Further Notes on Meteor Crater in Northern Central Arizona (No. 2)

BY

DANIEL MOREAU BARRINGER

Proceedings
of
The Academy of Natural Sciences of Philadelphia
Vol. LXXVI, 1924, pages 275-278

FURTHER NOTES ON METEOR CRATER IN NORTHERN CENTRAL ARIZONA (No. 2).[1]

BY DANIEL MOREAU BARRINGER.

It will probably be of interest to the members of the Academy to know that the meteoric mass—probably a large cluster of iron meteorites—which made this remarkable crater, has been located under the southern wall, as predicted in my paper read before the National Academy of Sciences at its autumn meeting in 1909.[2] An exploratory drill hole, shown in the lower illustration on Plate XIII, at a vertical depth of 1376 feet, has recently passed through about thirty feet of undoubted meteoric material, that is to say, highly oxidized meteoric iron or so-called iron shale, cementing small fragments of sandstone and still smaller fragments of Variety A and Variety B of the metamorphosed sandstone previously described.[2] The drill is irremovably stuck at this depth, but so much iron shale has been brought up by it as to make the conclusion inescapable that the main mass of the meteorite is underneath the southern wall of the crater. This iron shale is certainly due to the oxidation of what is termed shale-ball meteoric iron, which, as stated by Dr. George P. Merrill, I was the first to find and describe.[3] The material which has recently been encountered by the drill probably represents the upper portion or outer shell of the iron mass, which, in my present opinion, was largely composed of this shale-ball variety of iron meteorites rather than what is known to the scientific world as the ordinary Canyon Diablo meteorites. These, it is of interest to know, are probably residuals, which have survived the decomposition of larger shale-ball meteorites. That is to say, in every case they were probably unoxidizable nucleii in oxidizable shale-ball meteorites. On this

---

[1] Presented to the Academy for publication March 10, 1923, but withheld at request of the author. Paper No. 1 appeared in these PROCEEDINGS for 1914. —*Ed.*

[2] "Meteor Crater in Northern Central Arizona"—read before the National Academy of Sciences at its Autumn Meeting at Princeton University, November 16th, 1909.

[3] "The Meteor Crater of Canyon Diablo, Arizona, Its History, Origin, and Associated Meteoric Irons"—Smithsonian Miscellaneous Collections, Volume 50, Part 4, published January 27, 1908.

"Contributions to the Study of the Canyon Diablo Meteorites"—Smithsonian Miscellaneous Collections, Volume 50, Part 2, published September 12, 1907.

theory the characteristic pittings of the ordinary Canyon Diablo meteorites, which have been ascribed to fusion of the iron in its passage through the atmosphere, are due to the oxidization, since the fall, of the shale-ball type of iron which once filled these cavities. This type of meteoric iron oxidizes rapidly, owing to the fact, as was long ago pointed out by Dr. J. W. Mallet, F.R.S., that it contains a small amount of chlorine. Some of these so-called ordinary Canyon Diablo irons (to distinguish them from the oxidizable or shale-ball irons) have holes in or through them of several inches in length, and one of these holes, in a specimen at the Academy of Natural Sciences of Philadelphia, is nearly five inches in length and only from one-half to three-quarters of an inch in diameter. I cannot conceive of the iron being fused in any such manner during its passage through the atmosphere. This cavity, for example, and all the other pits and cavities so characteristic of the common unoxidizable type of Canyon Diablo meteorites which are to be found in a great many museums were, in my opinion, once filled with the oxidizable or shale-ball variety of iron, which has long since oxidized into rust and been blown or washed away. It is evidence of this fact that, when the meteorites are first found, many of these more or less round cavities contain a certain amount of loose iron shale. From what has been disclosed by the drill it is probable that a considerable portion of the impacting mass, on the theory that it was largely composed of shale-ball iron, has undergone oxidation and is now in the form of iron shale.

It has been my privilege to be the first to discover and prove the true origin of this remarkable crater. I have long since been absolutely convinced that it was formed by the impact of a mass of meteoric iron and that, in view of the evidence collected by me, the nature of its origin was not debatable. As stated in my previous papers on the subject, in addition to the abundance of other proof therein set forth, small amounts of undoubted meteoric material (iron shale) were encountered in the depths of the crater, in the majority of the twenty-one drill holes which were sunk seventeen to eighteen years ago. These were put down more or less in the center of the crater on the incorrect theory that the impact had been vertical or nearly vertical, and because of the lack of knowledge of the direction from which the mass approached the earth. The distance from the nearest of these old drill holes to

the present drill hole is over 1600 feet. The mass seems to have approached the earth at an angle of approximately 45°, and from a direction slightly west of north, and to have made a slight curve to the west in its slanting flight through more than 2500 feet or one half-mile of solid rock (limestone and sandstone) owing, according to Professor Elihu Thomson, to the rotation of the earth. There now seems to be no longer room for doubt that its greater portion is buried under the southern wall. Professor William F. Magie aided me in the summer of 1909 in recognizing and correlating the evidence which seemed to indicate that the mass approached the earth from the above general direction, a conclusion which resulted in the latest drill hole being located on the southern rim of the crater. All the available evidence is in favor of the mass having been a compact cluster of an enormous number of shale-ball iron meteorites, and there is no evidence whatever against this theory. These have probably undergone oxidation to a large extent, as water runs freely out of the bottom of the drill hole. The arguments will doubtless be recalled by those who have been interested in the subject.

It is a source of gratification that the deductions which I made years ago from the observed facts have been proved. The adding of the final proof of the meteoric origin of the crater is of unusual scientific interest in that it furnishes a strong argument in support of the theory, in which I personally believe, that all of the lunar craters have had a similar origin.[4] If so, we seem to have evidence of undoubted value as to the manner in which the planets and their

---

[4] In this connection the reader is referred to a recent paper by the author which was published in the July and August issues (1924) of the Scientific American. The following paragraph was inadvertently omitted when the paper was published:

I am sure that geologists familiar with the effects of mountain-building forces on this earth (the gradual uplift at, roughly speaking, right angles to the pressure exerted and the contemporaneous or subsequent sculpturing by erosive agencies) will find it difficult to explain the lunar mountains on the theory that they are due to the operation of similar forces. The semicircular Apennines, for example, suggest to me that the meteoric mass which, in my opinion, made Mare Imbrium, approached from the northeast. The behavior of the melted rock in this case would be not unlike that of liquid mud, as an illustration, the impetus or the thrust having come from that direction. The fault scarps on the lunar surface, which are probably due to contraction on cooling, are not, as I contend, inconsistent with the impact theory. The fact that the visible lunar surface, and much the larger part, is covered by craters which in my opinion are the evidence of additions of extralunar masses, makes the inference strong that the seas and mountains which fringe them have also been caused by the impacts of similar but presumably much larger masses.

moons may have been built up. It is not difficult to conceive of them as being molten in their early history, owing to the heat produced by the impacts, and that their surfaces on cooling gradually passed from this condition into a plastic and then into a solid one. The revolving molten mass would of course assume a spherical shape. However, I am informed that the orbs of our system need never have been really gaseous or liquid to have assumed practical sphericity if large enough. The moon never having had an atmosphere, and therefore never having been subject to erosion, has beautifully recorded on the outer surface which is presented to us all of the later impacts, some of which seem to have been made when the surface was in a more or less plastic condition.

I am very grateful to Professor Magie and to Professor Thomson for their unswerving faith through many years in the meteoric or impact theory of the origin of the crater, because of the facts and the deductions from them presented by me in my previous papers, and particularly so for their constant assistance and encouragement.

Explanation of Plate XIII.

Upper.—Showing uplifted and arched portion of southern wall (to the right) and derrick in central portion of floor where early drilling was done.

Lower.—Showing derrick of last drill hole, which is located in center of arched portion of wall beneath which meteoric material has been found.

BARRINGER: METEOR CRATER.

UPPER.—SHOWING UPLIFTED AND ARCHED PORTION OF SOUTHERN WALL (TO THE RIGHT) AND DERRICK IN CENTRAL PORTION OF FLOOR WHERE EARLY DRILLING WAS DONE.

LOWER.—SHOWING DERRICK OF LAST DRILL HOLE, WHICH IS LOCATED IN CENTER OF ARCHED PORTION OF WALL BENEATH WHICH METEORIC MATERIAL HAS BEEN FOUND.