.



CAPE YORK.

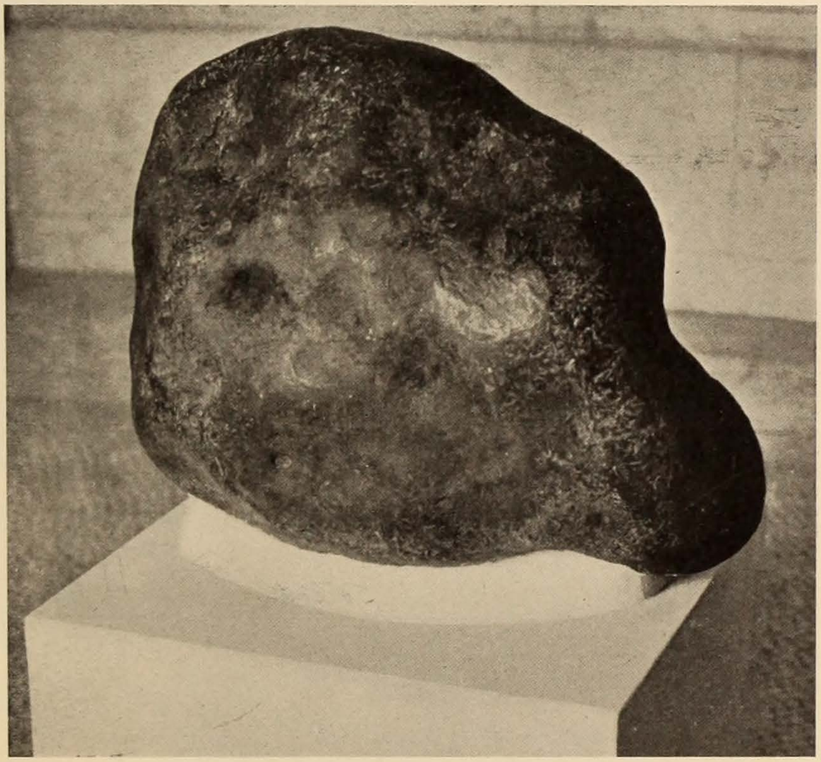
"The Woman". Weighs 3 tons.

THE CAPE YORK METEORITES,

"Ahnighito," or "The Tent," "The Woman" and "The Dog."

(Siderites.)

For centuries, and perhaps for thousands of years, the three masses of iron known as the Cape York meteorites lay on the north coast of Melville Bay near Cape York, Greenland, but they were seen for the first time by a white person, when they were visited by Commander Robert E. Peary, U. S. N., in 1894 and 1895 under the guidance of Tallakoteah, a member of the Eskimo tribe which up to the early part

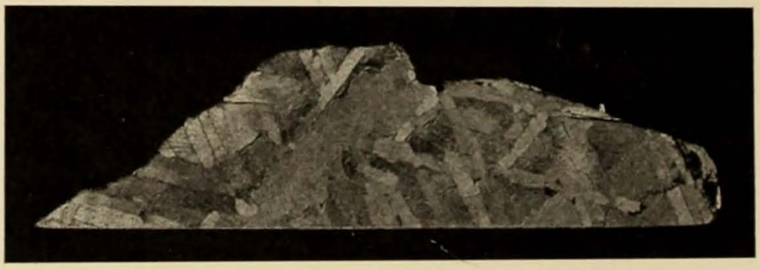


CAPE YORK.
"The Dog". Weighs 1100 pounds.

of the nineteenth century had obtained material for knives and other utensils from the masses.

The three meteorites were known as a group to the Eskimo under the name of "Saviksue" or "The Great Irons," and each had its own name suggested by its shape. The smallest mass, weighing about 1,100 pounds, was called "The Dog"; the next larger mass, weighing about three tons, was named "The Woman," because the shape was thought to suggest the squatting figure of a woman with a babe in her arms and a shawl thrown about her, and the largest mass, weighing more than thirty six and one half tons, was known as "The Tent." The last, however, has been formally christened by the daughter of the explorer with her own name, "Ahnighito." This great mass is 10 feet 11 inches long, 6 feet 9 inches high and 5 feet 2 inches thick.

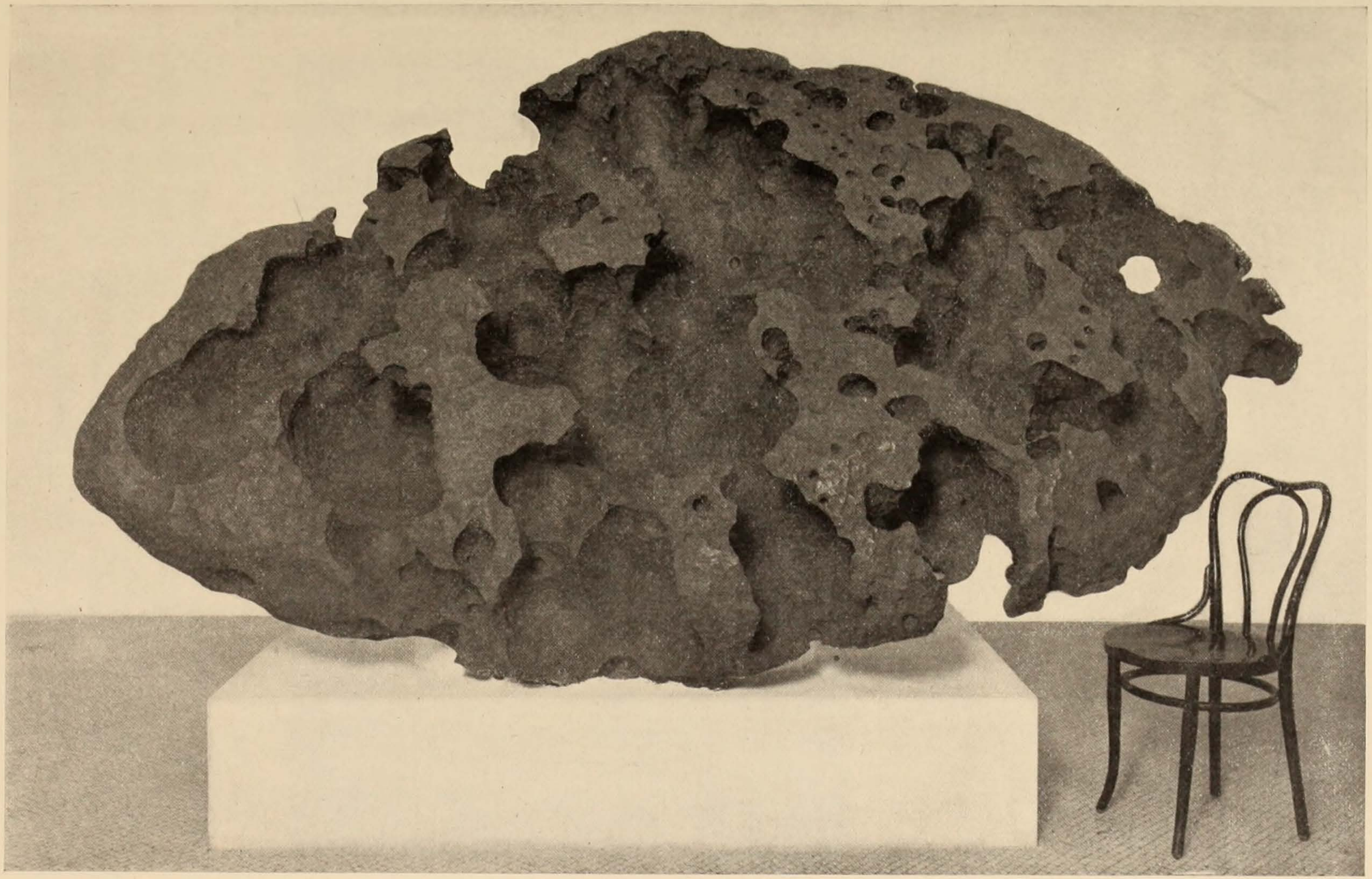
The Woman and the Dog were visited by Peary in 1894 and were obtained the following year after much difficult and exciting work, an incident of which was the breaking up of the cake of ice on which the Woman had been ferried from the shore to ship just as the mass was about to be hoisted aboard. Fortunately there was enough tackle around the meteorite to prevent its loss. In 1895, Commander Peary visited Ahnighito, also, which lay on an island only four miles from the two smaller masses, but he could do little toward its removal. The next year he made another voyage for the purpose of getting the great iron but was unsuccessful. His third attempt was made in 1897, and the meteorite was brought safely to New York in the ship "Hope."



SECTION OF AHNIGHITO. NATURAL SIZE.
Shows broad Widmanstätten lines.

The three masses are closely similar in chemical composition, analyses by J. E. Whitfield giving the following results:

	The Dog.	The Woman.	Ahnighito.
Iron	90.99%	91.47%	91.48%
Nickel	8.27%	7.78%	7.79%
Cobalt	0.53%	0.53%	0.53%



25

WILLAMETTE. (GIFT OF MRS. WILLIAM E. DODGE.)

Length 10 feet, height 6 feet 6 inches. Weight 15.6 tons. Rear side, showing deep pits formed by oxidation.

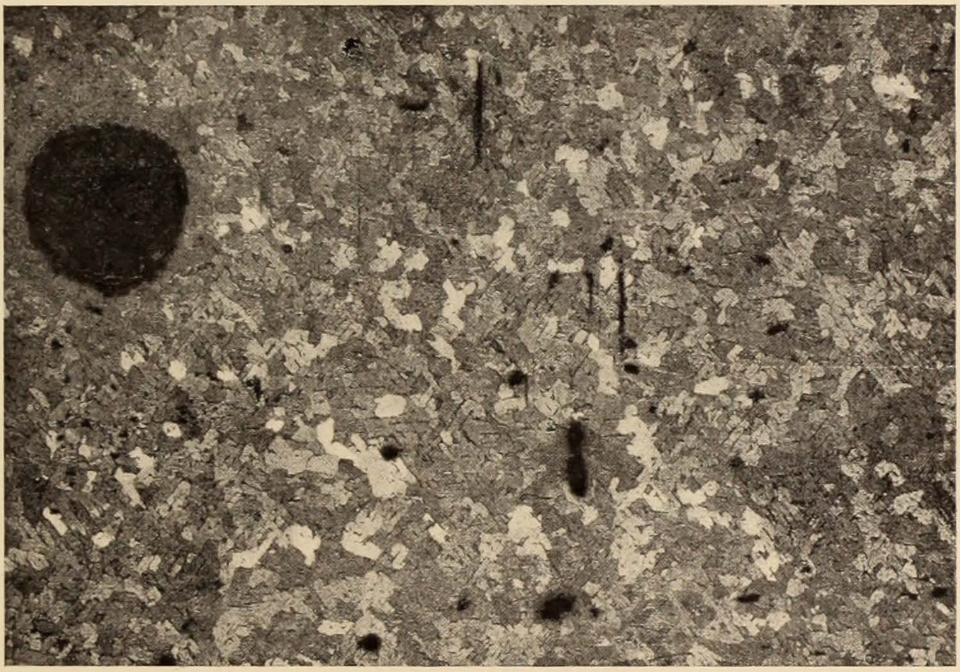
Besides these metals there are present small quantities of copper, sulphur, phosphorus and carbon. The similarity in chemical composition and the close proximity in which the masses lay when found indicate the probability that they are parts of the same fall.

WILLAMETTE

(Siderite.)

GIFT OF MRS. WILLIAM E. DODGE.

This is the most interesting iron meteorite, as to external characteristics, which has ever been discovered, and it is the largest ever found in the United States. Its chief dimensions are, length 10 ft., height



SECTION OF WILLAMETTE.

6 ft. 6 in., thickness, 4 ft. 3 in. On the railroad scales in Portland, Oregon, the net weight was shown to be 31,107 lbs.

Willamette was discovered in the autumn of 1902 in the forest about nineteen miles south of Portland, by two prospectors who were searching for ledges likely to contain mineral wealth, particularly gold or silver.

The finders at first supposed that they had come upon a ledge of solid iron, but the meteoritic character of the mass was soon ascertained. Later one of the prospectors removed the meteorite to his own ranch three-quarters of a mile distant, but the owners of the land on which it had been found instituted suit for its recovery, and the contest was carried to the supreme court of the State before the finder relinquished his claim. The specimen was received at the Museum in April, 1906.

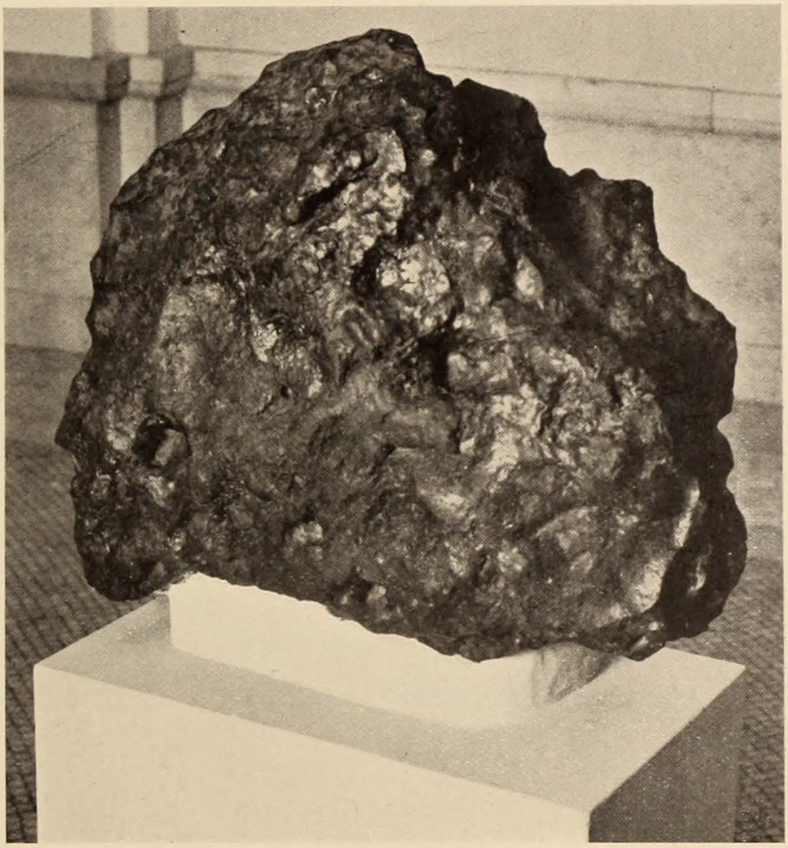
The most striking characteristic of Willamette, next to its size, is the series of hollows and deep pits which indent its surface. The broad shallow hollows on the front side, "brustseite," (side now turned toward the wall) were probably caused by friction against the atmosphere and consequent melting and flowage of the iron during the flight of the meteorite through the air. The deep pot-like pits on the rear side (the side now facing the center of the Foyer) are most probably due to rusting while the meteorite was lying in the ground where it fell, and they seem to have had their origin in the decomposition of spheroidal nodules of troilite. Note also the cylindrical holes which penetrate deeply into the mass from both sides. These probably began with the decomposition of rod-like masses of troilite. In addition to these holes and pits the surface of the mass is indented with small shallow depressions which also seem to be a feature of the decomposition of the iron.

A fractured face shows Willamette to be remarkable for its coarse granular texture, the grains being bounded by almost definite planes suggesting crystals. A polished and etched surface shows rather broad Widmanstätten lines. Chemical analysis shows that the meteorite contains about 91.55 per cent iron, 8.09 per cent nickel and a small amount of cobalt, phosphorus and sulphur.

CANYON DIABLO.

(*Siderite.*)

Canyon Diablo is a siderite which is popularly famous chiefly from the fact that it contains diamonds. This gem stone has been definitely proven to occur in only two meteorites, the other being a Russian fall, although many masses are known to contain carbon in the form of a soft black powder. The discovery of diamonds in Canyon Diablo was made in 1891 by Professor G. A. Kœnig of Philadelphia and was afterward confirmed by Dr. George F. Kunz of New York, Professor Huntington of Harvard University, Professor Moissan of Paris and other investigators. In 1905 Moissan dissolved a fragment of Canyon Diablo weighing



CANYON DIABLO.
Weight, 1087 pounds. Diamonds have been found in specimens of this fall.

several pounds and obtained not only recognizable crystals of the diamond, but also crystals of a mineral corresponding exactly in composition to the extremely hard artificial silicide of carbon (CSi_2) known as carborundum. This new mineral has been named moissanite, and this is the first time that it has been found in nature.

Canyon Diablo was found in 1891 at and near Coon Butte, Arizona, in the vicinity of the town of Canyon Diablo. The original size of the mass is not known, but thousands of fragments have been collected, varying in weight from a fraction of an ounce up to 1,087 pounds. More than 16 tons of this material are said to have been found within the radius of 2½ miles of Coon Butte. Coon Butte is a conical hill rising from 130 to 160 feet above the surrounding plain and containing a crater-like hollow about three-quarters of a mile in greatest diameter and probably 1,460 feet deep originally.

There is no lava of any kind in Coon Butte or in its immediate vicinity, and it is now supposed to be most probable that the "crater" was caused by an immense meteorite striking the earth at this point. The main portion of the mass has not yet been discovered, the fragments which have thus far been found being only the portions separated from the original mass during its passage through the atmosphere and at the time of its impact with the earth.

Two fragments of Canyon Diablo are in the Foyer collection, one of which weighs 1,087 pounds and is the largest piece which has been discovered. It was described and figured by Professor Huntington in the Proceedings of the American Academy of Arts and Sciences, Boston, for 1894. A slice of the meteorite in which a diamond was found is in the general Museum collection and is figured on page 15.

A polished and etched section shows strong Widmannstätten lines which are comparatively broad and somewhat discontinuous. The meteorite consists of 91.26 per cent iron and 8.25 per cent nickel and cobalt, with small quantities of copper, platinum, iridium, phosphorus, sulphur, carbon and silicon. Nodules of troilite are abundant in some parts of the masses. Through decomposition and erosion these nodules have given rise to deep holes in the iron.

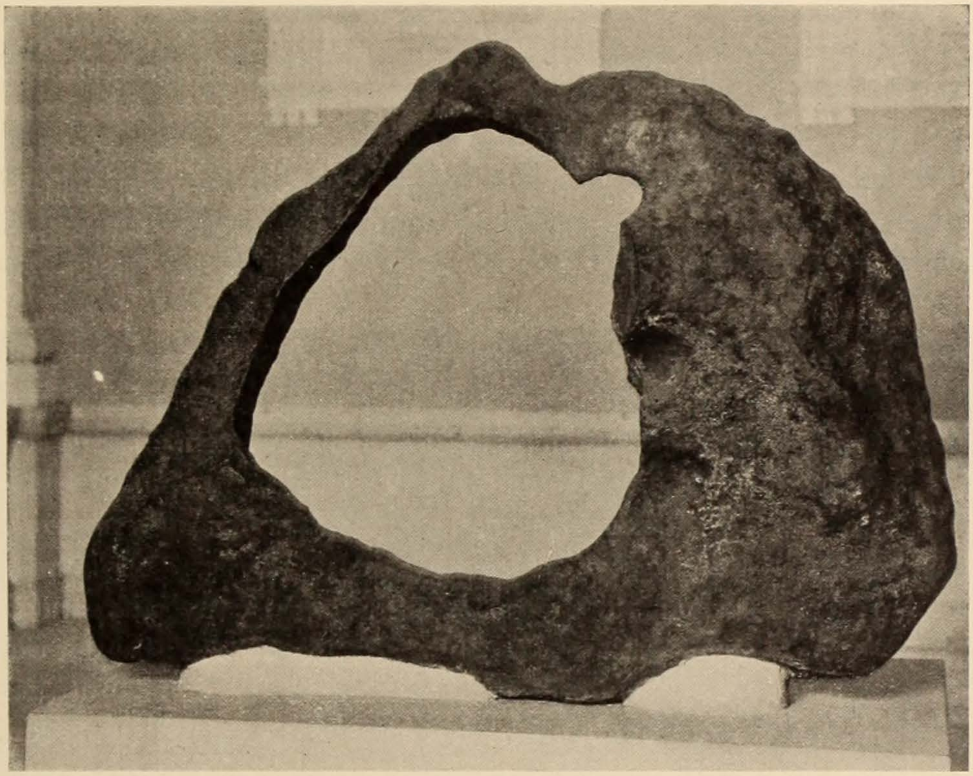
TUCSON.[1]

(Siderite.)

The Tucson meteorite, which is also known as the "Signet" or the

[1] This specimen is a reproduction in cast iron of the famous Tucson meteorite, the original of which is in the National Museum at Washington. The model from which this reproduction has been prepared was presented to the American Museum by the Smithsonian Institution. The original weighs 1,400 pounds, and this cast has the same weight.

"Ring" on account of its peculiar shape, was found in the Santa Catarina Mountains about thirty miles northwest of the city of Tucson, Arizona, and its existence was known to the Spaniards for at least two hundred years before the region became part of the United States. Tradition, indeed, relates that this and many other fragments fell in a single meteoritic shower about the middle of the seventeenth century. The attention of Americans was first drawn to this and its mate, the Carleton meteorite,



TUCSON, OR "SIGNET."
Weight, 1400 pounds. A cast in iron.

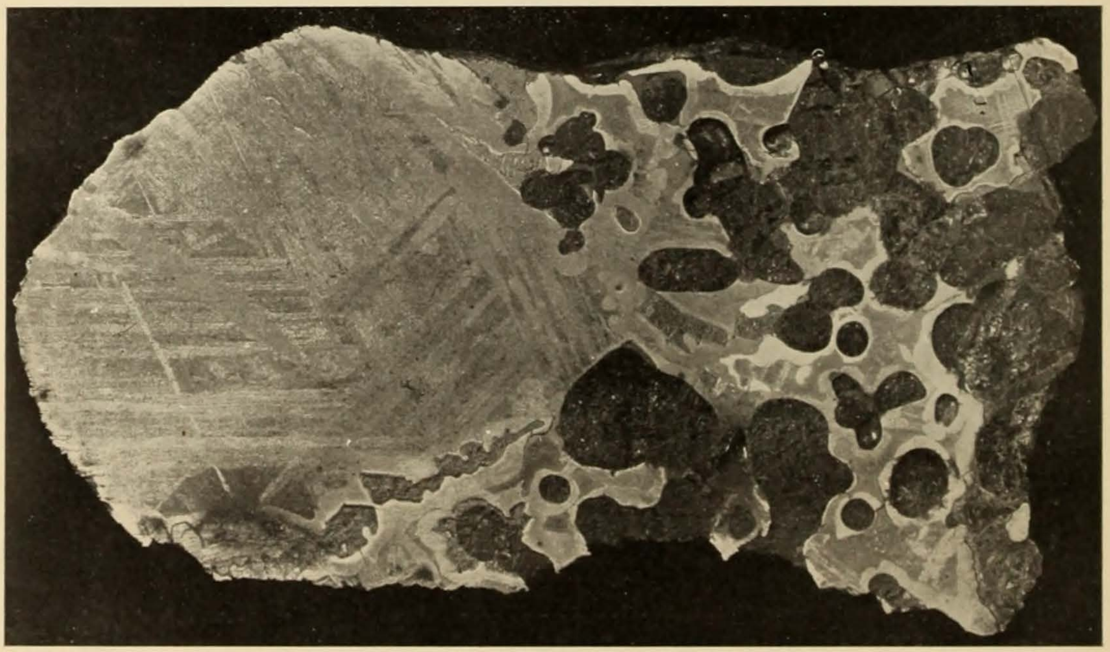
in 1851 by Professor John L. Leconte, who described them as being in use by the blacksmiths of the town as anvils. In 1863 Signet was taken to San Francisco and thence transported by way of the Isthmus of Panama to the Smithsonian Institution at Washington. Carleton, weighing 632 pounds, had been removed to San Francisco the preceding year and was afterwards deposited in the hall of the Pioneers' Society in that city.

Tucson is classed as a siderite, but its average composition shows the presence of from 8 to 10 per cent of stony matter included in the nickel-iron, and the proportions of the mineral constituents vary considerably in different parts of the mass. The nickel-iron is an alloy consisting of 89.89 per cent iron, 9.58 per cent nickel, 0.49 per cent cobalt and 0.04 per cent. copper, while the stony matter consists of olivine, carrying an unusual quantity of lime and associated with noteworthy quantities of schreibersite and chromite.

BRENHAM.

(Siderolite.)

Brenham is classed as a siderolite, but some of its fragments are entirely of nickel-iron. The etched section shown in the Foyer illustrates clearly the peculiar texture of the mass. The metallic portions consist



BRENHAM.
Siderite (left) and Siderolite (right) in the same piece.

of about 88 per cent. iron, 10 per cent. nickel and 2 per cent. other substances. The dark green and glassy portions are crystals of olivine, which break out from the iron almost entire.

The Brenham meteorite was found in the year 1886 scattered in many pieces on the prairie in Brenham Township, Kiowa County, Kansas, over an area more than a mile in length. The fragments were hardly covered by the original prairie soil, and several of them were projecting through the sod. Nearly all were found by being struck by mowing machines, plows or other farm implements. The occurrence of heavy "rocks" in a region where stones of any kind are a great rarity was a source of surprise to the ranchmen and led finally to the discovery that they were meteoritic in origin.

About thirty fragments of the meteorite have been found, several of which were used for many purposes about the ranches and had a rather prosaic history before their value was learned. The smaller but heavier (75-pound) mass here exhibited was used for years to hold down a cellar door or the cover of a rain barrel, while the larger but lighter (52.5-pound) mass served as a weight on a hay-stack. It is probable that the meteorite of which these are fragments burst soon after reaching the earth's atmosphere. The total weight of all the fragments of Brenham which have been found is about 2,000 pounds; the largest piece known weighs 466 pounds, the smallest an ounce or two.

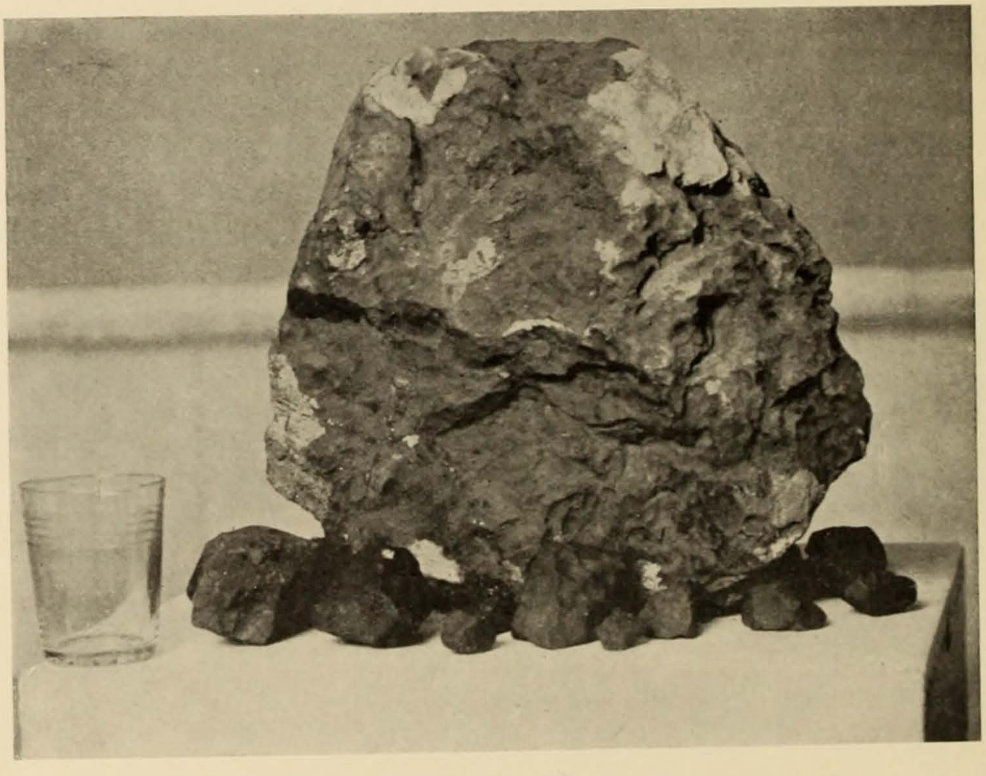
Other specimens of this meteorite may be seen in the Morgan Hall of Mineralogy on the Fourth Floor.

FOREST CITY.

(*Aërolite.*)

On Friday, May 2, 1890, at 5:15 P. M., a brilliant ball of fire shot across the sky from west to east in northern Iowa, its flight being accompanied by a noise likened to that of a heavy cannonading, or of thunder, and by scintillations like those of fireworks. The meteoric light was dazzling even in the full daylight prevailing at the time and the noises, which were due to explosions, were heard throughout a district 200 miles in diameter. This meteor was the Forest City meteorite.

The meteorite burst when it was about 11 miles northeast of Forest City, Winnebago County, whence its name, and most of the fragments were scattered over an area about one mile wide and about two miles long. More than a thousand fragments of this meteorite have been found, most of which weigh from $\frac{1}{20}$ of an ounce to 20 ounces, but a few weigh several pounds. Each is a perfect little meteorite. The largest of the group, which is exhibited here in the Foyer collection, weighs about 75 pounds. The black glassy crust over the surface of all the masses shows that the meteorite exploded early enough in its atmospheric flight for even the smallest fragments to become superficially fused by friction with the air. The fragments show a "primary" and



FOREST CITY.

Shows crust on large and small pieces.

a "secondary" crust, the former formed before and the latter after the bursting of the original mass.

Forest City consists essentially of feldspar, enstatite (a member of the orthorhombic-pyroxene group of minerals), graphite, troilite and nickel-iron. The iron is present in small particles disseminated through the masses and in definite lines suggesting the Widmanstätten figures of a siderite.

The approximate mineral composition of Forest City is

Nickel-iron	19.4%
Troilite	6.2%
Silicates (feldspar, enstatite, etc.)	74.4%

The nickel-iron is an alloy consisting of

Iron	92.7%
Nickel	6.1%
Cobalt	0.7%

The specific gravity of the mass is 3.8. Some chromite is present, but not as much in proportion as is found in the Long Island, Kansas, meteorite.

Some of the smaller individuals of this fall may be seen in the general Museum collection on exhibition in the Morgan Hall of mineralogy (No. 404 of the fourth floor).

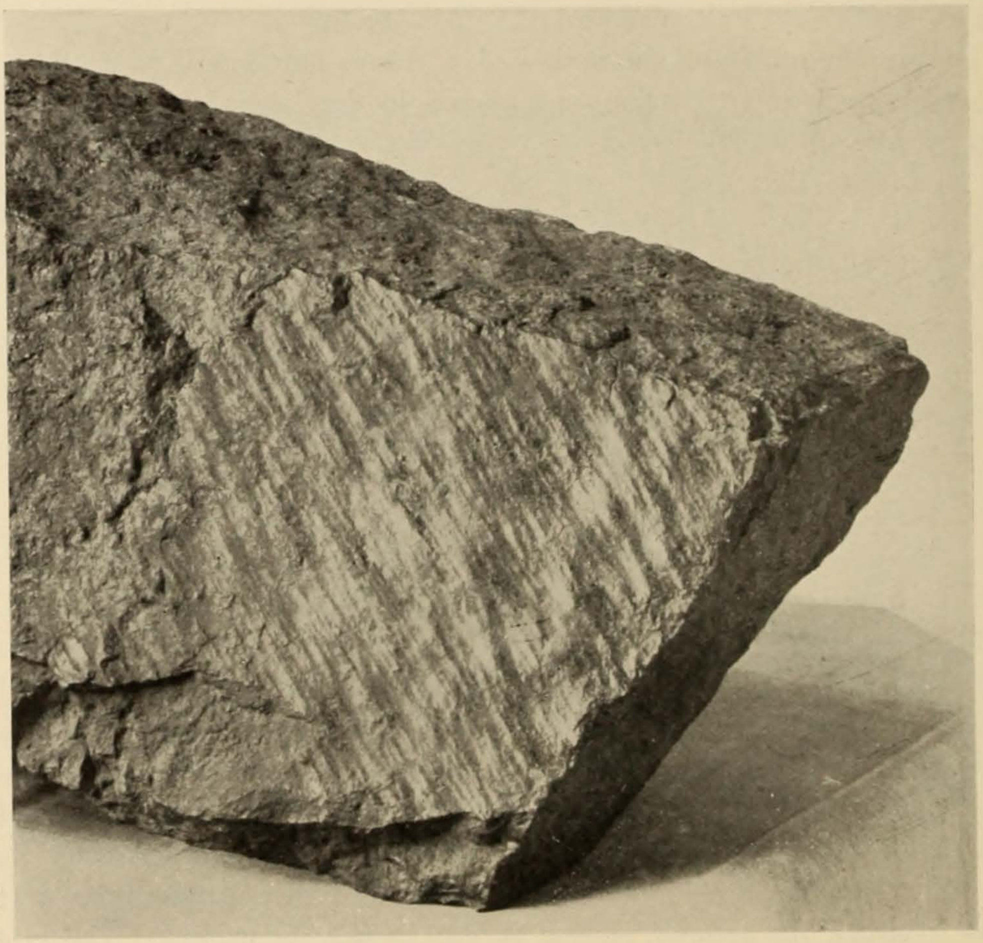
LONG ISLAND (KANSAS).

(Aërolite.)

Long Island is the largest stone meteorite known, the fragments which have been recovered aggregating more then 1,325 pounds in weight. The pieces here exhibited weigh together 86 pounds, the largest weighing 32½ pounds. Some of them show the original external surface of the meteorite, but most of them show only fractures. The meteorite was found in more than 3,000 pieces scattered over a gourd-shaped area only 15 or 20 feet long and 6 feet wide in the northwestern corner of Phillips County, Kansas, near the town of Long Island, whence its name. The small area of distribution shows that the mass burst just as it struck the ground, or that it was broken by impact. The late time of bursting is also indicated by the lack of secondary crust on the pieces.

Stony matter makes up about 80 per cent by weight of Long Island, the remainder having originally been nickel-iron and troilite, now partly changed to limonite through rusting. On the polished surfaces of some of the fragments in the case the nickel-iron may be seen as small shining dots. The stony matter consists essentially of the minerals bronzite (one of the orthorhombic pyroxenes), olivine and chromite and bears a close and interesting resemblance to the terrestrial basaltic igneous rock peridotite. The content of chromite (9 per cent of the whole) is remarkable and is the highest yet reported in meteorites.

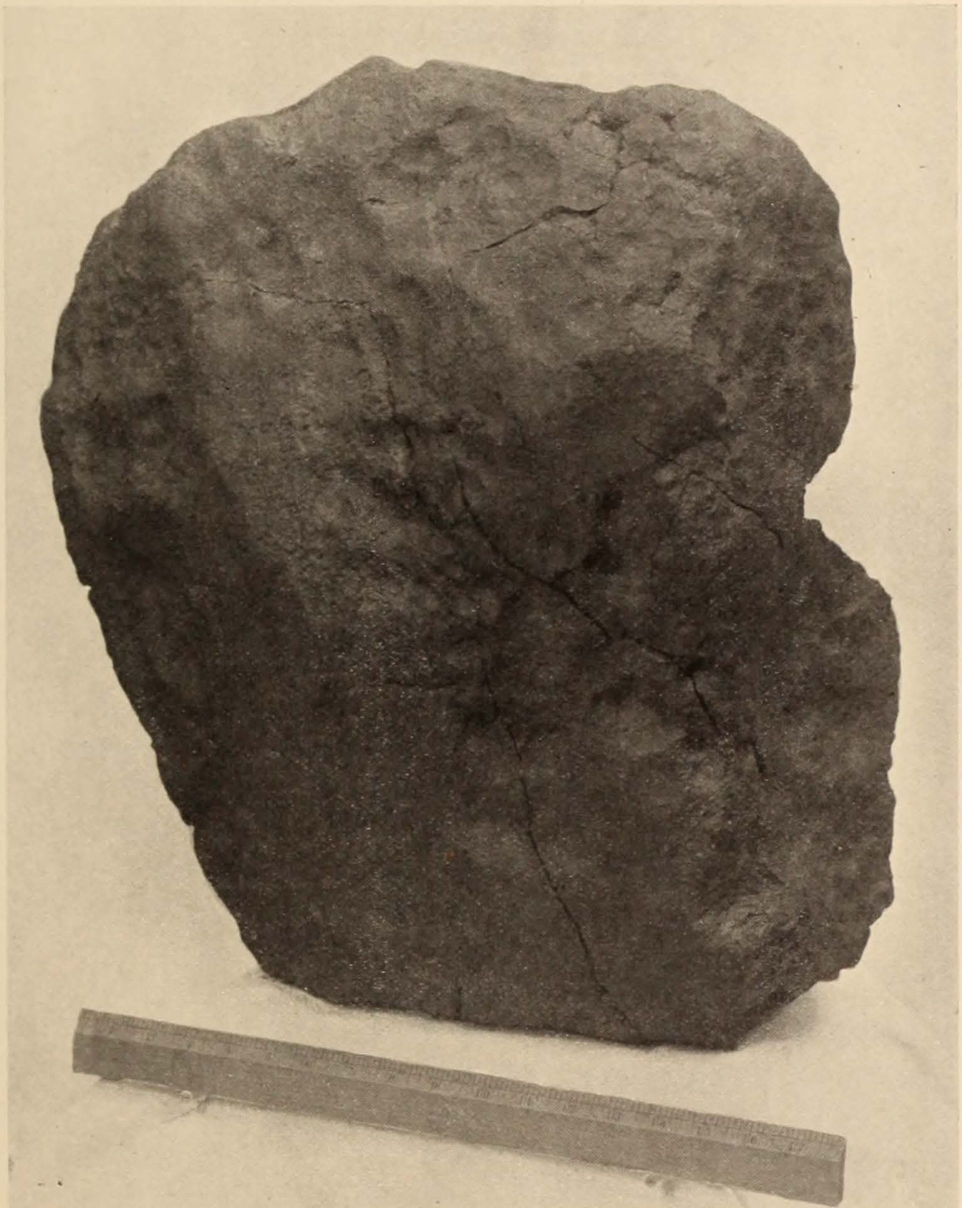
Long Island presents a feature heretofore unknown in meteorites. Certain of the planes of fracture show striated surfaces with grooving and polishing (slickensides) due to the parts grinding together in their



LONG ISLAND.
Slickensided surface showing movement in the mass before it fell.

flight through space before the mass reached our atmosphere. Two of the pieces in this case show such slickensided surfaces and one of them is illustrated on this page.

Other fine specimens of Long Island may be seen in the general meteorite collection on the fourth floor of the Museum (Hall No. 404).



SELMA.

Weight, 306 pounds. Front or "Brustseite."

SELMA.

(Aërolite.)

The Selma meteorite is believed to have fallen at about 9 o'clock, P. M., July 20, 1898, but it was not found until March, 1906. The meteor of July 20, 1898, seems to have traveled in a direction somewhat west of north, and its flight is said to have been accompanied by a heavy rumbling noise and a "trail of fire ten or twelve feet long." The meteorite was found about two miles north-northwest of Selma, Alabama, near the road to Summerfield, and it takes its name from the nearest town, as is the rule with meteoritic falls.

Selma weighs 306 pounds in its present condition, and it is probable that its original weight was about four pounds more, one or more small fragments having been lost from the mass. It is one of the ten largest aërolites ever found, and is the fourth largest aërolite that has fallen in the United States. The others having been broken up, this is probably the largest entire stone meteorite in the country at the present time. Its dimensions are: length, as it rests on its pedestal, 20½ inches; width, 20 inches; height, 14 inches.

In shape Selma is roughly polyhedral without pronounced orientation features, but it is probable that the upper side, as the specimen now lies, was the "brustseite" or front during the flight of the mass through the atmosphere. This side is bluntly pyramidal in shape. The original glassy crust of the meteorite has been mostly decomposed and washed away so that the characteristic thumb-marks, or piëzoglyphs, have been partly obscured. These peculiar markings may be seen on the front of the meteorite and in the illustration on page 37. The mass is deeply penetrated by cracks on both sides, and the position and character of the fissures indicate that they were caused by unequal heating during flight through the atmosphere, the tension produced not being enough, however, to cause complete fracture.

During the years while the meteorite lay buried in the ground alteration due to decomposition advanced considerably. A cut and polished fragment shows the unaltered stone to have a dark brownish-gray color and to be made up of spheroidal "chondrules" firmly imbedded in a matrix of similar matter. The largest chondrules observed are one eighth inch across, but these are extremely rare and most of the particles have less than half this diameter. Close examination with a strong magnifying glass enables one to see minute grains of iron scattered through the mass. The stony portion of this meteorite consists of olivine, enstatite and a monoclinic pyroxene, while the iron contains a little troilite. The specific gravity is 3.42.

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