COON MOUNTAIN AND ITS CRATER.

BY DANIEL MOREAU BARRINGER.

Foreword.

In October, 1902, I heard for the first time—in casual conversation with Mr. S. J. Holsinger—of Coon Mountain or Coon Butte and its crater, which is located in the northern part of Arizona. He stated to me at the time that he had never seen this remarkable crater, but had heard of it on several occasions, and had heard that quite a large amount of meteoric iron had been found in the immediate vicinity and that some had been found on the inside of the crater, which latter statement was subsequently proved to be incorrect.

I naturally was very incredulous of the theory which, Mr. Holsinger informed me, was held by some of the people living in the neighborhood of Cañon Diablo, namely, that this great hole in the earth's surface had been produced by the impact of an iron body falling out of space, if for no other reason than that I realized that the crater must have been examined by members of the United States Geological Survey while making the topographical maps of this region, and in their report they evidently did not accept this theory.

Nevertheless, the subject continued to interest me so much that upon my return to Philadelphia I determined to speak to my friend, Mr. B. C. Tilghman, in reference to it, because of his general scientific knowledge. This was in the latter part of January, 1903. We decided to write to Mr. Holsinger for further information, and upon receipt of this took the necessary steps to locate the mountain under the United States Mineral Land Laws. Since then, between us, Mr. Tilghman and I have collected an astounding array of evidence in favor of the correctness of the above theory of the causation of this great hole in the earth's surface, and in refutation of the theory adopted by Mr. Gilbert, of the United States Geological Survey, that it was produced by a steam explosion.[1]

[1] See Presidential Address by Grove Karl Gilbert, 1895, before the Geological Society of Washington, published by the Society in March, 1896. Also published in *Science*, N. S., Vol. III, page 1, 1896. Also 13th Ann. U. S. Geol. Sur. Rep., Part I, p. 98, and 14th Ann. U. S. Geol. Sur. Rep., Part I, p. 187. Also Chamberlin and Salisbury's *Geology* (1904), Vol. I, p. 569.

In fact we can now prove that this crater is due to the collision with the earth of an extra-terrestrial body, possibly a small asteroid, which was presumably metallic in nature.

We do not know, and indeed may never know, whether this great meteor was originally an irregularly shaped fragment or whether it was a spheroid, but we have strong reason to believe that the composition of the exterior was that of nickeliferous iron, containing in minute quantity platinum and iridium.

Since acquiring possession of the property, we have learned that this meteoric fall has been the subject of many papers and that the composition of the iron, and the fact that it contains microscopic diamonds, has been well known, upwards of ten tons of iron specimens having been shipped away from this locality; although, singularly enough, the presence of platinum and iridium has not been suspected. The presence of these metals was ascertained for us by Mr. H. H. Alexander, of the Globe Smelter, Denver, by subjecting the iron and the magnetite (the origin of which we shall attempt to explain hereafter) to the fire assay test, samples of each having been sent to him for the purpose. Their presence has been also confirmed by the very high chemical authority, Dr. J. W. Mallet, F.R.S., of the University of Virginia, whose letter on the subject is herewith submitted.[2]

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[2] UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, VA.

August 17, 1905.

D. M. BARRINGER, ESQ., Philadelphia.

DEAR MR BARRINGER:

About a fortnight ago I was at last able to undertake the examination you desired of the residue sent me by Mr. Alexander from solution in dilute hydrochloric acid of 25 lbs. of the Cañon Diablo meteoric iron, and I now report results:

I first repeated twice the assay experiments made by Mr. Alexander, and obtained substantially the same results that he did.

It then seemed to me desirable to apply a method which should not involve any addition of foreign metals (though I have full confidence in the purity of Mr. Alexander's lead, gold and silver), and to avoid determination of platinum "by loss."

I therefore boiled the greater part of the residue sent me by him with a mixture of strong hydrochloric and nitric acids as long as there was any action. This was a very tedious affair, the Schreibersite (phosphide of iron and nickel), which formed a large proportion of the residue, being but slowly attacked, and there being a strong tendency to boiling over from sudden, irregular evolution of nitrogen dioxide. The solution obtained was evaporated two or three times with hydrochloric acid, diluted, filtered and treated with a current of sulphuretted hydrogen, first cold and then while heated. This gave a copious precipitate of sulphur (from reduction of ferric to ferrous chloride) colored brownish by the sulphides of the platinum metals.

This precipitate was filtered off, well washed with water, dried and burned. The small residue left was then reconverted into chlorides, and the platinum and iridium separated in the usual way, by partial reduction of the iridium salt and precipitation of that of platinum with ammonium chloride.

It has seemed to Mr. Tilghman and to me to be better for us each to discuss this matter from our separate points of view—he from the point of view of a physicist, chemist and mathematician, and I from the point of view of a geologist.

The number of arguments which between us we have worked out, in support of the theory that this gigantic hole is an impact crater, will be set forth in the two following papers. It must be remembered that while a great deal of the evidence collected by us is positively in favor of the theory, much of it is negatively so; that is to say it disproves the theory that this great hole is the crater of an ancient volcano, or was produced by an explosion of steam, which latter theory seems to have been adopted by Mr. G. K. Gilbert on what seems to be very insufficient evidence. Perhaps it would be more accurate and just to say that he has adopted this theory because of an inadequate examination of the phenomena at Coon Mountain, or, as it is frequently called, Coon Butte; for had he examined the surface carefully, it does not seem possible to me that any experienced geologist could have arrived at such a conclusion.

Coon Mountain and Its Crater.

There is to be found in the almost level plain country, about five miles almost due south of Sunshine Station, on the Atchison, Topeka & Santa

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The result represented 3.63 grammes platinum and 14.96 grammes iridium per ton (of 2,000 lbs.) of the original meteoric iron, with probably a trace of rhodium. . . . .

I add the following remarks:

1. Mr. Alexander in using his method undoubtedly dissolved out with *aqua regia* from his cupelled button not only gold and platinum but some iridium, so that the loss of weight (after deduction of gold added) represented not merely platinum, as he assumed, but in part iridium also.

2. On the other hand, it is not certain that in my process *all* the iridium is dissolved out from the original material (residue sent me by Mr. Alexander) by *aqua regia* as used.

3. My results as to separation of the two platinoid metals are fairly trustworthy, but would be more so if there had been a larger absolute quantity of material to work on.

4. It is of course possible that these platinoid metals are not uniformly distributed in the original meteoric iron.

Believe me,
Sincerely yours,
(Signed) J. W. Mallet.

From the specimen of Cañon Diablo iron you left for me, with drill holes in it and a memorandum as to drills being blunted and spoiled, I have obtained five excellent microscopic diamonds—quite like those of South Africa in appearance and markings.

J. W. M.

Fé Ry., in Coconino county, Arizona, a very remarkable and almost perfectly round crater, differing in many respects, as will be hereafter seen, from any crater on the earth's surface with which I, at least, am familiar. The rocks exposed in this region, and for many miles around in every direction, belong to the Aubrey formation of the Upper Carboniferous series. These beds are perfectly horizontal, never having been disturbed since they were laid down except by volcanic tremors, which were probably the cause of several small but deep cracks in the vicinity of Cañon Diablo gorge and running parallel with it. Erosion has removed the upper strata which overlie these beds elsewhere in the region, so that now the uppermost stratum which is found is red sandstone, and this exists only as isolated and quite widely separated flat-topped buttes. It is not likely that this stratum was ever of great thickness. The portions of it which are left vary from a few feet to less than fifty feet in thickness. At the place now occupied by Coon Mountain and its crater (for it should be stated that this crater is within a rather low long mountain rising out of the level plain to a height of from 120 to 160 feet, the irregular top of the mountain forming the rim of the bowl-shaped crater) this sandstone stratum, at the time the crater was made, probably existed here as a flat-topped butte of considerable area, not over thirty feet in height above the surrounding limestone plain. The exact locality now occupied by the mountain and the crater was no doubt very similar to portions of the present surrounding plain before the event which produced them. These isolated buttes of red sandstone, which are dotted over the plain, probably average from fifteen to twenty feet in thickness. Underneath this sandstone there are from 200 to 350 feet of yellowish-gray calcareous sandstone, which when eroded and weathered has the appearance of limestone. In fact, this stratum, which is well shown in the neighboring gorge of Cañon Diablo, is referred to by the United States Geological Survey as the Aubrey limestone. For the sake of clearness it will hereafter be referred to as limestone. Underneath this limestone there is a stratum of apparently from 800 to 900 feet in thickness, but probably much less,[3] of very light gray, almost white, fine-grained sandstone; and underneath this stratum there is a thin stratum of yellow sandstone, the thickness of which is not definitely

[3] It is probable that these figures are very excessive and that the true thickness of this sandstone stratum at this point much more nearly approximates the thickness given to it in the record of the Winona well given below. The record of our bore holes and as obtained from the surrounding exposures must of necessity be unreliable, for reasons which will hereafter appear.

known. This seems to be the uppermost member of what are known as the "Red Beds," for underneath this yellow sandstone there is a reddish-brown sandstone, the thickness of which is given by the United States Geological Survey as more than 1,000 feet. The following record of a well driven by the Railroad Company at Winona, less than thirty miles distant in an air line from the crater first mentioned, shows the thickness of these various strata at that point. It is assumed that the Geological Survey obtained these figures from the Railroad Company, since the figures which they give as to the thickness of these strata, at the place where the A., T. & S. F. Ry. crosses the Cañon Diablo gorge, closely approximate the record of the well.[4] There are no eruptive rocks of any sort in this neighborhood, the nearest eruptive rocks to the so-called crater above referred to being a mountain known as Sunset Mountain about twelve miles in a southeast direction, the Black Mesa in a west and southwest direction about twenty miles distant, and the San Francisco Mountains and the flows therefrom about forty-five to fifty miles distant in a northwest direction. The latter, as is well known, are composed of many volcanic craters and the material ejected therefrom. Some of these craters are of comparatively recent origin, geologically considered, but presumably of much greater age than Coon Mountain and the crater it contains. The Black Mesa above referred to is supposed to be a flow from the San Francisco craters. In the San Francisco Mountains there are many volcanic cones containing more or less perfect craters. These are true volcanic craters. Such, for instance, is the well-known "Sunset" crater, a few miles north of the Santa Fé Railroad and easily accessible from Flagstaff. I have no hesitancy in saying that there is absolutely no connection between the first mentioned crater, which I shall hereafter attempt to describe, and these volcanic craters. And more than that, there is not a single point of similarity, excepting perhaps that of the round shape of the interior basin.

As above stated, the crater which is the subject of this paper is to be found in an area composed of level beds of stratified rocks (Carboniferous sandstones, limestones and shales), which extend uninterruptedly,

[4] Record of Winona well: Aubrey limestone, 185 feet; Dakota sandstone, 456 feet; Red sandstone, 16 feet plus.

"Although no direct measurements have been made in that immediate vicinity, the thickness of the Aubrey limestone at Cañon Diablo is probably not far from 300 feet. At Winona, where its surface is considerably eroded, 185 feet remain. The gray sandstone next below is between 400 and 500 feet thick. The Red Beds are about 1,000 feet thick. Next below is the Redwall limestone which is 600 feet or more in thickness." From information furnished by U. S. Geological Survey.

with the exception of the above volcanic areas, for easily seventy miles in every direction. Generally speaking the same rocks are exposed in the Grand Cañon of the Colorado, the cañons of the Little Colorado and of the stream known as Cañon Diablo, which is distant to the southwest and west only two and one-half miles. The cliffs exposed in this cañon are composed entirely of the upper portion of the limestone bed above referred to, as the cañon does not cut down to the underlying light gray sandstone also referred to above, and the overlying thin red sandstone stratum has been eroded off in this locality. In this crater and around it are to be found nothing but stratified sedimentary rocks or the fragments thereof. Viewed from the railroad across the perfectly level plain, Coon Mountain presents a very peculiar appearance to anyone accustomed to study the sky line. Such an observer would see a small mountain or butte, about one and a half miles long, rising out of the level plain, the sky line of which (the rim of the crater) is very irregular, the mountain differing widely in this respect as well as in its light color from other mountains in the region, which show the usual rounded appearance and gentle lines produced by erosion, and the dark color produced by the eruptive rocks of which they are composed.

Coon Mountain or Coon Butte, as it is often called, does not suggest to one viewing it, especially at close range, from any direction, the existence within itself of a large crater, approximately 3,800 feet in diameter (its diameter along a north-and-south line passing through it being 3,654 feet, while its east-and-west diameter is 3,808 feet) and approximately 600 feet deep from the rim of the crater to the surface of the interior central plain. It is a fact worthy of mention, but after all just what one would expect when one realizes the cause of its origin, that this mountain presents very much the same view to an observer stationed several miles distant, whether he stands on the north, south, east or west side of the mountain. This so-called mountain has an extreme elevation of about 160 feet above the level of the plain, and an average elevation of about 130 feet. Upon closer examination it is found to be composed to a great extent on its outside slopes of an enormous quantity of fragmentary material, which is made up as follows: red sandstone fragments, limestone fragments, white sandstone fragments and a few small yellow and brown sandstone fragments; the largest masses probably weighing upwards of 5,000 tons (these are nearly always limestone) down to silica in powder of microscopic fineness (pulverized sand grains) which will be described hereafter. I have made no attempt to compute the amount of this fragmentary

material, but roughly guess it to be in the neighborhood of 200,000,000 tons; perhaps rather less than more. An additional reason for the existence of the elevation known as Coon Butte or Coon Mountain is to be found in the fact that the uppermost strata exposed in the walls of the interior crater dip quaquaversally, or generally speaking in every direction from the exact center of the crater, at an angle usually varying from ten to forty degrees, and in one case from sixty to seventy degrees. It should be stated, however, that in this case it is evident that a great, presumably wedge-shaped, piece of the material of the cliffs which form the sides of the crater and the rim, has nearly been turned out bodily by the force which produced this enormous hole in the earth's surface. The effect of this would be, of course, to turn the strata nearly on edge at this place. Naturally, this wedge-shaped piece—an expression which is used for want of a better one—lies between two faults, on the other side of each of which the strata dip at a much lower angle, not to exceed perhaps twenty degrees in the one case, that is to the north, and not to exceed five or ten degrees in the other, that is to the southwest. On the west side of the crater the strata are upturned so that they dip at about forty-five degrees west. It is an interesting fact that many large fragments of limestone, which have been hurled out of the crater, are to be found at least a mile from it; and if I am not mistaken there are several large fragments, weighing perhaps fifty tons each, which are more than a mile distant from the center of the crater. These fragments, great and small, are distributed concentrically around the crater, being more abundant near the rim than distant from it. It is worthy of note, however, that the greater number of the larger fragments of the limestone stratum, some of them weighing probably over 5,000 tons, are to be found on the slopes of the mountain outside of the crater, on an east-and-west line passing through the center of the crater. That is to say, there are two places on the rim where these large fragments are most abundant; one almost directly east of the center and the other almost directly west of the center. It is also interesting to see how shattered and cracked many of the exposed limestone fragments are, showing probably that they have been subjected to the concussion from a great blow. These great and small angular blocks of limestone lie in every conceivable position on the slopes of the mountain, many of them standing on end so to speak, that is with the lines of stratification showing a vertical or nearly vertical dip.

I have made more than ten trips to this locality and have examined almost every foot of the ground around it most carefully, and have

failed to find a single piece of eruptive or metamorphosed rock, or any rock indicative of solfateric activity, which has not in all probability been brought to the locality by Indians or the prehistoric inhabitants of this region.

The sharp edges of the angular fragments of rock, which have certainly been expelled out of this crater with great force, are indicative of the recent origin of the crater. In fact, I am ready to believe that it is not more than 2,000 or 3,000 years old, and perhaps much younger. Cedars have been found growing on the rim which are upwards of 700 years old. Were it not for this fact the evidence afforded by the fractured surfaces of the rocks would indicate even a more recent origin.[5]

The interior of the crater can best be likened to a great bowl, excepting that there is an almost vertical escarpment running around the upper portion of the basin, formed of cliffs composed of limestone and the overlying red sandstone. From the bottom of the limestone stratum, or where the more or less shattered and disintegrated white sandstone begins to be seen underneath the limestone cliffs, a great interior fringe of talus commences, which is composed of angular fragments of red sandstone, limestone and gray or white sandstone. This talus slopes at a very low and, for talus representing the effect of weathering, an unusual, or as I think an impossible, angle toward the interior of the plain; but before it reaches the center it disappears underneath stratified sedimentary material which was undoubtedly deposited while the interior of the crater was a lake bottom. There are about seventy feet, and perhaps somewhat more in places, of this material, as has been proved by the shafts and drill holes which have penetrated it. It is composed very largely of wind- and water-borne silica or pulverized sand grains, in which are found numerous fresh-water shells. There are some layers composed almost entirely of microscopic shells, and in some of these sediments there are to be found great numbers of miscroscopic organisms which have silicious skeletons. There has been no opportunity to submit these fresh-water shells and organisms for examination, but it is intended to have this done at an early date. Underneath this sedimentary material there is to be found a more or less compact and unknown quantity of pulverized sandstone (silica), containing here and there angular rock fragments or so-called boulders. The upper portion of this sedimentary material forms, with the over-

[5] It is possible that the cause of this crater may possess considerable historical interest, as explaining the hitherto unexplained fact that throughout this portion of Arizona there are indisputable evidences that the prehistoric civilization ceased abruptly several thousand years ago, according to the necessarily rough estimates of the time which has elapsed.

lying accumulations of soil and wind-blown material and a certain amount of talus which for the greater part has been distributed by torrential action, an almost level central plain in the present visible bottom of the crater. Just how far these lacustrine deposits extend toward the cliffs and underneath the talus, which has been brought to its present position by torrential action, has not yet been determined, but enough is known to state quite positively that they cover the greater portion of the surface of the ancient visible bottom of the crater. As above stated, underneath this sedimentary material there is to be found an incredibly large amount of what has been locally termed silica, and which certainly is due to the pulverization of the sandstone strata and the sand grains composing them. This so-called silica (this name will hereafter be used in referring to this material) is almost free from impurities; several analyses having shown it to contain upwards of 98 and even 99 per cent. SiO_2. To be properly understood this silica should be examined under a microscope. When so examined it is found to be composed of broken sand grains; some of the minute fragments being as large as the half of a sand grain, but the vast majority are very much smaller, and many of the fragments are so small as to be invisible under an ordinary lens. Under a strong glass or microscope they have the general appearance of broken pieces of ice, being of every conceivable shape and almost invariably having very sharp edges, and of course being translucent. Much of this so-called silica is so finely pulverized that no grit can be noticed when it is placed between the teeth, and in fact can be truthfully described as being an impalpable powder. At many places this silica is less finely subdivided than has been described above and is distinctly gritty when placed between the teeth; but at no place has there been found any particle of it which is larger than one of the small sand grains which go to make up the strata in which the crater is found. Without further explanation it can be stated definitely that this silica is nothing more or less than pulverized sandstone. How many million tons of this material there are it would be impossible to estimate. It composes a great part of the enormous rim, over three miles in length measured around the base of the mountain, in which the crater is situated. The amount of it within the crater is absolutely unknown; for it has been found by means of drill holes to a depth of more than 850 feet. At places both on the exterior of the rim and in the interior of the crater, underneath the sedimentary deposits, it is found admixed with a small percentage of lime carbonate, which admixture can of course be readily understood when it is remembered that there is shown in the walls of the crater a calcare-

ous sandstone (herein referred to as limestone for the sake of convenience) which has a thickness of some 250 to 350 feet. If one digs down through the surface soil a foot or more, almost anywhere on the outside of the rim, among the angular fragments which have been thrown out of the hole he will come into this silica, and a great number of trenches and several shafts have shown it to continue downward certainly to the solid or rather more or less shattered rock upon which all of the fragmentary material forming the rim rests. One of these shafts, almost at the base of the mountain and near the surrounding plain, is forty-eight feet in depth. However there are, especially on the southern side of the mountain, several dry washes, where this almost snow-white silica has been exposed for hundreds of feet in length and in places to a depth of upwards of ten feet. It is difficult to understand how this exposure could escape the eye of any careful geologist making a circuit of the crater. If noticed by him it would certainly seem that he would have examined it and ascertained its nature. Having done this, it would seem that he would have been impelled to make a few shallow trenches at different places around the crater, in order to determine how much of this material there was. Having then proved it to exist on all sides of the crater in enormous quantities, it would seem to me that he could not have explained its presence in any other way than that which we have adopted; especially in view of the fact of there being so much corroborative evidence of even a more convincing character. Briefly, it seems to me impossible that this silica could be produced by volcanic action, or by a steam explosion, and I assume that it could be produced only by the pulverizing effect of an almost inconceivably great blow. It should be stated that the silica on the outside of the rim, and to a less extent underneath the sedimentary material in the bottom of the crater, is plentifully admixed with broken fragments of red sandstone, limestone and white sandstone of all sizes within the limits mentioned and sharply angular shapes. It also should be mentioned that the many cuts and shafts (over fifty in all) which we have caused to be made on the outside of the crater, have shown that the silica carrying with it these broken fragments, especially those of smaller size, has evidently welled out of the crater almost like liquid mud, or perhaps, more accurately, like flour when it is poured out of a barrel. It is an interesting fact that it often contains innumerable angular fragments of sandstone in which the grains of sand (some pulverized into silica, some whole and unbroken) are no longer coherent, an effect which we have assumed has been produced by tremendous concussion. It would seem that

these fragments, before they disintegrated entirely, were caught in the flow of silica and carried gently outward and deposited where they are found at present, surrounded by the almost snow-white silica. As the sandstone is itself often very white, the outline of these fragments is not readily distinguished in the sides of the open cuts, until they have been exposed for some time to the weather. However, it is to be remembered that there are in the silica, as far as we have explored it with trenches and shafts, great numbers of perfectly solid coherent sharply angular pieces of sandstone and limestone, as well as of the incoherent fragments. So far as it can be observed the white sandstone stratum, where it is exposed beneath the limestone cliffs inside the crater, is in this same incoherent condition. It is as if it had received a tremendous blow, the concussion from which caused the solid sandstone to disintegrate and become almost like compacted sand, since it can in many instances be dug out and crumbled by the fingers. The effect of this has been of course to cause the sandstone stratum at this point to occupy more space than it previously occupied. The result of this has undoubtedly been the raising of the superimposed limestone and red sandstone strata, causing them to show, when viewed from the interior of the crater, several anticlinal and synclinal folds, and to dip outwardly from the center of the crater, and in this way assisting in forming the elevation locally known as Coon Mountain, which has already been described.

No order is to be observed in the distribution of the angular fragments either within or without the crater, excepting that which I have already referred to, that the greatest amount of large limestone fragments, which it should be remembered is the most coherent rock of the series and the one which has most successfully resisted disintegration, is to be found almost due east and due west of the center of the crater; and also excepting that at certain places there are to be seen spurts of one kind of solid fragments, for example white sandstone, aggregating in amount thousands of tons, and extending from the rim of the crater almost down to its base.

These tongues of fragmentary material, which seem to have been spurted out of the crater with such force as to displace everything which they met, are very interesting; especially those of the white sandstone, some of the fragments of which exhibit very beautiful examples of cross-bedding. The lowest members of the series which was ejected are the red sandstone and the overlying yellow sandstone, small pieces of which are to be found in relatively small quantities on the surface of the southern and southeastern portion of the rim. These are almost

certainly from the upper portion of the Red Beds already referred to.

This brings me to describe more particularly the rim itself. On first examination it would seem that the fragmentary material and silica are almost equally distributed on all sides of the crater. Upon closer examination, however, it is found that there is vastly more of it to the southwest, south and southeast than to the northeast, north and northwest. It also will be observed that the fragmentary material is much more comminuted to the southwest, south and southeast than it is on the opposite sides of the crater. It will also be observed that the limestone cliffs on the interior of the crater are much more shattered to the southwest and south than anywhere else, and the limestone bed itself is raised higher, and to the southeast is to be found the great wedge-shaped piece of the material forming the cliffs and rim, which was turned over and seems to have been near to going out bodily. It will also be observed that the lowest point on the crater is on the north rim, somewhat to the west of a north-and-south line passing through it; and finally the ejected fragments, of ten tons or more in weight, are found distributed over the plain at a greater distance south and southeast of the crater than anywhere else. From all of these facts, the inference is unavoidable that the cause which produced the crater acted with somewhat more violence in a southwest, south and southeast direction than in the opposite direction.

It would be possible to extend this description of the crater to a much greater length; but I hope that in the above I have stated most of the salient facts which would impress the careful observer. Now, there are only three conceivable causes for such a tremendous disturbance of the horizontal strata at this point, and I will take them up separately.

I. *An extremely violently acting volcano.* This can be set aside as being impossible inasmuch—

First: No lava is to be found, or any other volcanic rock, for many miles in any direction. Nor is there to be seen any sulphur, which is found in most volcanic craters of recent origin.

Second: I assume that huge fragments of rock, weighing perhaps upwards of fifty tons, could not have been expelled from the crater and deposited a mile or more distant from its center by volcanic action, in the absence of other numerous and indisputable facts to show that a volcano existed at this place. Moreover, any stone which has been hurled from a volcanic crater through the agency of steam is usually of igneous origin.

Third: We know absolutely the series of rocks at this point, and this

series has been described in the first part of this paper. We also know that only the uppermost strata have been hurled out of this hole by some terrific force. Briefly, it would seem to me to be impossible that any geologist carefully examining the region could reach the conclusion that this is a volcanic crater, or in any way produced by volcanic agencies.

II. *A steam explosion.* This is the theory which seems to have been adopted by the United States Geological Survey to account for this remarkable crater, on the report of one of its members, Mr. Grove Karl Gilbert, and his associates.[6] To me it seems incredible that they could have adopted this explanation of the crater and its surrounding phenomena, if they had carefully examined the surface as above described, for the following reasons:

First: Such a violent paroxysmal outburst of steam as they assume in order to account for Coon Mountain and its crater is, to the best of my knowledge, unrecorded, unless perhaps in connection with some great volcano, and even there its force, I assume, has been, with few exceptions, less than the force expended here; and in such volcanic manifestations there were a number of such explosions, not merely one.

Second: The vast amount of steam required to do the amount of work accomplished at this place could only be stored up in regions of present or recent volcanic activity. There is no evidence that this has ever been such a region.

Third: As suggested above, it is inconceivable to me that there could have been, even in such a region, much less in a region of undisturbed stratified rocks, such a *single* great steam explosion, before which and after which all was quiet.

Fourth: I assume that such an explosion would not have produced the beautifully round crater which we have here; and, moreover, it seems certain that the country round about would be seamed for miles with cracks and fissures, perhaps more or less radial, through which in all probability steam would have ascended for many centuries. Nothing of the sort has been found here. It is certain that the crater was made in an instant of time, after which all was as quiet as before. Any one visiting the locality is impressed by the many evidences of this fact. It is also certain that the crater is very recent, comparatively little or no erosion having taken place since it was made. The evidences of this are to be found on every side. If there had been

[6] See Thirteenth Ann. Rep. U. S. Geol. Sur., Part I, p. 98, and Fourteenth Ann. Rep. U. S. Geol. Sur., Part I, p. 187. Also *Science*, N. S., Vol. III, p. 1, and Chamberlin and Salisbury's *Geology* (1904), Vol. I, p. 569.

much erosion, such as must have taken place in order to account for the great amount of talus which is to be observed on the inside of the crater, supposing it to have accumulated in the usual way, the crater would certainly not be as round as it is. If originally round, it would certainly have been greatly deformed by the process. It could not weather round. It is perfectly clear that this is contrary to any known mode of action of erosion. Therefore it is certain that the talus did not accumulate in the usual way, and that its presence and distribution must be explained on some other theory than that of weathering. This view receives further support from the fact that the very low angle (about twenty degrees from horizontal) which the upper portion of the talus on the interior of the crater makes in its descent from the base of the almost perpendicular cliffs, is a very unusual one.

Fifth: Granting that such a single violent steam explosion is not an absurb hypothesis, it would seem that on this hypothesis there would be abundant evidences of solfateric activity within and without the crater, especially in the immediate vicinity; such as redeposited or secondary silica, carbonate of lime and other minerals which are usually deposited by hot spring action. These minerals would certainly be found within the crater and in the cracks which, under this hypothesis, it would seem should be found traversing the horizontal stratified rocks forming the plain on the outside of the crater. Neither the cracks nor the minerals are to be found. In short, there is no evidence of any sort at or near this spot of solfateric action.

Sixth: If a steam explosion had formed this crater, it is inconceivable to me that it would not have thrown up rocks from a greater depth than that represented by the three uppermost strata, together with a very small portion of the upper part of the Red Beds which underlie them. Nothing would seem to be more certain than that the greater portion of these Red Beds and the great Carboniferous series of strata extending thousands of feet under them, as exposed by the Grand Cañon of the Colorado, only seventy miles distant, are undisturbed In other words, the series of strata at Coon Mountain have not been disturbed, at least to the extent of being thrown out, for a greater depth than the upper portion of the Red Beds, geologically speaking, or about 1,200 feet more or less—perhaps as much as 1,300 feet—below the present surface of the plain.

Seventh: A steam explosion I assume could not have pulverized the individual sand grains, as they have been pulverized here, and produced as a result the millions of tons of "silica" which exists on the inside of the crater and on the outside of the rim as already described. It is not

Additional Argument against the Theory of a Steam Explosion.

Eighth: Even if a steam explosion could have produced the silica dust it would have blown, as Mr. Tilghman points out (see page 899), such finely divided material high into the atmosphere, after the manner of the great Krakatoa explosion in 1883, and a very large portion of this material would certainly have been carried away by air currents and finally deposited far from the crater, instead of in the crater or on the exterior slopes of the mountain immediately surrounding it, where finely pulverized material is distributed in enormous quantities in such a manner as to warrant the belief that it and the rock fragments contained in it behaved not unlike a liquid when they were expelled by some force out of the crater. Again, the dust or minute particles or filaments of volcanic glass expelled from the volcano of Krakatoa were not only certainly of igneous origin, but when examined under the microscope were in every case found to be more or less round in shape, instead of being sharply angular particles of crystalline quartz, due, as is safely assumed, to the disintegration or rather pulverization of sand grains.

conceivable to me, as I have already stated, that this material could have been produced in the quantities in which we find it in any other way than by a heavy blow.

III. *The impact of an extra-terrestrial body.*

I shall attempt now to describe briefly such facts as are evident to any geologist making an examination of the region which furnish strong affirmative evidence that this crater could have been made *only* by an extra-terrestrial body falling out of space and moving at great speed. Something between ten and fifteen tons of meteoric iron have been shipped away from this locality, most of it going to the various museums of the world. It is a fact, so far as I know, that none of the "iron shale" or magnetic iron oxide, which will be described hereafter, is to be found in any of these museums; why I cannot understand, for the scientific interest which attaches to it is very great. It is probably not generally known that by far the greater portion of the meteoric iron which has been shipped from this locality has been found lying on the plain immediately surrounding the crater, and much of it has been found on the rim itself. At Cañon Diablo a merchant, Mr. F. W. Volz, tells me he has shipped nearly ten tons of this iron, and he also tells me that before he came to the country a merchant from Winslow shipped perhaps half as much. Both of these merchants hired Mexicans to look for iron specimens in the neighborhood of the crater. These men discovered several pieces weighing from 600 to over 1,000 pounds.

Since we have come into possession of the property we have found several thousand pieces, in all something over a ton, of various sized fragments of meteoric iron, the largest weighing as I remember 225 pounds, down to pieces weighing much less than an ounce or only a few grains. These meteoric iron specimens (known to the scientific world as the Cañon Diablo siderites) are so well known that I shall not attempt to describe them. The following analysis by Messrs. Booth, Garrett and Blair, of Philadelphia, may be taken as representing the general composition of these irons: Si 0.047; S 0.004; P 0.179; C 0.417; Ni 7.940; Fe 91.396; total 99.983. In the present discussion it is far more interesting to state that they have been found more or less concentrically distributed around the crater and to an extreme distance, so far as we know, of two and one-half miles from it, a few small specimens having been found in Cañon Diablo gorge. It is a remarkable fact that these so-called "irons" (to distinguish them from the so-called "iron shale") are very angular in shape, indicating by their fracture that they may have been violently torn off or burned from similar ma-

terial. Some of them contain holes or cavities which were probably once occupied by nodules of troilite (sulphide of iron). Such nodules are beautifully shown by sawing through some of the larger specimens in the Ward and other collections. When exposed to the action of the atmosphere these have oxidized, leaving the cavities they had occupied. Occasionally some of the specimens have a noticeable amount of iron oxide or shale adhering to them, but as a rule they are very free from this. They are usually covered, however, with a very thin film of iron oxide, which may be easily rubbed off with a wire brush if the specimen has been previously heated. When this is done their appearance would indicate that they may have been torn or burned from presumably similar material.

It is a fact worthy of note that so far none of these specimens of meteoric iron have been found at any depth beneath the surface. They are usually lying on the surface or partially or wholly covered by the merely superficial soil, and are distributed, as already stated, more or less concentrically around the crater, most of the small specimens being found, however, to the north and northeast. That there are great numbers of them contained in the thin soil overlying the solid limestone composing the level plain on all sides of the mountain is proven by the fact that we have found several specimens, from seven pounds to twenty-seven pounds in weight, so imbedded in digging a trench for a pipe line from Cañon Diablo gorge to the crater. They have not been found in the numerous cuts or shafts which have been made in the silica. Four of them, weighing three or four pounds each, have been found on the interior of the crater, and, so far as I know, these are the only iron specimens which have been found inside of the crater. These were found above the cliffs already described. Considerable "iron shale" has also been found inside the crater, among the talus at the base of the cliffs. I shall propose hereafter a possible explanation of the fact why these irons are found only on the surface. It is also worthy of note, as already stated, that we have found more of the smaller irons, on or in the surface soil, on the north and northeastern portion of the rim than in other places.

Now there have been found abundantly distributed around the rim, and especially on and in its northern portion, and nearby on the plain, very large quantities, probably aggregating a ton or more in weight, of magnetic oxide of iron. This is so abundantly distributed over the northern surface of the rim and over the surrounding plain, and is so apparent to the casual observer, that it seems wonderful to me that Mr. Gilbert and his associates did not make any reference

to it in their report. It is certainly different from any substance in nature with which I am familiar, and had they taken the trouble to have it analyzed they would have found that the large pieces almost invariably contain nickel (certainly in all the specimens examined) to the same extent, proportionately speaking, as it is found in the Cañon Diablo meteoric iron, from which this magnetic iron oxide was no doubt produced. However, if they had merely broken open some of the larger pieces of this magnetic iron oxide, which it seems to me they could not have failed to see, they would have observed in some of the specimens the characteristic green hydroxide of nickel. The iron oxide was produced, as I assume, by the heat generated from friction while the great iron meteor passed through the earth's atmosphere. As above stated, it has been determined for us that the larger pieces of this so-called "iron shale" contain invariably iron, nickel, iridium and platinum in the same relative proportion (remembering that two are in the form of oxide while the others are in the metallic state) as they are found in the iron from which this material was separated. In the very minute pieces of shale the nickel has been leached out to a greater or less extent. For the sake of clearness and because of the peculiar laminated structure, I shall hereafter refer to this magnetic oxide of iron as "iron shale," adopting the local name by which it is known. This iron shale is very much more magnetic than the original metallic meteoric iron, which in some specimens is only feebly so.

It should be stated in this connection that the surface of the surrounding country for perhaps several miles, concentrically around the crater, contains minute particles of this iron shale, either in the shape of fragments or as spherules. It is found everywhere in the vicinity of the crater, on the rim and on the outside plain. We have assumed that these small particles once constituted a portion of the great luminous tail of the meteoric body which, in our belief, by its collision with the earth made the crater.

Having observed all these things, containing as they do many arguments in favor of the theory that this great hole in the plain was produced by the impact of a body falling out of space, and against the theory that it was produced by either volcanic action or by a steam explosion, it naturally suggested itself to us to endeavor to prove *absolute* synchronism of the two events, namely, the falling of a very great meteor on this particular spot and the formation of this crater. The easiest method of doing this, which at once suggested itself to us, was to have a number of open cuts made through the silica and rock

fragments on the outside of the rim, and to sink a number of shallow shafts through this material, in order to find if possible pieces of the meteor *overlaid by and thoroughly admixed with* the rock fragments and silica which certainly came from great depths in the adjacent hole. Numbers of these cuts were made before finding the objects of our search, but at last we began to find them and now we have found nearly one hundred pieces of meteoric material, some of them as much as fifty pounds in weight, a number of feet beneath the surface in the silica, overlaid and underlaid in no particular order by the various kinds of rock fragments described above, namely, white sandstone, limestone and red sandstone. In one case that I remember we found a large piece of meteoric oxidized material or "iron shale" about six feet beneath the surface in the silica, directly underneath an angular fragment, several feet in diameter, of red sandstone. On the top of this red sandstone was a piece of limestone, and on top of the limestone was a still larger piece of white sandstone. I merely mention this case as it is interesting to reflect that the white sandstone comes from a depth of at least about 400 feet below the surface, and yet it is found on top of the red sandstone fragment (the surface rock) and the limestone fragment which, when the geological order of the rocks is considered, lie above it. However, the most interesting piece of work in this connection which we have done is to be found in one of the shafts on the rim, which shaft is forty-eight feet deep. In this shaft we found vertically one above the other no less than seven quite large specimens of meteoric material or iron shale; the first one being found twelve feet beneath the surface, and the last one being found twenty-seven feet beneath the surface, underneath a large fragment of red sandstone. These pieces were from a pound to probably thirty pounds in weight. On top of the uppermost specimen, and at varying distances between it and the other specimens found in this shaft, there was the usual admixture of silica, white sandstone fragments, limestone and red sandstone fragments. On no conceivable theory other than the one which we have adopted can the facts above described be explained.[7]

I have used the words "meteoric material" because this material is somewhat unlike any which up to that time had been found on the surface. Such material has, however, since been found on the surface,

[7] Since the above was written Mr. Tilghman has informed me that he has by means of a small magnetic separator found distributed through samples of silica, taken from deposits on the slopes of the rim, an appreciable amount of metallic iron in the form of very minute particles and scales which are covered by magnetic oxide of iron. These of necessity are meteoric in nature. They have been found by him in silica which was taken from several feet beneath the surface.

several large specimens, one weighing over 200 pounds and others over 100 pounds, having been found nearly a mile west of the crater, and many small ones distributed around it, generally to the northeast, north and northwest. This material is usually roughly globular or oval in shape, the outside having been converted into hydrated oxide of iron, while the interior is usually magnetic oxide of iron, showing when broken open in nearly every instance the green hydroxide of nickel. In a number of instances, however, these so-called "shale balls" (I again adopt the local name) are found to contain *a solid iron center*. We have some specimens where these iron centers probably weigh as much as twenty to thirty pounds, the total weight of the shale ball being considerably more than this. The magnetic oxide which surrounds the iron center usually presents a more or less laminated appearance, and I assume therefore that much of the so-called iron shale found on the surface, as small flat or slightly curved pieces or thick scale, from an inch to six inches in length and from one-sixteenth inch to several inches in thickness, has resulted from the alteration of shale balls, the iron in the great majority of the cases where these were small or were detached from the meteor in the upper atmosphere having had time to be entirely converted into magnetic oxide. There is such a great similarity of appearance that this inference is to me unavoidable, and I have recently noticed that the pieces of laminated magnetic iron oxide are often grouped, especially where they have been found on the outside plain some distance away from the crater, as if a shale ball, or a piece of metallic iron which was once covered by magnetic oxide of iron, had fallen on this spot and the magnetic oxide of iron had been disintegrated, either by the force of the fall or afterwards by ordinary atmospheric agencies.[8] It is worthy of note that the flat or slightly curved pieces of iron shale are found, like the iron specimens, only on the surface or in the surface soil, and to date at least have not been found admixed with the silica and rock fragments on the outside of the rim, as the shale balls are frequently found.

This brings me to attempt an explanation of the fact that these so-called shale balls are to be found beneath the surface on the outside of the rim, and admixed with the fragmentary material which was certainly expelled from the crater, to a proven depth of twenty-seven feet, and that the angular pieces of meteoric iron have been found up to date *only* on the surface or in the shallow soil which overlies the rock

[8] It may easily be, however, that pieces of metallic iron were found at some of these spots and taken away by the merchants who made a business of collecting these specimens for sale to museums, etc. See footnote 9.

fragments and the silica, which forms part of the rim, or on the surrounding limestone plain.

On April 11, 1904, it was my good fortune to observe, while at Pearce, Arizona, between five and six o'clock in the afternoon, a very brilliant meteor. This same meteor was observed at Tucson, Arizona, by Mr. Holsinger, who had been in charge of our exploratory work for some time previous to this. He was at the time over seventy miles distant from Pearce in an air line. It is a source of much regret that the sun was shining at the time, for otherwise the spectacle would have been a most brilliant and instructive one. As it was, however, the meteor was so large and so brilliant that the following facts could be most clearly determined: The head of the meteor was blue-white in color; from this head there seemed to dart from time to time, and almost from the moment the meteor became visible, many jets of bluish-colored light. Behind the meteor was a glorious comet-like tail, the color of which was generally yellow. From behind the meteor and out of this tail there appeared from time to time, and after the meteor had been visible for an appreciable length of time, great flaming drops, not unlike drops of burning tar. These rapidly fell behind the meteor, being distanced by it. In shape they were, generally speaking, somewhat like a gourd, with the small ends, which as I remember seemed to bend slightly downward, pointing toward the rapidly receding meteor. I counted as many as five of these drops. Mr. Holsinger thought he saw more than five.

Bearing in mind what I have related above, I shall now offer an explanation of the difference in distribution of the pieces of metallic meteoric iron and the so-called shale balls, realizing fully, however, that in the first place not enough work has been done to state with positiveness that no large pieces of iron are to be found in the fragmentary material forming in great part the slopes of the mountain, and in the second place that the explanation which I offer may be proved to be an erroneous one. I am inclined to believe that many of the thousands of pieces of metallic meteoric iron which have been found distributed around Coon Mountain, and which are generally known by the name of the Cañon Diablo siderites, were pieces that were torn loose from the surface of the meteor when it entered the earth's atmosphere by the violent expansion strains set up because of the intense coldness of the main body of the meteor, which of course was cooled to the temperature of outer space, and the intense heat immediately generated upon the entrace of the meteor into the earth's atmosphere. This would explain the darts of light which Mr. Holsinger and I saw going out of

the front of the meteor above referred to, from almost the instant the meteor became visible.[9] These fragments would naturally soon fall behind the meteor, and in the case which is the subject of this paper probably reached the earth after the collision had taken place and all of the material had been thrown out from the crater produced by the impact. The same would be true of the first "shale balls" to be detached, the origin of which, it seems to me, can be explained as follows. As the front surface became more heated it is possible that fewer of these irons would be thrown off, and almost certain that some of the iron would be melted and would naturally run back to the sides or to the rear surface of the meteor, from which from time to time it would be detached. This burning iron would then drop behind, as in the case of the meteor observed by Mr. Holsinger and myself, and form the shale balls above referred to. On this theory the laminated structure which I have spoken of is possibly due to the fact that the melted iron ran back over the meteor to its rear surface, or at least to its sides, and was detached therefrom in a pasty condition. This would seem to offer an explanation of the five flaming drops which I saw falling behind the meteor in April, 1904, and why they were not seen until the meteor had been visible for an appreciable length of time.

These shale balls probably continued to drop off from the great Cañon Diablo meteor, referred to in this paper, until the very moment

[9] Since writing the above it has occurred to the author that the pieces of metallic iron, and the pittings known as "thumb marks" which they show, are due to the very high temperature developed by friction against compressed air in passing through the earth's atmosphere. Dr. Mallet has confirmed this, and points out that in the case of iron meteorites this temperature would of course be still further raised by burning. He has also told me that this is a commonly accepted theory of the cause of these characteristic pittings. The effect of this furious burning, produced by the friction against the compressed air ahead of the flying iron meteor, would probably be to make great irregular cavities or furrows on its surface, as in the case of the 14-ton Willamette meteorite described by Mr. Henry A. Ward in the *Proceedings of the Rochester Academy of Science*, Vol. 4, pp. 137-149, plates 13-18. Whether the spaces represented by such cavities or furrows were once partly filled with nodules of troilite is not of importance in this connection. Having this action in mind it can readily be seen how these furrows or cavities in meeting might cause unconsumed pieces of metallic iron to be liberated, which would then fall behind the main body of the meteor and still burning reach the earth after the collision. Not only "thumb marks" but so-called "ring" meteorites are perfectly explainable on this theory. It receives very strong support from certain iron specimens which have recently been found by us (and since this paper was written) in the trench for the pipe line between Cañon Diablo gorge and the crater. To these specimens when found a large amount of magnetic oxide of iron or iron shale was still firmly attached, and occupied the "thumb mark" pittings on the specimens as well as being adherent to the more or less flat surfaces. When it is found in the pittings, generally referred to by the term of "thumb marks," it is distinctly shaly in character and is seen to curve upward from the bottom of the cavity. There is much to recommend this theory, but may there not be truth in both this theory and in the one just mentioned?

of collision. It is very natural, therefore, to conclude that some of them must have been caught before they reached the surface of the earth by the outgoing rock fragments and silica which poured out of the hole at the moment of collision. They were doubtless all burning fiercely at this moment, and would have continued to burn, like those which were detached in the upper atmosphere, until all of the iron was converted into magnetic iron oxide, had enough oxygen been present to produce this result. However, some of them seem to have been smothered out when covered up by the silica and the rock fragments included in it. This would perfectly explain why some of them have iron centers and some of them do not possess this peculiar feature, and why the pieces of iron shale continued to rain down for some moments after the collision. An interesting fact which is perhaps worthy of note is, that these iron centers nearly always show a peculiar exudation of drops of moisture, often colored green, partly perhaps from the presence of nickel. This exudation, Dr. Mallet explains to me, is due to the presence of chloride of iron. It is singular, however, that only one of the pieces of meteoric iron which we have, one of those which was found in the trench for the pipe line and is referred to in footnote 9, exhibits this peculiarity, it being confined to the so-called iron centers, which have only been found in the shale balls which were entirely covered and surrounded by silica and rock fragments.

During the many visits which I have paid to this remarkable spot, I have made a most thorough search for any other stone than the sandstone and limestone fragments above described. I have found a number of pieces of flint and some pieces of eruptive rock, but in every case there was every reason to believe they had been brought there by Indians who visited this locality, as many of them were pieces of "matates," in which the Indians and prehistoric inhabitants of this country ground their corn; and especially because most of them were found in the near neighborhood of the Indian "hogans" or camps. I had another object, however, than that of trying to find pieces of igneous or eruptive rock, which was to find if possible some pieces of meteoric stone, on the theory that perhaps the great meteor, which by this time I had become firmly convinced produced this crater, was partly metallic and partly stony in composition; in other words, a siderolite. A most careful search of the country for miles around failed to reveal the slightest evidence in favor of this theory. None of the pieces of iron, and by this time several thousands of such pieces have been found on all sides of the crater, have attached to them any particle of stone; except indeed where some pieces of iron

shale have been found adhering to small fragments of limestone and sandstone, or in one small specimen which I found including them, showing conclusively that this iron oxide was in a liquid or fused state when it fell to the earth. In this specimen there are sealed together, as sealing wax would hold them, three small angular fragments of sandstone, and another piece of iron shale which I have is firmly adherent to a piece of limestone, upon which it evidently fell when in a melted condition. The latter specimen shows the green hydroxide of nickel. The result of my careful search has been the conclusion that there is not the slightest evidence in favor of the meteor having been part iron and part stone.

It is only fair to state, however, that upon one of my recent visits to the crater, or accurately on June 24, 1905, I found on the surface of the plain, about a mile and a half west of the mountain, a very remarkable aerolite or meteoric stone. This is as different from all the other meteoric specimens which we have examined, which have come from this locality, as one specimen can be from another. It is subangular in shape, having on one side a rather sharply pointed protuberance, with a generally round and smooth surface which is covered by quite a heavy film of oxide of iron. Two corners were broken off when I found it. The fracture exhibited was very fresh, in fact almost as fresh as the fracture produced by me when knocking off a piece of it for analysis, which was made by Mr. H. H. Alexander and is as follows: SiO_2 37.32%; Fe 22.30%; Ni 1.65%; Al_2O_3 2.53%; CaO 2.96%; MgO 23.02%; S 2.34%. See also description and analysis of the stone which will be hereafter published by Dr. Mallet.

It has some curious markings, looking as if it possibly had received a blow before it entered the earth's atmosphere, these markings being covered with the same film of oxide of iron which cover the rest of the aerolite. A comparison of this analysis with the analysis of the Cañon Diablo meteoric iron shows the wide difference between the two, and the fact that it does not contain a trace of platinum or iridium and relatively small percentages of iron and nickel, while every specimen which has been examined of the meteoric iron or iron shale found in this locality contains the first mentioned metals, is very significant and is in favor of the theory that the aerolite or meteoric stone specimen is not in any way connected with the others.

Now comes a story which is at least very interesting, for as a coincidence, if such it is, it is very remarkable. Two years ago, about January 15, 1904, while two of our employees at Coon Mountain were watching the camp—we had suspended operations during the winter—

they were awakened, so they told us, by a loud hissing noise, and looking northward saw that the heavens were brilliantly lighted, and while rushing out of their tent saw a meteor fall somewhere northwest of the mountain, between them and the railroad. We paid no especial attention to their story, and supposed that although they might have seen a meteor fall, it had come to the earth, if it came to the earth at all, many miles distant. However, if we have been able to fix the dates correctly, on the same evening, at the same moment, a few minutes before nine o'clock, the hour being fixed by the train schedule, Dr. A. Rounsville, of Williams, and Dr. G. F. Manning, of Flagstaff, Arizona, were travelling to Cañon Diablo station, where Dr. Manning had been called to visit a patient. Just before the train stopped Dr. Rounsville saw from one of the windows, on the south side of the train, a blazing meteor fall in the direction of Coon Mountain. According to Dr. Rounsville's statement Dr. Manning did not see the meteor fall, but only saw the very brilliant light produced by it. It is very probable that this was the same meteor that was seen by our employees at Coon Mountain. If so it would appear that our two employees saw it from one side, while Drs. Rounsville and Manning saw it from the other, the observers being about 12 miles apart. As accurately as I can determine, it was very near a spot at the intersection of the two lines of sight, a spot which of course they could not locate exactly, that I found the above described meteoric stone—the only one, so Mr. Volz, of Cañon Diablo, tells me, that has ever been found in this locality, and his intimate knowledge of the locality extends for a period of over fifteen years. That a small stony meteorite should have fallen on almost exactly the same spot on the earth's surface as the great Cañon Diablo iron meteorite fell many centuries ago, is certainly a most remarkable coincidence. I have stated the facts as accurately as possible, and I have no opinion to offer as to whether or not these involve anything more than a coincidence.

I have endeavored to describe in this paper as briefly as possible only such matters as would appeal to a geologist and which have come within my personal observation. Such as they are, after a very careful study of this locality, they do not leave in my mind a scintilla of doubt that this mountain and its crater were produced by the impact of a huge meteorite or small asteroid, and that this fell upon the earth almost vertically, with probably a slight inclination toward the north. As is explained above, the greatest effort seems to have been expended on the southern side of the crater, as evidenced by the walls of the crater itself and by the great amount of material thrown out on the

southern rim, and by the fact that this material is much more comminuted than similar material elsewhere on the rim, and by the further fact that on this portion of the rim alone do we find fragments of the yellow and red sandstone, which we know to be from the deepest strata of which fragments have been expelled from the crater. This theory is still further borne out by the fact that most of the shale balls and smaller meteoric iron specimens have been found on the northern rim, which position they would occupy if they fell slightly behind the meteor itself, and yielded more than it did to the retarding effect of the earth's atmosphere and to the force of gravity.

In using the words "northern" and "southern" in the above connection, I mean by "northern" any direction between northwest and northeast; and by "southern" any direction between southeast and southwest. However, the direction from which the meteor came is a matter which is not as yet susceptible of positive proof and is of probably small importance at this time.

To summarize, we believe we have proved the following facts:

First. That a great meteor, the whole or at least the outside of which was metallic in nature, did fall to the earth at this locality, and that it was so large that portions of it became fused and were detached.

Second. That this great hole in the upper strata of the Aubrey formation was made at the instant of time when this meteor fell upon this exact spot. Having proved these facts, the conclusion is unavoidable that this hole, which as we have seen cannot have been produced by a volcano or by a steam explosion, was produced by the impact of the meteor, which, even admitting that it retained some large proportion of its planetary speed, must have been of great size.

Having proved these facts, and having been prevented by wet silica, a material very difficult to penetrate with a shaft, from sinking with a horse-whim to a depth of more than 200 feet, we put down a number of drill holes in the hope of finding evidence of the meteor beneath the central plain in the crater, using the ordinary type of rotary well-boring machinery. Several of these drill holes encountered obstructions, at least one (and probably more) of which would seem to be meteoric, inasmuch as a magnet put down at the time was strongly attracted to the obstructing object and brought up from it material which assayed four-tenths of one per cent. of nickel. We were unable to force the drill past this obstruction. In another hole the extreme depth of 1,020 feet was reached. In this, however, over 100 feet of red sandstone (the Red Beds above referred to) was penetrated. This seemed to be in place and to form the floor of what,

judging by the results of artillery experiments, we have termed the inner or interior crater, somewhere in which we suppose the wreck of the meteoric body to lie. In *all* of the holes the material (silica, broken and whole sand grains and some pieces of dense layers of cemented material composed largely of carbonate of lime) brought up by the drill from underneath the lacustrine sedimentary formations shows when concentrated many minute fragments of iron shale or minute shale balls which contain an appreciable percentage of nickel, and are therefore doubtless meteoric in nature. It seems certain that much of the nickel has been leached from these fine particles of meteoric material, but notwithstanding this fact they invariably have been found to contain a small fraction of one per cent. of this element, and in other respects are generally similar to the fine particles of iron shale which we have found on the outside of the crater. This evidence, to say the least, is strongly corroborative of, if not absolute proof of, the above theory. To test it still further, however, we are now proceeding to sink with a steam hoist a double compartment shaft in the exact center of the crater. Unless we should be prevented by difficulties which we cannot overcome, this will be sunk to such depths as will demonstrate the existence, as we suppose in a fragmentary condition and several hundred feet below the central plain, or the non-existence of the extra-terrestrial body which, in my best judgment, produced when it collided with the earth the crater which I have endeavored to describe.[10]

[10] It should be borne in mind that this paper treats only of such facts as are of interest to the scientific world, and has no reference whatever to the commercial value of the discovery.