THE RICHARDTON METEORITE

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At 9:48 P.M. Mountain time, June 30, 1918,[1] a meteorite was seen to fall in the country between Richardton and Mott, North Dakota. Pieces fell on both sides of the line between Stark and Hettinger counties within a strip about 9 miles wide from north to south and 5 miles wide from east to west. The center of this area lies in altitude 46°37′30″ N. and longitude 102°16′17″ W., about 20 miles south of Richardton.

The following data in regard to finders and specimens have been collected. The finds are arranged in geographical order from north to south.

Names of Finders	Section	Township	Range	Specimens	Weight	
					Pounds	Ounces
Rochus Steiner........	26	137	92	1 piece in fragments	6	12
Geo. B. Steiner........	?	137	92	1 piece	13	......
Nickolas Kuntz	27	137	92	1 piece	11	8
				1 piece	2	10
Bernard Kuntz	27	137	92	1 piece said to weigh	9	......
				1 piece	2	4
Lewis Loran..........	33	137	92	1 piece	18	$5\frac{1}{4}$
				1 piece	7	$0\frac{1}{2}$
				1 piece	4	......
				1 piece	0	12
Frank Miller..........	12	136	93	4 fragments	7	......
Leo Kern..............	18	136	92	11 pieces (largest 3 lbs.)	9	$5\frac{1}{2}$
Mat Schmidt.........	18	136	92	15 pieces	7	......
Benedict Fried........	24	136	93	24 pieces ($\frac{1}{2}$ to $2\frac{1}{2}$ lbs.)	17	......
Jacob Fried...........	26	136	93	4 pieces	1	......
Jozim Olheiser........	28	136	92	3 pieces	2	13

This lists a total of 71 pieces, weighing 123 lbs. 6 oz. It is reported, however, that at least 60 lbs. of material in addition

[1] The date was erroneously reported as July 26, 1918, in a preliminary statement in *Science*, New Series, Vol. XLIX (Jan. 24, 1919), p. 92.

to some of that listed above were purchased on the spot by Mr. T. A. Treganza.[1] It is probable that about 200 lbs. of material have been recovered from the fall, of which the Loran boloid, weighing 18 lbs. 5½ oz., appears to be considerably the largest.

As noted in the description of Modoc,[2] the distribution of the members of a meteorite fall follows in general the order of their size, with the largest pieces farthest in the direction of flight. The Richardton meteorite fell toward the north, and all the units weighing more than three pounds apiece came from the most northerly strip, 2 miles wide, while only one small specimen, weighing 12 oz., was found there. On the other hand, although the number of pieces found in the southern end is greater than that found in the northern part of the area, nearly all the individual examples are small.

The Richardton meteorite is of the veined, spherical chondrite class (Cca) of Brezina's classification, as may be recognized from the following descriptions of those specimens which have been studied by the writer. The descriptions are arranged in order of the size of the specimens.

1. The Loran specimen, weighing 18 lbs. 5½ oz. (8,338 gm.), may be likened in shape to an axe-head. It is a five-sided wedge, the sharp edge being 20 cm. long, and the blunt end 12 cm. by 11.2 cm. From back to edge the piece is 18 cm. long. Part of the crust has been broken from the mass, especially from the corners. In fact the corners of most large specimens are battered because the meteorite fell at a low angle to the surface of the earth, so that most of the pieces seem to have rolled or bounded after striking the ground. Few pieces penetrated the soil and none is known to have broken through the sod.

The largest Loran specimen appears to have six subparallel veins, the traces of three of which can be followed entirely around the mass, but the other three split up into branches and are less definite. All the veins branch into two or more members, and in

[1] The writer has sent three letters to Mr. Treganza, Britt, Iowa, in regard to his purchases. However, as none of these letters brought a reply, no further information about this interesting collection can be offered in this article.

[2] O. C. Farrington, *Nat. Acad. Sci.*, Mem. XIII (1915), p. 307.

some places the branches reunite, in the manner of anastomosis. Here and there within them there is a concentration of troilite and iron. The traces of the veins stand out like welts upon the unbroken surfaces (Fig. 1); otherwise the surface of the meteorite seems fairly smooth, although variegated with the characteristic shallow depressions, like thumb-prints, which are common to many stony meteorites. In addition to the subparallel veins before noted, there are at least two others roughly at right angles to them, which are less clearly marked than the series of six. It may be there are really more than two in this group. In any case, they are not prominent, and either they are discontinuous, or else the vein-filling material is wanting in places, making them inconspicuous on that account.

The crust seems to be of equal thickness on each face, apparently being a secondary fusion surface everywhere except on the side shown in Fig. 1, which appears also to have been the side protected from the rush of air after disruption of the meteorite. All the surfaces show the system of tiny cracks, like the crazing of china, which is common to stony meteorites.

On places from which the crust is broken it can be seen that the matrix of the stone is pale gray, speckled with pale brown chondrules as large as 3 mm. in diameter. The matrix is friable and easily broken, the chondrules breaking freely out of the matrix. There appears to be a good deal of troilite, but the iron does not show so clearly because it lacks the reflecting fracture faces which make the troilite apparent.

2. The Loran specimen weighing 7 lbs. $\frac{1}{2}$ oz. (3,186 gm.) is an irregular hexahedron with three pairs of subparallel sides. It may be described as an irregular rhombohedron, of which two axes are at right angles to one another, the third axis being at approximately right angles to one axis and inclined at an angle of about 80° to the other.

The crust is almost complete except for one side, which is a nearly plane fracture surface. Almost parallel to the fractured face are veins which can be traced completely around the stone. The fracture face itself follows one of the veins, so that much of the surface is vein material. This vein is cut by two short

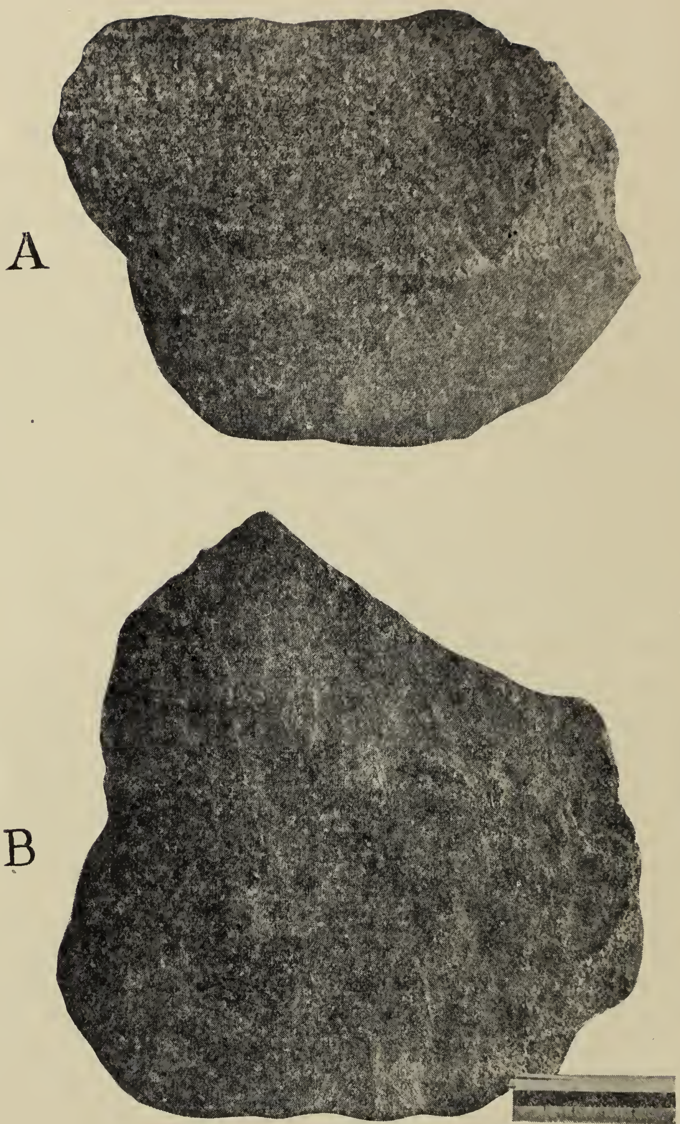


FIG. 1

A, The large, wedge-shaped specimen of the Richardton Meteorite, lying on one side, the edge of the wedge being to the left, showing traces of the veins on the smooth, primary-fusion surface.

B, Side view of the same specimen standing on the smooth face shown above, showing the secondary-fusion surfaces developed after disruption of the meteorite. The two lower corners are broken. The scale reads in centimeters.

cross-veins and offset by one. The veins in this specimen seem to be composed largely of troilite. Troilite is disseminated throughout the stone and forms ledges along the veins.

3. The largest member of Kern's collection is a well-crusted specimen, bounded by one flat side and a hemispheroid. The flat surface appears to be a fracture plane following a troilite vein. The stone weighs 1,357 gm.

4. A seven-sided boloid found by Nickolas Kuntz, weighing 2 lbs. 10 oz. (1,192 gm.), is covered with shallow depressions of the common finger-print type. It shows several veins of more than one group. There is no smooth face which may be interpreted as that sheltered during flight.

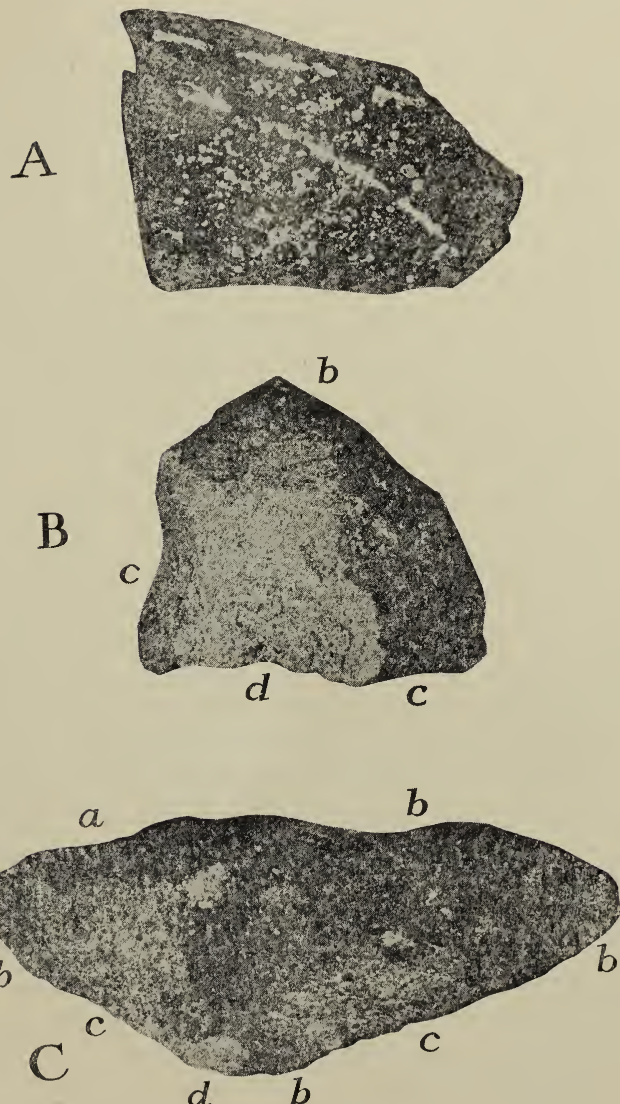
5. Preserved at the University of North Dakota is a very black coated specimen found by Bernard Kuntz, weighing 1,022 gm. One side is smooth, showing clearly the traces of intersecting veins, and the other faces are pitted with shallow depressions. Either the smooth face was the side away from the rush of air during flight, or it is of earlier origin than the rough faces, which may be secondary surfaces fused over after disruption during passage through the atmosphere.

6. Fourteen small pieces weigh 515, 498, 349, 312, 309, 305, 240, 232, 207, 168, 163, 161, 127, and 123 gm. respectively. These specimens are rounded boloids covered with fused crust, angular fragments completely covered with fused crust of various degrees of denseness, pieces broken either by impact with the ground or during examination by the finders, and combinations of these groups. In many cases troilite in melted blebs embosses the fused surfaces, indicating that many secondary faces follow the planes of veins.

This group of small specimens furnishes evidence of at least three degrees of fusion. First, there are black faces which are very smooth and show the traces of veins as welts, apparently sides protected from the direct impact of air in flight. Other black faces are dappled with small finger-print-like depressions, lumps and depressions being equally covered with fusion crust, having been corroded apparently by the blast of hot air compressed in front of the meteorite during its passage through the air. Second, there are rough surfaces, not smoothed by fusion and still bearing the roughness of original fracture, burned to a dark-brown color, the points being rounded off and black, but the depressions being unfused in places. These areas cut sharply across the black, well-fused faces, and are clearly of later origin. Third, a few small fragments have some surfaces only slightly fused; perhaps the words "scorched" or "singed" well describe the degree of fusion. Only the points of rough, broken surfaces are blackened by fusion, most of the area is light gray and unfused, but here and there outstanding pyroxene chondrules and troilite grains have melted and run a few millimeters over the unfused material. These faces, in some cases, are in the form of spalls out of the other types of fusion crust. It is clear that they are the youngest of the fused surfaces (Fig. 2, *B* and *C*).

Under the microscope it can be seen that these stones are composed chiefly of olivine, monoclinic pyroxene, glass, metallic iron, and troilite. The texture is markedly chondritic. The matrix consists chiefly of small crystals and fragments of olivine and pyroxene scattered throughout a scanty, glassy matrix. The chondrules are of the following types: (*a*) Spheroids, each composed of part of an olivine crystal. (*b*) Spheroids, each composed of part of a pyroxene crystal. (*c*) Little spheroids of colorless glass. (*d*) Larger spheroids containing well-defined olivine crystals. In some examples the crystals are crowded together, in others they are scattered in the glassy ground-mass of the chondrule. In a variety of this type the crystals appear to be arranged with their crystal axes parallel. (*e*) Glassy chondrules with radiating and fibrous cryptocrystalline texture. Some of the large pieces of olivine show many minute inclusions in irregular linear distribution.

A notable characteristic of this meteorite is the veining (Fig. 2, *A*). The veins are composed chiefly of troilite, and metallic iron and nickel. They are not continuous, for they contain areas in which there is no metallic material. The veins seem to vary in different cases from containing almost nothing but metal to carrying only troilite. In most cases metal and sulphide are mingled in a manner which suggests contemporaneous deposition or con-



Photograph by W. A. Force

FIG. 2

A, A polished surface showing the apparent concentration of metal in veins. Some of the chondrules have so high a polish that one must look closely to distinguish the metal from the polished chondrules.

B, A specimen showing the natural fracture face (*d*), the tertiary fusion surface (*c*), and a little of the secondary fusion surface (*b*).

C, A specimen showing all degrees of fusion: (*a*) indicates the primary, (*b*) indicates the secondary, (*c*) indicates the tertiary fusion faces, and (*d*) indicates the broken, unfused interior of the meteorite.

centration. Parts of the veins have been examined in both polished surfaces and in thin sections under the microscope. The metal seems to have been deposited without any violence having affected the chondrules, as a general thing; however, one chondrule seems to be represented by only half a sphere, the metal being in juxtaposition with the plane side. In most cases, nevertheless, the metal or sulphide partly surrounds or incloses the unbroken chondrules. The writer has seen no case of a chondrule penetrated by metal, although some of the chondrules include tiny grains of troilite in bordering zones. In cases where both metal and sulphide are in the vein the two are mingled in irregular shapes which have a smooth surface of contact; in some cases the troilite is scattered both within and near the borders and outside the metal, in other cases taking the place of the chief constituent of the vein and containing small irregular grains of metal.

Iron and troilite veins are not uncommon in stony meteorites. In some cases both minerals are present, and in others there is but one. Of American falls the following are reported definitely to contain iron veins: Danville,[1] Marion,[2] Farmington,[3] Estacado,[4] and Pipe Creek.[5] Troilite veins are reported in both McKinney[6] and Cosby Creek.[7] In most of these the iron and sulphide are concentrated apparently in the veins, although in most other meteorites the iron and troilite are disseminated in irregular grains throughout the mass. The relations of the minerals are commonly obscure; for example, Bath Furnace[8] has troilite intruding riven metallic particles as though of younger age than the iron, and also troilite completely enclosed in iron, indicating the opposite. But in Allegan[9] the sulphide does not occur as blebs within the iron as the silicates do, indicating that it is not necessarily either antecedent or contemporaneous with the iron. In the case

[1] Farrington, *op. cit.*, quoting Smith, p. 156.

[2] *Ibid.*, quoting Brezina, p. 296.

[3] *Ibid.*, quoting Meunier and Preston, p. 187.

[4] *Ibid.*, quoting Howard and Davison, p. 174.

[5] *Ibid.*, quoting Brezina, p. 353.

[6] *Ibid.*, quoting Brezina, p. 291.

[7] *Ibid.*, quoting Shepard, p. 138.

[8] *Ibid.*, quoting Merrill, p. 50.

[9] *Ibid.*, p. 30.

of Richardton, however, the troilite and iron seem clearly to be contemporaneous.

Polished surfaces, parallel to a vein and cutting the vein, totaling a surface of 10 sq. cm., show nickel iron containing irregular grains of troilite, in which there are three specks of metallic copper, the largest grain measuring about 0.6 by 0.08 mm. This seems to be the first report of metallic copper in a meteorite. Copper has been determined in traces by chemical analysis, but the character of its occurrence was unknown. It has been remarked before that, whatever the conditions under which metallic iron and nickel are deposited in these and similar veins in meteorites, the conditions must have been reducing in the extreme. It is not surprising, therefore, that, with iron in the reduced forms of ferrous sulphide and metal, copper also should be metallic. Copper inclosed in iron sulphide, which is also inclosed in metallic iron, may suggest that some of the sulphur was once in combination with the copper, previous to reduction of the metals.

A determination of the specific gravity of two small specimens without metallic veins, weighing 168 and 127 gm. respectively, gave the result 3.76. Specimens with veins would yield a higher specific gravity determination.

Following is an analysis by J. E. Whitfield, for privilege of early publication of which we are indebted to Dr. George P. Merrill, of the National Museum:

	Percentage
Metallic portion	19.90
Silicate portion	80.10

The metallic portion yielded as follows:

	Percentage
Fe	90.89
Ni	8.92
Co	0.15
P	0.04
	100.00

The silicate portion yielded:

	Percentage
SiO_2	44.49
TiO_2	0.10
Al_2O_3	2.46
Cr_2O_3	0.64
Fe_2O_3	4.34
P_2O_5	None
MnO	0.19
FeO	16.23
CaO	2.69
MgO	28.32
Na_2O	0.85
K_2O	0.165
	100.475

These analyses were made from fragments apparently representative of the matrix of the meteorite, but not representative of the vein material. From the absence of sulphur and copper in the analysis it appears that the vein material is generally different from the rest of the stone.

On November 9, 10, and 11, 1919, the following data and evidence were collected at the places noted.

At Mandan, 70 miles east and about 10 miles north of the locality of the fall, several people saw the meteorite. It happened that there were two troop-trains in the yards at the time and any noise the meteorite made was not noticed during the celebration.

At Dickinson, 30 miles northwest of the locality, the meteorite appeared as a bright light which went out suddenly, accompanied by a rushing, roaring sound which seemed to shake the air.

A person interviewed in Richardton was in New Leipzig, about 20 miles southeast of the locality, at the time the meteorite fell. He had just gone to bed when he was startled by a brilliant light, which he took momentarily for the headlight of a locomotive; however, he went to the window and saw a meteorite passing to the west of the town, going apparently in a northwest direction and falling at a low angle. The witness recalled that there was a roaring sound like that of an airship for about two minutes, followed by a violent explosion; it was a fearful and terrifying noise, rattling the windows and shaking the house severely, resembling an earthquake. To others at New Leipzig it sounded like rolling artillery.

Mr. Bernard Kuntz, Section 27, Township 137, Range 92 west of the fifth principal meridian, saw the fall. To him the flight seemed to be from southwest to northeast, making the countryside as bright as day. He described the noise as like that of an airship or a motorcycle. He found several specimens.

Mr. Nickolas Kuntz lives on another quarter of the same section as Bernard Kuntz. All his family were in bed and asleep at the time, but they were awakened by the light and noise, which they took to be caused by lightning, thunder, and rain. Mr. Kuntz found one boloid weighing $11\frac{1}{2}$ lbs., which was in a shallow hole on plowed land; another weighing 2 lbs. 10 oz., which was lying on the surface in a pasture; and a third weighing about $9\frac{1}{2}$ lbs.

Mr. Rochus Steiner, living in the northwest quarter of Section 26, Township 137, Range 92, made a written record of the fall. According to his notes it was 10:39 P.M., Sunday, June 30, 1918. He noticed first a bright light for one-half minute; then there came a sound like rolling thunder which shook the windows of the house, followed by a whistling like that of a bullet. He found a broken meteorite partly buried 5 or 6 inches in the loose earth at the roadside, the pieces weighing about $6\frac{3}{4}$ lbs.

Mr. Leo Kern, Section 18, Township 136, Range 92, saw the fall. He was walking home about 10 o'clock at night, when suddenly there was a bright light. At first it was like a bright shooting star; then it became a streak of fire until it burst like a Roman candle. It appeared to be coming from the southeast, falling at an angle of about 15° to the horizontal. It made a "rattling sound like an airship," and when it burst the earth all about him trembled, and the house shook with the violence of the explosion. He prudently took shelter behind a telegraph pole, as the meteorite appeared to be coming directly toward him. After the explosion he heard pieces flying through the air like whistling bullets, and pieces rattled against the roof of his barn, where he found some later. After the meteorite had burst there appeared to be a trail of "smoke or steam" in the line of flight. Several specimens were found by his daughters, Misses Emma and Irene Kern, and contributed by them to the collection of the University of Minnesota.

Mrs. Nell F. Rodenbour, postmistress at Lemmon, South Dakota, writing February 25, 1919, describes the fall as follows:

I saw this meteorite myself and can only describe it thus: At about 11 o'clock at night we heard a dull roar like thunder, and we all ran out of the house to see, and there appeared a bright flash of light across the whole sky. It fell to the northwest, more north, and left a tail of light which remained for fully fifteen minutes.

Lemmon is about 45 miles south and 8 miles east of the place where most of the meteorite fell.

Mr. N. R. St. Marie, of Hettinger, North Dakota, wrote on February 27 as follows:

The writer was lucky enough to get an almost perfect view of the meteorite. I was seated in an auto sky-gazing, when it attracted my attention as a shooting star. In a moment I saw that it was out of ordinary. Starting from very high it fell rapidly earthward, a little to the east of north, about 10 or 15 degrees, I judged. As it came down it illuminated the landscape to almost the brilliancy of sunlight, but the light was first of a green and later of a yellow hue. A faint whistling was discernable to part of our party; others, however, said they didn't notice any sound.

I was 65 miles south and 15 miles west of Hettinger at the time.

In answer to further inquiry, on March 1, 1919, Mr. St. Marie added:

I first noticed it very high in the heavens giving the appearance of being nearly over me; as it approached the earth it appeared more and more to the northeast.

This observer was 100 miles south and 30 miles west of the locality of the fall at the time.

Mr. Lewis Loran, Section 33, Township 137, Range 92, found several specimens of the fall, and was a witness of the phenomena. On December 12, 1918, he wrote the following detailed description of the fall:

It was June 30, at 10 P.M.; my wife and I were in my yard, and I looked at the sky and I discovered the meteor. It was as large to me as about two inches in diameter, and it was just where the sun is about the first week in November at fifteen minutes after twelve. It came nearer and nearer, and larger and larger, so at last I thought I must go out of its way or it would strike me. It was at least as big to me as the sun is sometime in August when it sets, but more than three times as light; then it flashed out (it was a cloudless night and no wind), and it was all still. I said to my wife, "Where is it now? It has to come. It is so near to the surface of the earth." It just took this long to say these words when we heard a great racking in the air in the same direction, and in a few seconds we heard the pieces sounding through the air like shells. We could hear that there were some smaller and some larger pieces, and that some went beyond us and some fell south of us. But the worst racking and noise was the exploding in the air. It seemed that it shook the ground under my feet, and I could hear the windows in my house rattle. We could not see the pieces, but we could hear them, and we could tell that they came from the direction from which the meteorite came.

The light of the meteor was seen over more than 400 square miles, and the noise was heard over 250 square miles.

The following account of the fall was written by Mr. Orris W. Roberts, meteorologist, United States Weather Bureau, Bismarck, North Dakota:

This meteorite was observed by the writer. I was driving my automobile some distance east of Bismarck on the night in question. As we make reports of such phenomena I am in position to give some information. The time of observation was 10:48 P.M., June 30, 1918. The meteorite appeared to move somewhat north of east and the explosion was plainly to be seen, although no report reached the observer. The light was intense, lighting up the entire sky. . . . . The location of the meteorite at the time of the explosion as located on our reports would indicate that it occurred over eastern Hettinger county.

Writing on March 19, 1919, Mr. Roberts recalled that the meteorite appeared to be falling at an angle of less than 45° to the horizontal. Bismarck is 74 miles east and 10 miles north of the locality where the meteorite fell.

There is apparent a discrepancy of about an hour between the time of fall as given by Mr. Roberts, a trained observer, and that given by almost all the other witnesses. The explanation is that Mr. Roberts, stationed at Bismarck, uses Central time, whereas the other observers quoted live west of the Missouri River, which is the geographical boundary between users of Central and Mountain time in that latitude. Mr. Roberts' estimate that the explosion occurred over eastern Hettinger county is shown by other witnesses to be correct. The green light noted by Mr. St. Marie may have been caused by the presence of copper in the meteorite. Mr. Loran's estimate of the area over which the meteorite was seen and heard is low, because it must have been seen at a distance of one hundred miles in every direction, and the sound was heard at least fifty miles from the place of fall.

One who has read the descriptions of other meteorite falls may recognize a notable expansion with the times in the language of the witnesses. Doubtless the phenomena have been generally similar. There have been a streak of light, the noise of disruption or merely of the swift passage of masses through the air, and in some instances the whistling of smaller pieces. In early descriptions the witnesses compared the noises almost exclusively to thunder and the rolling of wagons; later came comparisons to the roar of artillery fire or the rumble of cannons, then to noises like a railway train, and to the sound of a train of cars on a bridge. The Modoc fall in 1905 perhaps is the first to have been compared to the noise of machine-gun fire, but in the descriptions of the Richardton fall the noises of small pieces are compared to that caused by the flight of shells and bullets; whereas, to describe the general noise of the fall, the witnesses introduced in comparison the motorcycle and even airships.

The Richardton meteorite is the third to be reported from North Dakota, the others being two iron meteorites: (1) at Jamestown, Stutsman County, weighing originally 4,015 gm., found in 1885, date of fall unknown; and (2) at Niagara, Grand Forks County, weighing 115 gm., found in 1879, date of fall also unknown. Richardton is the only fall which has been reported as seen to fall in North Dakota, and it is by far the largest found in the state. Of the three meteorites, the only one preserved in collections of the state is Richardton. Two representative boloids, weighing 2 lbs., and 12 oz., respectively, are at the state university. Both the Jamestown and the Niagara meteorites are widely distributed throughout the collections of the world. In this connection it may be urged that finders of meteorites should try to have a representative of every fall placed on exhibition some-where, preferably at the state university museum, within the state in which it fell. In this way some of the public would become familiarized with meteorites, their general appearance, and their nature. The work of the collector and scientific investigator would be lightened if the finders of meteorites could be deterred from believing that meteorites contain gold, silver, platinum, radium, and other rare metals in large quantities, and from investigating meteorites with sledge hammers.

With the help of Professor W. O. Beal, of the department of astronomy of the University of Minnesota, the azimuth and vertical angle of the fall of the meteorite have been computed, using the description of Mr. Loran.

In Mr. Loran's position at 12:15, the true local time is 12:45 P.M., at which time the sun is 12° W. of S. In his latitude on the seventh day of November the sun is at an elevation of 27° above the horizon at noon. Thus, according to Mr. Loran the meteorite fell in a direction 12° E. of N., making a vertical angle of about 27° with the earth's surface.

Mr. St. Marie, 100 miles to the south and 30 miles west of Mr. Loran, thought the meteorite started to burn immediately above him. His bearing from Mr. Loran was 17° W. of S., showing that Mr. Loran's estimate of 12° W. of S. must be nearly correct. Furthermore, Mr. St. Marie estimated the direction of flight as from 10° to 15° E. of N. Mr. St. Marie and Mr. Loran were $104\frac{1}{2}$ miles apart at the time of their observations, representing the locations of the incipient incandescence and the landing of the meteorite. If the meteorite fell in a straight line the altitude of the meteorite when it started to burn was at least $54\frac{1}{2}$ miles above the earth's surface, allowing $1\frac{1}{2}$ miles for the earth's curvature. This height should be increased probably to at least 60 miles because the meteorite probably did not fall in a straight line, but rather in a parabolic curve, although there are no data recorded about that except Mr. St. Marie's note that the meteorite appeared to fall progressively more toward the east. It seems safe to say that the meteorite started to burn at a great, but not an unusually great, height above the earth. Heights of 40 and 100 miles bound the region in which meteorites commonly start to burn.

At a height of 60 miles above the earth the air is extremely thin, indicating that the meteorite entered the atmosphere at a very high velocity, otherwise it would not have developed enough friction with the air to cause combustion. The meteorite fell near latitude 46° 30′, in June, at approximately 10 P.M., at an angle of 27° to the surface, going northward, from which data it follows that the meteorite was falling toward the sun when it was intercepted by the earth. Falling at an angle of about 90° to the course of the earth, the meteorite entered the earth's atmosphere at neither the highest nor the lowest velocity possible relative to the earth. In other words it fell neither directly opposite to the earth's flight, the condition of maximum velocity, nor did it catch up with the earth, a condition of minimum velocity. However, a meteorite falling toward the sun at the distance of the earth's orbit commonly has a velocity of 25 miles per second. By the earth's attraction the velocity might have been increased to 30 miles per second. It seems a conservative estimate to call the velocity of the meteorite when it entered our atmosphere about 30 miles per second.

The general unbroken condition of most of the examples of the fall, in spite of their brittle nature, indicates that the meteorite struck the earth's surface at a relatively low velocity. It is not clear why a meteorite should become incandescent in a very tenuous atmosphere, 60 miles above the earth, and then why its broken fragments after disruption in much denser air should not burn, unless the velocity is decreased enormously during its passage through the air. The meteorite must have passed through at least 117 miles of air from the time it commenced to burn until it reached the earth. This thickness of atmosphere appears to have offered enough obstruction to the passage of the meteorite to reduce the velocity from probably about 30 miles per second to something much less. All this, of course, is quite in accordance with commonly accepted notions as to the general behavior of meteorites. If anything, the height at which the meteorite is estimated to have commenced to burn is somewhat low for the velocity postulated. However, the general probability of the conclusions reflects most creditably upon the accuracy of the observations of both Mr. Loran and Mr. St. Marie.

Although after explosion it seems that the meteorite was not incandescent, it certainly was fused additionally; for all the surfaces freshly exposed by the main disruption were completely fused over by the time the fragments reached the earth. To such an extent was that accomplished that it is not quite certain to the writer that all the material discovered entered the atmosphere as parts of a single mass. Many of the smaller pieces, particularly, appear as if they may be units of a shower. Among the smallest pieces certain specimens show clearly three degrees of fusion. All the specimens from the northern part of the locality are covered with a thick, well-fused crust. Only the small pieces from the southern part of the area have slightly fused surfaces. These small pieces went through at least 5 miles less of the atmosphere than the thoroughly fused pieces, and some of them, at least, are fragments of a second disruption which must have occurred very near the earth. Presumably the small pieces fell first because they offer more areal resistance to the atmosphere per unit mass than the larger pieces.

Unquestionably atmospheric obstruction is responsible for the fusion and disruption of the meteorite. Disruption is commonly ascribed to shock of impact with the air, and to the disruptive effect of heat. The heat, however, probably penetrates a very little distance beyond the crust of actual fusion and combustion, and the character of meteorite ruptures certainly is not like that due to the spalling of heated surficial masses. In most cases meteorites are broken through the main mass, rather than shelled off in the familiar manner of insolation spalling of massive rocks. In the case of the Richardton meteorite, rupture was facilitated in places by the presence of metallic and troilite veins, which are planes of weakness. Several specimens are bounded partly by more or less fused metallic vein matter.

The question arises as to why the light of the meteorite ceased with its disruption. The disruption of the meteorite is described as an explosion, but this is probably a poor choice of words. There is apparently nothing in the meteorite capable of causing an explosion; but if it had exploded, part of the mass would have continued at a higher velocity relative to the air and part at a speed less than that previous to its explosion. The fact is that the light ceased after disruption, proving that the velocity was lessened rather than increased, and indicating that the meteorite fell apart but did not explode. Such a disruption, of itself, should not decrease the velocity of flight, and except for the influence of the larger surfaces exposed, before noted, the meteorite fragments should have continued to burn after disruption as before. The fact that they did not burn again indicates that the velocity of the meteorite was so decreased at the time of disruption that the exposure of intensely cold surfaces from the interior of the meteorite, added to the increased damping effect of the atmosphere on larger surfaces, was sufficient to prevent the intense temperatures necessary for burning. Thereafter, the velocity of the meteorite must have decreased progressively as it entered denser and denser air until it reached the surface. Although not heated enough by this obstruction to burn brightly after disruption, the meteorite certainly was heated enough to cover the larger pieces with a heavy fused crust, and to form a thinner crust on the smaller pieces. The smaller pieces had a thin crust both because they went less rapidly than the larger pieces through the air, and because they went a shorter distance through the atmosphere after disruption.

Many residents of the district in which the meteorite fell have assisted greatly in collecting data and specimens. In addition to those especially mentioned above, Mr. John Muggli, of Richardton, has extended many courtesies and has given much help. Mr. W. A. Force, of the Photo Art Shop, Minneapolis, has given of his time and experience in securing the photographs from which the illustrations are made. Funds and opportunity to investigate the phenomena of the fall and to collect specimens for the museum were provided by the University of Minnesota.

A new fall has been named, classified, and described. The phenomena of fall have been reported more fully than usual, and certain conclusions in regard to the direction of flight, velocity, and consequences of disruption of the meteorite seem to follow reasonably. The meteorite is noteworthy for the concentration of metallic iron and nickel and iron sulphide in veins. The discovery of visible, metallic copper in a meteorite is announced.