METEORITES

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THE QUINN CANYON METEORITE.
A TYPICAL IRON METEORITE.

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Meteorites

There are many reasons why meteorites are interesting objects, and chief among these is the fact that they are our only tangible source of knowledge of the universe beyond the earth. With other heavenly bodies we can make only such acquaintance as can be derived from the rays of light which come from them, but meteorites can be handled, dissected and subjected to the same methods of analysis as terrestrial substances. This and other reasons have led to the exercise of great care and diligence among civilized peoples during the last century and a quarter at least, in order that as many of these bodies as possible may be preserved and gathered in large collections and their various features carefully compared and studied.

In respect to the number of meteorite falls represented in one collection, Field Museum of Natural History at present holds the foremost place. Of 820 meteorite falls known at the present time, specimens of 670 may be seen in the Museum collection. The opportunity for the comprehensive study of these bodies at this Museum is therefore unrivalled.

For many of the falls a fragment or section serves as the representative. Many other falls are represented by complete individuals and some of these are the only ones known.

From the number of meteorite falls occurring on a measured portion of the earth's surface, it is possible to calculate the number which is likely to occur annually on the earth as a whole. This has been ascertained

to be about 900. But as three-fourths of the earth's surface is covered with water, three-fourths of this number, at least, will never be found. Many of the remainder which have fallen in the desolate and uninhabited places of the earth will never be found because of the lack of finders. For these and other reasons, the number of meteorites actually recovered over the whole earth does not average more than three. Meteorite collections increase therefore slowly. Not all meteorites found in collections, however, were seen to fall. The specific characters of meteorites are now so well known that a mass can be determined as a meteorite even if its fall was not observed. In fact, the internal characters of a meteorite generally furnish more positive evidence of its origin than the testimonies of human witnesses.

It is not known from what part of the universe meteorites come nor under what conditions they originate. Different investigators at various times have attempted to prove that meteorites are earth, moon or sun substance, but the suggestions have not proved satisfactory. For several reasons meteorites could not have come from the earth. For instance, they differ in composition in some respects from any substances found on our planet; again, to have been hurled away from the earth they must have received a much greater initial velocity than any terrestrial eruptive force has ever been known to exert. A velocity of at least five miles per second must have been given them and this is far beyond the power of any volcano. Moreover, a large amount of matter would need to be flung into space from the earth in order to furnish that which reaches us as meteorites, as only a very small proportion of that ejected could ever come into the range of the earth's attraction again. Similar reasons preclude the belief that meteorites could have come from the moon.

Objections to the view that meteorites could have come from the sun are found in the difficulty of conceiving how a globe in so vaporous and heated a condition as the sun could produce solid bodies. Even if the sun has a solid core from which compact or concrete bodies could start, they would need to pass through an intensely heated atmosphere before they could arrive in free space, and it seems hardly possible that the solid nature of small bodies could be preserved under such conditions. Moreover the orbits of some meteorites make a considerable angle with the plane of the solar system known as the ecliptic, while a body ejected from the sun, in order to reach the earth, must move in this plane.

The class of heavenly bodies to which the origin of meteorites has been most generally attributed within recent years is that of the comets. Largely through the work of the late Prof. H. A. Newton, of Yale University, the orbits of many of the important shooting star or meteor showers were found to be identical with those of well-known comets, these orbits being in some cases those of comets which had disappeared. Thus the August meteors or Perseids were found to have the same orbit as Tuttle's comet and the November or Leonids the same as that of Tempel's. Biela's comet, which disappeared in 1872, has its place in the heavens represented by the so-called Andromedes meteor shower. Accordingly, Newton believed, and the view has been widely adopted, that meteorites are simply large meteors which originate, as do the small meteors or shooting stars, from the disintegration of comets.

If the differences between the meteors which produce meteorites and those which result in star showers so-called were only those of size, this view might be accepted, but investigation shows that meteorites almost never fall during star showers.

Only a single case is known—that of the Mazapil iron, which fell November 27, 1885—of a meteorite reaching the earth during a star shower. So isolated a case may be accounted a pure coincidence. Another objection to the view that meteorites are portions of comets may be found in the fact that comets are not known to possess great bulk or even to be composed of solid matter. There are indications that their substance is largely or wholly gaseous. In this case their disintegration could not yield the large masses of stone and iron which come to us as meteorites.

Another suggested origin of meteorites has been that they are parts of a shattered planet or planetoid. All evidence seems to indicate that meteorites are fragments of some larger celestial body or bodies. How large this body or these bodies may have been is uncertain. The rings of Saturn are known to be made up of multitudes of distinct, small, solid bodies, and it may be that groups of this nature are the source of meteorites. The planetoids, some of which are known to be of irregular form, are another possible source. But the assumption that the meteorites which reach the earth may have originated by the disintegration of larger bodies belonging to the solar system requires for its acceptance (1) a satisfactory suggestion as to the nature of the forces by which such disintegration could have taken place, and (2) an explanation of the inclination of the orbits of some meteorites to the ecliptic.

A possible solution of the first difficulty has been suggested by Prof. Chamberlain of the University of Chicago, in the differential attraction exerted by the passage of a small body within a certain distance of a larger, dense one. The distance within which disruption would take place for incompressible fluids of the same density is given by Roche (Roche's limit) as 2.44 times the radius of the large body. Since solid bodies

possess some internal elasticity, it is probable that the passage of a larger body at a somewhat greater distance than even this would disrupt a smaller one. Here, then, is a possible shattering force. Another would be found in collisions of two bodies, but these would be less numerous than approaches, and these collisions taking place between bodies moving at planetary velocities would be likely to generate enough heat to vaporize their substance. The passage of a large body near a small one might also account for the peculiar positions of the orbits of some meteorites since it would, in addition to exerting a disrupting effect, tend to change the orbit of the smaller body. Such a change has often been observed to be produced in the orbit of a comet by its passage near a planet. Hence a comet passing near a smaller body might change the orbit of the latter, drawing it out of the ecliptic and giving it a hyperbolic or even a parabolic form. By such means the inclination of some meteoritic orbits may have been produced.

All known meteorites can for convenience be grouped roughly into two classes—stone and iron meteorites. In addition, an intermediate group known as iron-stone meteorites in which the proportions of stone and iron are about equal is usually recognized.

Most stone meteorites have a grayish interior covered with a black, and more or less shining crust. In some, the mass of the stone is so dark as to be wholly black or brownish-black. Again, in others it is nearly white. Further, the crust does not always differ in color from the interior, especially in the case of brown or black meteorites. Metallic grains scattered through their mass usually form a feature of stone meteorites. The coherence of the stone meteorites is usually such that they do not break easily under the blow of a hammer and they take a fair polish. Some,

however, are so soft that they can be crumbled in the fingers.

The iron-stone meteorites differ from the stone variety chiefly in their abundance of metal. Instead of occurring as minute, scattered grains forming but a small percentage of the mass of the meteorite, the metal makes up about half the mass and is often continuous. Single nodules of the metal often reach the diameter of one inch or more. Further, the metal may be so abundant as to form a matrix of a sponge-like character in the pores of which silicates are held. Thus by gradation the iron-stone meteorites pass to meteorites made up entirely of metal—the iron meteorites.

The metal of iron meteorites is, when observed immediately after falling, of a silver-white to grayish-white color and usually malleable. It is composed chiefly of iron alloyed with from five to twenty-five per cent of nickel. When found immediately after falling also, iron meteorites usually exhibit a blackish or bluish crust through which the silvery-appearing interior gleams here and there; but any long continued exposure to the weather usually causes the entire surface of such meteorites to become a rusty-brown color.

A far larger number of stone than iron meteorites has been "observed" to fall. Of about 350 observed falls only 10 have been of iron meteorites. On the other hand, among meteorite "finds," the iron meteorites largely predominate. This is chiefly for the reason, doubtless, that the iron meteorites by their relatively great weight, metallic composition and silvery appearing interior attract the attention of the ordinary observer much more quickly than the stone meteorites. The latter show to the casual observer no striking differences from terrestrial rocks, and are thus easily overlooked.

All meteorites have their surfaces indented by pits of a more or less regular size and shape. These pits resemble depressions such as may be made in a lump of clay by pressing one's thumb into it and hence they are often called "thumb marks." Similar pittings are produced on terrestrial rocks by the action of desert winds, and the cause is the same in both cases, namely, the erosive action of the air, aided somewhat by particles of stone. On iron meteorites the pittings are larger and more irregular than on stone meteorites and correspond to some extent to the structure of the iron.

Meteorites as a rule have little warmth when they arrive upon the earth. The stone meteorites are almost always spoken of as being "milk warm" or "barely warm" by those who pick them up immediately after their fall but in some cases they have been intensely cold. Thus one of the stones of the Colby, Wisconsin, meteorite fall which occurred at 6:20 p. m., July 4th, 1917, although the evening was one of summer heat, was coated with frost when it was picked up shortly after its fall. Not only are the stone meteorites not hot themselves on falling, but the ground where they fall does not give any indication of being burned or heated. No baking of the soil or charring of vegetation can be observed. Where meteorites have fallen, as has sometimes been the case, in haystacks, barns or other places where a little heat might start a fire, they have never produced any incendiary effects. This lack of heat is contrary to the general belief, the common opinion being that meteorites are intensely hot when they reach the earth. This opinion is evidently based on the brilliant light emitted by them in their course through the atmosphere. A little consideration of the matter, however, will convince one that no heating should be expected.

1. The substance of stone meteorites is a poor conductor of heat.

2. The period in which they might acquire heat is extremely short, but a few seconds at most.

3. Any portion of their surface sufficiently heated to become in a condition even approaching viscosity is immediately removed by the pressure of the surrounding air.

With the iron meteorites the case is somewhat different, since they are much better conductors of heat. They, therefore, generally possess considerable warmth when picked up immediately after their fall. The Cabin Creek meteorite is described as being "as warm as could be handled" after being dug from a hole three feet deep. The Mazapil meteorite was so warm that it could be "barely handled" on removal. The heat emitted, even in these cases, however, was not great. Any accounts, therefore, of intense heat being manifested by meteorites can usually be assumed to be false, the observer's previously formed opinion probably coloring his testimony if his testimony is sincere.

No meteorite fall has ever positively been known to have destroyed human life. Accounts purporting to describe such catastrophies prove on investigation to refer to events so distant either in time or place that they cannot be verified. Perhaps the most narrow escape experienced was that of three children in Braunau at the time of a fall of a meteorite there in 1847. This meteorite was an iron weighing nearly 40 pounds which fell in the room where the children were sleeping but, while it covered them with debris, it caused them no serious injury. Other meteorites have fallen near human beings, but have never struck them so far as credible information goes. That personal injury or death might be caused by the fall of a meteorite is entirely possible, it is remarkable that some falls, such for instance as the showers in Iowa, which occurred in comparatively thickly settled communities, should not have caused serious injury to the inhabitants.

Von dem donnerstein gefallē jm 1492 xcij. iar: vor Ensisheim.

DRAWING MADE IN 1493 TO ILLUSTRATE THE FALL OF THE ENSISHEIM-ALSACE METEORITE.

The oldest observed meteorite fall of which specimens are preserved is that which occurred at Ensisheim in Alsace, November 16, 1492. Between 11 and 12 a. m., with a "loud crash of thunder and a prolonged noise heard afar off," according to the accounts which have come down to us from that time, a stone weighing 260 pounds fell in a field at Ensisheim, making a hole five feet deep. It was taken to the village church, being regarded as a miraculous object. King Maximilian, who was then at Ensisheim, had the stone carried to his castle; and after breaking off two pieces, one for the Duke Sigismund of Austria and the other for himself, forbade further damage and ordered the stone to be suspended in the church. For a long time it hung in the vault of the choir, but later was removed to the Rathaus. A copy of a drawing made at the time, representing the fall of the meteorite, is shown accompanying.

Phenomena of light and sound similar to those above mentioned, usually accompany the fall of a meteorite. These phenomena may be of a startling and even violent character or they may be scarcely perceptible. Their nature and extent obviously vary with the distance of the observer from the place of passage of the meteor, or from its place of fall, and with the time of fall. Occasionally the passage of a meteor producing meteorites may be observed over an area of thousands of square miles. Falls occurring during the daytime may present no visible phenomena of light, and occasionally no sound may be heard, but usually one or other is observed.

A striking feature of some meteorite falls (striking both figuratively and literally), is that a large number of individuals, sometimes thousands, fall at one time and place. Such occurrences are called meteoritic showers, and present phenomena of much interest. These showers have taken place on various parts of

the globe and at various times without any seeming regularity or relation. Three of the largest showers, those of Estherville, Forest and Homestead, took place within the boundaries of the state of Iowa, and three others, Knyahinya, Mocs, and Pultusk, fell in Hungary and the neighboring Poland. The phenomena of violent sounds and brilliant light are generally intensified in these showers, though not always to a marked degree. The distribution of the meteorites of such a stone shower is usually over an elliptical area, with the longest axis of the ellipse in the direction of the movement of the meteor. The greatest distance along which the individuals of a shower have been observed to be distributed is sixteen miles.

Besides showers of stones, showers of iron must have occurred at Toluca, Mexico, Canyon Diablo, Arizona, and some other localities, because large numbers of iron meteorites of similar characters are found at these places.

Most iron meteorites show on etching with acid or heating, a peculiar structure which, so far as is known, is not possessed by any terrestrial substance. This structure is due to three alloys of nickel and iron which have a crystalline arrangement according to the planes of an octahedron. On etching a polished section of such a meteorite this structure is displayed in the form of a network of intersecting bands known as Widmanstätten or Widmanstättian figures, so named after their discoverer, Alois von Widmanstätten of Vienna, who first observed them in 1808. These figures are constant throughout a single meteorite, but differ in separate falls. The bands vary in widths from fine to coarse, becoming narrower as the percentage of nickel increases. Iron meteorites having less than 7 per cent of nickel do not exhibit these figures. They show on etching only a network of minute lines, which are arranged in three directions at right angles to each other, or in other words, according to the lines of a cube. Other iron meteorites show no markings upon etching. Their structure may have been destroyed by pre-terrestrial heating or their content of nickel may have been too high for crystallization.

A feature peculiar to about nine-tenths of all stone meteorites is that of being largely made up of rounded grains or spherules. These spherules, known as chondri or chondrules, differ from any structures found in terrestrial rocks. They consist of the same minerals which make up the substance of the meteorite, usually in granular or acicular imperfectly crystallized forms. They may be a peculiar mode of crystallization or may owe their spherical form to trituration such as may occur in a meteoric swarm when its component parts beat against each other.

Several compounds occur in meteorites which do not occur terrestrially. The most important of these are schreibersite and cohenite, respectively a phosphide and carbide of iron and nickel. A sulphide of calcium, oldhamite, not found terrestrially, also occurs in meteorites. The occurrence of such compounds as well as the large amount of unoxidized iron in meteorites indicates an absence of oxygen in the conditions under which they were formed.

The stone meteorites are chiefly composed of silicates of magnesium, in the form of the minerals known as enstatite and chrysolite, and the iron meteorites consist chiefly of iron with from 5 to 20 per cent of nickel. Some cobalt and copper usually accompany the nickel and, in some cases, platinum.

The Museum meteorite collection is exhibited in twelve cases in Hall 34 on the second floor of the building and in one case in Stanley Field Hall on the main floor.

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ETCHED SECTION OF THE SHREWSBURY IRON METEORITE.
SHOWING WIDMANSTÄTTEN FIGURES.