The Excavation of a Meteorite Crater Near Haviland, Kiowa County, Kansas

By

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The Haviland, Kansas, meteorites were first recognized by Mrs. Frank Kimberly, who discovered them on the Kimberly farm near the above town of Haviland, Kiowa County, Kansas, in 1885, but not until some years later did scientists visit the locality. The first to make critical examinations of the meteorites that were collected by Mrs. Kimberly were Dr. F. W. Cragin and Chancellor F. H. Snow of the University of Kansas (1890). Subsequently the site was also visited by Dr. George F. Kunz, Dr. Robert Hay, and others, all of whom collected specimens from this fruitful field, which is now known as the "Meteorite Farm."[10]

Apparently the above investigators failed to note the peculiar features of a small depression, then regarded as a "buffalo wallow," near the eastern border of this meteorite-sprinkled area. This depression early yielded two good specimens of meteorites, according to Mrs. Kimberly, in addition to many oxidized fragments that were described by Dr. Hay.

As the Kimberlys recently described it to the senior author, this depression was formerly deeper than the buffalo wallows of that vicinity and was surrounded by a definite rim, higher than the adjoining level of the sodded plain. It held water longer than any of the other depressions on the farm and was employed as a watering place for stock during the early years of the Kimberlys' residence there. In view of its distinctive characters, when compared with buffalo wallows, it is surprising that the early scientists visiting the location did not suspect its true nature, for it drew the senior author's attention upon his first visit there in 1925. At that time the depression, together with the field in which it is located, had been under constant cultivation for about twenty years but evidence of the rim was still discernible. Small oxidized meteoric fragments were then found along the eastern and southern portions of the low, rounded rim, and the matter of exploring the depression was discussed with the Kimberlys. They, however, chose to do their own investigating and about one year later a report was received to the effect that they had excavated to a depth of 2½ ft. to 3 ft. and had found oxidized meteorites in the deposits they had penetrated. The eagerness of the writers to further explore the deposit was therefore augmented but not until the present year was permission granted and plans perfected for working there, when the Colorado Museum of Natural History, in cooperation with the Nininger Laboratory, appropriated a sum for preliminary excavations.

The surface measurements of the depression were 35 ft. x 55 ft. (10.7 m. x 17 m.), in the form of an ellipse with its axis lying west northwest, to east southeast. The excavation was carried out under the direction of the senior author, as follows:

By means of a team and road scraper, or "slip," a north-south cut was begun, 36 ft. x 14 ft. (10.8 m. x 4.3 m.) and carried down to a central depth of 6.5 feet (2 meters). This yielded many meteorites, as a rule almost completely oxidized and ranging in size from as small as wheat grains to as much as 15 lbs. (6.9 kgs.). All were surrounded by a layer of rust-colored soil from 1 cm. to 2 cm. in thickness. They were frequently found in groups, or "nests," of a half dozen or more, usually consisting of one larger than the others, with the small examples grouped irregularly about it, often in contact.

The distribution of the specimens was along a thin horizon which sloped downward toward a point along the axis of the ellipse, 20 feet (6 meters) from its eastern rim. When a depth was reached where no more meteorites were found, the excavation was extended westward 6.5 feet (2 meters) and was carried downward to a depth of 11.5 feet (3.5 meters). In the first excavation no specimens were found below 5 feet (1.5 meters) and this depth was reached only in the central part of the extreme western edge of the cut. In the widened excavation specimens were found to a depth of 9.7 feet (3 meters) in the central area and sloping upward to within 18 inches (.5 meter) of the surface to the north and south. Several specimens of more than 22 lbs. (10 kgs.) were obtained; the largest, weighing approximately 85 lbs. (39 kgs.), was found against the west wall and about 3.4 feet (1+ meter) north of the middle of the excavation. Two others not quite so large were found at depths of 6.3 feet (2 meters) and 7.5 feet (2.3 meters), the former about 5.5 feet (1.7 meters) to the southwest and the latter about the same distance due south of the largest specimen.

An inspection of the west wall of our excavation then clearly revealed water-marks which indicated the former depth and form of the small crater. The water-marks reached a depth of about 5 feet at their lower extremes in the central area. Lying just under the lower water-mark and parallel to it was the meteorite horizon, 12 to 18 inches in vertical thickness. Frequently as many as sixty-five were found in a single cubic foot of soil.

After passing the meteorite horizon the soil was found undisturbed. A channel was next cut from a point near the center of the west wall, running westward. Here the same distribution of specimens was found except that the slope of the specimen-horizon was much more gradual as indicated in Fig. 1. The slope from the center in the opposite direction, however, was fully as steep as were the north and south slopes. In other words the specimens were distributed so as to conform to the surface of an oblique inverted cone with their size increasing as the work proceeded downward.

The interpretation of this small crater involves, first of all, an answer to the question as to whether it belongs to the same fall as do the other specimens from Brenham, or Kiowa County, Kansas, which were described years ago. These consist mainly of pallasites with a few siderites and also several which were a combination of these two types. The specimens previously collected were distributed over several square miles but were mainly found on one quarter section. A few were found outlying to a distance of several miles but it has been well established that some of the meteorites were carried about by the early cattlemen, so that it is probable that their original distribution was restricted to a rather small area.

The specimens collected during the latter part of the 19th century showed all degrees of oxidation from that of a completely altered pallasite to others well preserved, except that no instance is recorded of a specimen clearly showing the original fusion crust. The peculiar types of oxidation discovered by the senior writer in 1929 and described under the name "Meteorodes"[9] have been found only in the vicinity of the crater under discussion. Nearly half of the specimens recovered through the recent excavation were of this meteorode type while the remainder had oxidized in the manner described by Kunz,[5] Meunier,[7] Hay,[3] and Winchell.[13] Several of the crater specimens show small amounts of unaltered metal in their central portions and one of about 15 lbs. was found at a depth of 5 feet, in the southern part of the crater, in which nearly all of the metallic reticulum remains sufficiently well preserved to take a good polish.

It is clear, then, that the only strictly distinctive aspect of the crater specimens is the presence among them of the meteorodes. Since these are associated in the crater with an abundance of specimens oxidized in the ordinary manner it would seem that we are fully justified in regarding the crater specimens as a part, perhaps the major part, of the long-known Brenham, or Kiowa County, fall. Accordingly we shall look for an explanation which will account for both the formation of the crater and the peculiar type of oxidation exhibited in the meteorodes.

Two such explanations are here offered. First, let us assume that there was a large mass of several tons which constituted the principal body of the fall. It approached the surface at a reasonably high velocity, driving a highly compressed cone of air in front of it. As recently explained by Dr. L. J. Spencer,[12] this highly compressed air cushion would produce, on encountering the soil, an explosive action. This explosion would not only produce the funnel-shaped crater, but by the same act would also shatter the meteoritic mass, which, by virtue of its very brief exposure to the frictional heat of passage through the atmosphere, still in large part retained the low temperature of space, so that it was in a very brittle state, save, perhaps, at its surface. Of the resulting fragments many were reduced to powder which was dispersed in all directions (all of the soil in the crater below the water-marks was found to be impregnated with minute particles of iron oxide, each surrounded by a zone of rust-colored soil which caused the crater soil to have a freckled appearance), while those which survived buried themselves in the walls of the funnel-shaped pit.

The peculiar grouping or nesting of specimens, so often noted during the excavation, may have resulted from the imperfect fragmentation of the outer, less brittle, portions of the mass which landed as jagged irregular scrap and later was reduced to numerous units by the complete oxidation of the narrow connecting strands of the metallic reticulum.

This hypothesis would also explain the formation of the meteorode, for the disruption of the mass just as it entered the soil would not allow for the sealing up of the freshly exposed iron, as would have been the case had the disruption occurred at a height and at a velocity where each fragment would have developed a thin fusion crust.

It is a fact well known to those who have had experience in caring for meteorites that a specimen which carries the protochloride of iron in its interior may remain unaltered for many years provided it is not cut or broken; but upon cutting the greenish liquid at once begins migrating to the surface, carrying the oxides of iron with it and this is likely to continue until the metallic iron is exhausted. This is precisely what has happened in this instance and has resulted in the formation of the meteorodes. Those fragments which contained no protochloride of iron or which were protectively sealed over when they landed, oxidized, if at all, in the ordinary way, forming the compact nodules of ferrite with embedded olivine chondrules or else shattering in the process of alteration. We found many examples representing both of these processes. The 15 lb. specimen mentioned above, in which the iron was not oxidized, proved on cutting to be one of those which carried the destructive Lawrencite and that began at once to generate greenish drops of this liquid on the polished surfaces. This may have fallen as a small individual meteorite accompanying the main mass and had its own fusion coating which protected it, until, by cutting it, we released the destructive agency.

The moisture in this pit doubtless played a part in hastening the processes of alteration but the fact that the specimen just referred to was buried below the average depth indicates that moisture was not the only factor which was responsible for the differences in alteration between specimens in the pit and out of it.

In offering the second explanation it also appears to be an appropriate time for a discussion of phenomena which accompany the passage of metorites through the earth's atmosphere. As visual phenomena are limited during the hours of daylight, much is necessarily assumed. This, however, may be based upon recognized laws.

Such phenomena vary in relation to the proportions of the meteorites, their speed and their durability—whether they survive the destructive forces they encounter or break up while in transit, whether they enter the atmosphere as single masses or in varying numbers of fragments. The evidence appears to indicate that the fragments of a meteorite that breaks up in transit will land without a semblance of order or relationship to each other, while on the other hand, the leading examples of a group of fragments will maintain their course in approximate association.

If we assume that a single meteorite mass accumulates before it a growing volume of highly compressed air, it is necessary for us to also concede that the proportions of this air mass will, ultimately, create sufficient resistance to retard its rate of progress. When this occurs, the speed of the propelling force, the meteorite, must be reduced in like proportion or pass through the obstruction, which, because of its density, has attained the character of a semi-solid. In its passage the meteorite, its surface already glowing and discharging gases and fused matter, is subjected to terrifically increased destructive forces. Its forward surface meets resistance that is equivalent to tens and perhaps hundreds of tons. Like pressure is exerted upon the lateral margins and the power of a nearly or quite perfect vacuum is its rear attendant. The surface of the meteorite is incandescent. The generation of gases is enormously accelerated and this adds to the density of the air obstruction.

Obviously the infinitely short period of time consumed in the passage of the meteorite through this mass of condensed air also represents the moment during which it is subjected to the greatest danger of disruption and then it is the less durable examples are broken up; the fragments in turn building up air obstructions and suffering further damage until the speed of these missiles is reduced to a point that insures against their further disintegration.

It is customary to regard the breaking up of meteorites in the light of "explosions." This is a questionable term, since it implies the application of an internal force, and we must look to the action of the condensed air and gases as an explanation of this phenomenon.

There are no visual evidences of the building up of an air mass before a falling meteorite, nor is the latter's progress through the air mass observable. We see only the results of the expanding gases and this is truly explosive, in both appearance and effect, for it is accompanied by detonations of a terrifying nature and erupted masses of "smoke." This appears to be admirably illustrated in the accompanying photograph of the meteor that passed over northeast New Mexico at 5:04 A. M., March 24 of this year.* As two glowing objects are reported to have emerged and continued in straight and parallel courses from the point shown in the photograph it may be assumed that the two nuclei at the apex of the glowing ball represent these fragments as they were emerging from the cushion of air and gas, which was then in the process of dispersing.

Fragments released through the breaking up of a meteorite, meet and respond to air resistance in relation to their proportions. That many, or all, are more or less deflected from the course of the originally intact mass, there can

*This remarkable photograph was made by Mr. Charles M. Brown of Mt. Dora, New Mexico, who used a No. 2A Brownie Folding Kodak. See illustration.

be no question; and of like certainty no considerable number of such fragments would be likely to maintain a course within the circumscribed limits of the Haviland crater.

It is proposed that the Haviland fall consisted of numerous fragments of varying proportions when it entered the earth's atmosphere. Whether or not these fragments were in close association or irregularly distributed within lateral limitations is problematical but in either case the individual fragments would be retarded by the resistance of the air in like ratio to those of an example that had been broken up in transit. Therefore, in neither case would all reach the surface of the earth at the same moment.

It is not unreasonable to assume, upon the visual evidence of comets, that the leading fragments probably were in close association and while they were subjected to the stresses imposed through accumulations of air, as described above, the resultant cylindrical column of low pressure and surrounding wall of high pressure that followed in their wake were aids in keeping the individual fragments within bounds. Not so the trailing fragments, however, for these would not only encounter normal resistance but also the unequal stresses that were set in motion by the preceding group of fragments. A degree of deflection would be inevitable.

When the air mass preceding the grouped fragments struck the surface of the ground a form of inverted explosion followed and this, doubtless, was of sufficient force to account for the Haviland crater; packing the earth to great density and at the same time forming an air cushion for the reception of the accompanying meteoric fragments. Many of the latter were probably fractured by the impact and this may be an acceptable explanation of the grouping of the fragments found in the Haviland crater and described above. Later arrivals might very readily have been responsible for a share of this damage but small and later-arriving examples were probably shattered and in addition to reducing their olivine content to sand-like consistency, would spread their metallic element in all directions. The fact that the largest masses occupied a central position in the crater, with sizes diminishing towards the margin of the depression lends itself in support of the above proposal. Obviously this will satisfactorily account for the proportionately greater number and volume of the fragments found within the crater than have been recovered from much larger areas outside of its limits.

The discovery and excavation of the Haviland crater furnishes the first example of a meteorite crater being excavated so as to reveal the distribution of meteorites in it and it suggests quite strongly the manner of its formation.

This discovery also opens up the way for the recognition of other accessible structures of its kind, which, the senior author has contended, may be much more prevalent on the earth than we have been wont to believe. Indeed, it is probable that we shall soon learn to recognize them as an important feature of the earth's topography.

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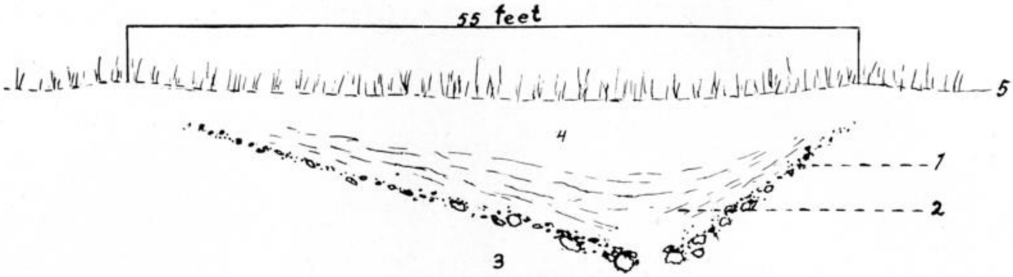


Fig. 1. Median section through the long axis of the crater. 1, the meteorite horizon; 2, water-marked soil; 3, undisturbed soil; 4, black heavy soil; 5, soil surface. Drawing by H. H. Nininger.

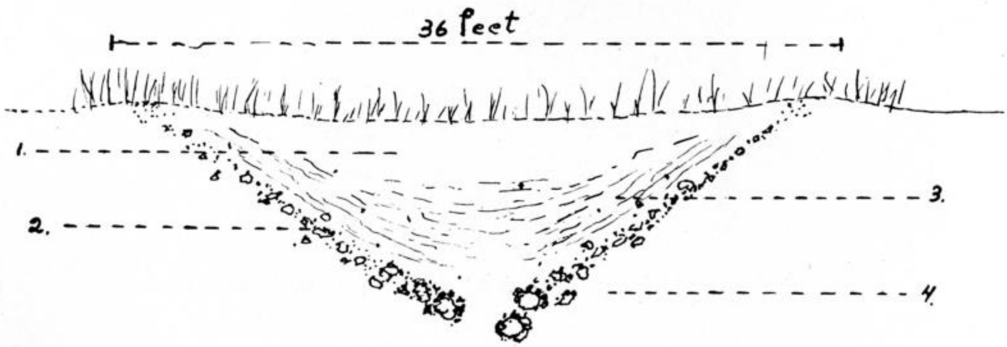


Fig. 2. Illustrates a section through the crater at right angles to the long axis, showing distribution of meteorites along definite horizon in the form of a funnel. 1, black heavy soil; 2, the meteorite horizon; 3, brown sandy clay, water-marked; 4, undisturbed soil. Drawing by H. H. Nininger.

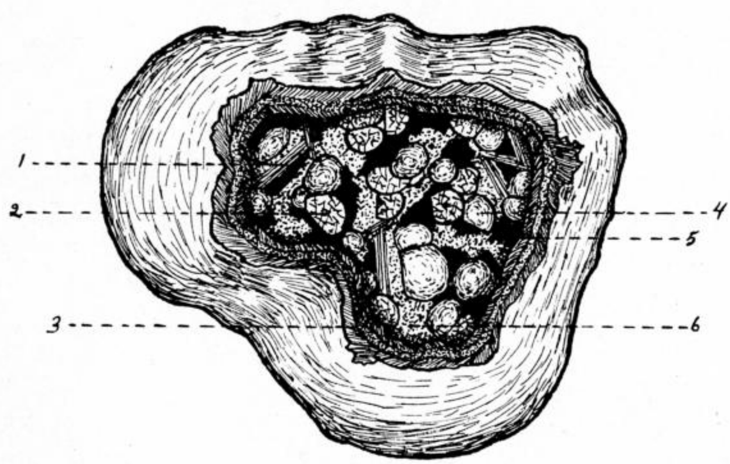
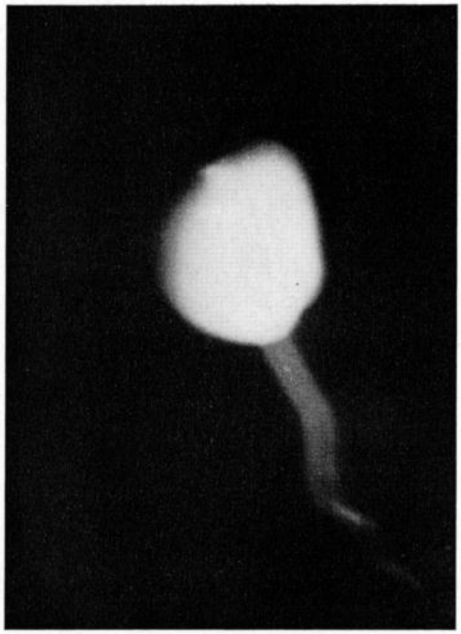


Fig. 3. A typical meteorode from the Haviland Crater. Ferrite shell broken away to show interior. Drawing by H. H. Nininger. 1, oxidized plates of taenite; 2, broken olivine inclusion; 3, layered ferrite wall; 4, unbroken olivine inclusion; 5, space left by migration of metallic constituents; 6, oxidized remains of metallic and sulphide constituents.



"The Great Meteor of March 24, 1933." (Copyrighted)

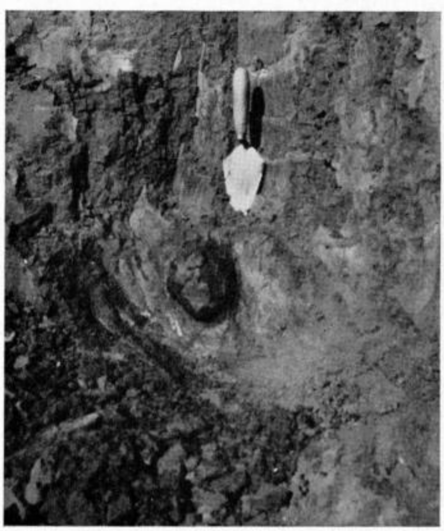


Fig. 4. A 15-lb. specimen in situ.

Fig. 5. Meteorites which were taken from approximately half of the Haviland Crater.

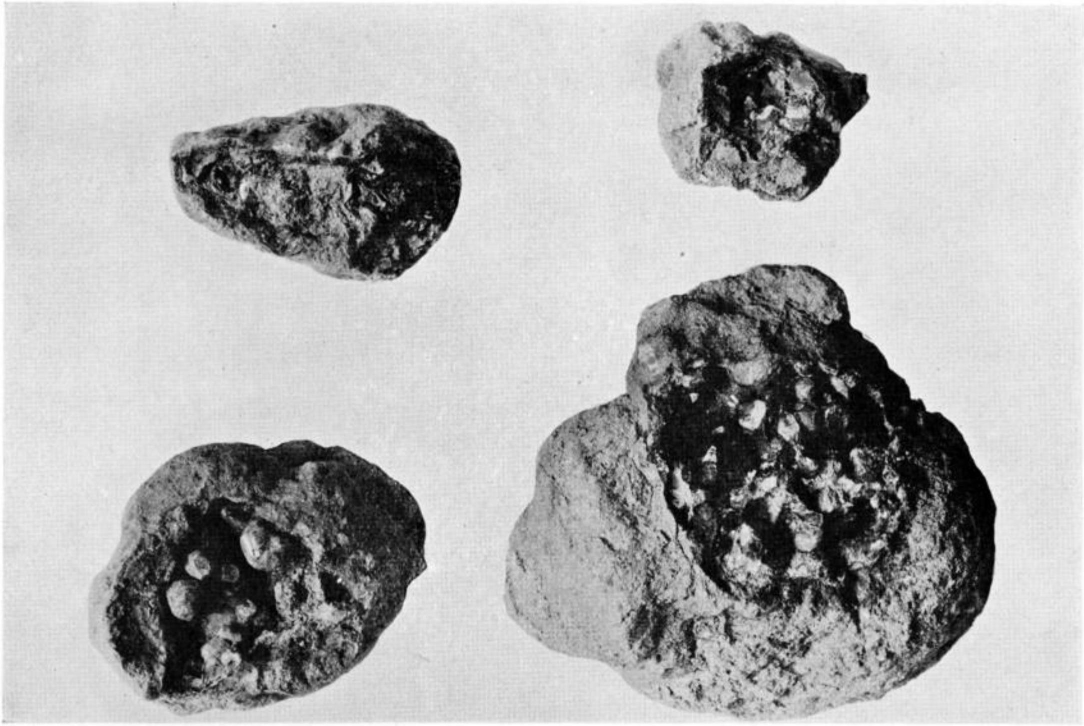


Fig. 6. Four meteorodes broken open to show their peculiar structure.

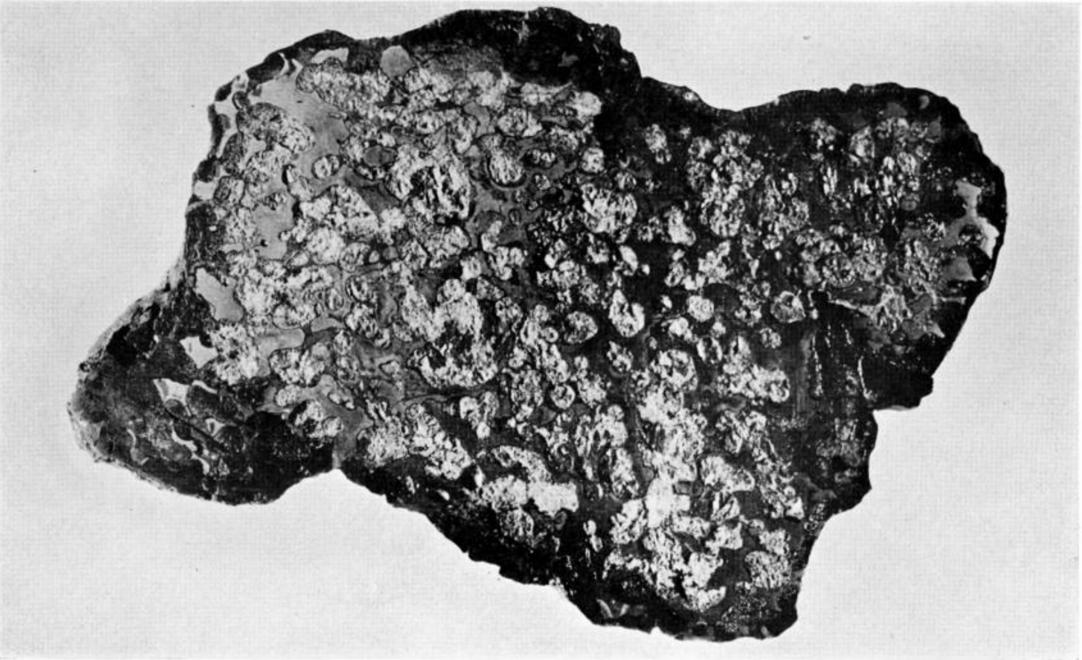


Fig. 7. Section of the 15-lb. specimen found 5 ft. below the surface of the crater. The metallic reticulum is very slightly altered.