

ART. XXXI.—*A description of the Rochester, Warrenton, and Cynthiana Meteoric Stones, which fell respectively December 21st, 1876, January 3d, 1877, and January 23d, 1877, with some remarks on the previous falls of Meteorites in the same regions ; by J. LAWRENCE SMITH, Louisville, Kentucky.*

A SHORT notice of the three meteorites which form the subject of this communication, was published by me shortly after their fall, the detailed account of their flight and fall having been deferred until I could make a more thorough examination. This I am now able to do, as there have been sent to me the entire stone that fell near Cynthiana, and a large portion of the fragments which have been saved of the other two.

The points of interest in connection with these three meteorites are as follows: *First*, they fell within a period of thirty-two days, and within a circumscribed territory of about two degrees of latitude and six degrees of longitude. *Secondly*, they differ from each other in their structural characteristics, and each has some peculiarity distinguishing it from the ordinary type of meteoric stones. *Thirdly*, they fell within a belt of territory, which I shall show has been the lodging ground of all the meteoric masses that have been observed to fall and have been collected in the United States during the past eighteen years, with the exception of about one kilogram.

1. *Rochester (Indiana) Meteorite.*

The passage of this meteorite through the earth's atmosphere has left but a small souvenir of its visit. It was well observed at Bloomington, Indiana, lat. $39^{\circ} 12'$, long. $36^{\circ} 32'$, by the distinguished astronomer Professor Kirkwood, who communicated to me at the time his observations; and he has subsequently given them more in detail to the American Philosophical Society, with the observations he had collected from others. I will therefore simply give a summary of the phenomena attendant upon its flight before describing the chemical and mineralogical characteristics of the stone which fell.

The bolide made its appearance about nine o'clock P. M., December 21, 1876, and was of extraordinary magnificence. It passed eastward over the States of Kansas, Missouri, Illinois, Indiana, Ohio, and parts of Pennsylvania and New York. Although no observations were made in the two last mentioned States, still Professor Kirkwood is doubtless correct in defining this as its course. At Bloomington its elevation was fifteen degrees. According to the calculation, the length of its observed track was from 1,000 to 1,100 miles, one of the longest on rec-

ord. Its height is supposed to have been thirty-eight miles above the place where the small fragment fell from it.

In various parts of its track, it threw off fragments, accompanied with the usual rumbling noise and commotion in the atmosphere common to the flight of these bodies. When crossing Indiana, the main body was followed by a train of smaller bolides, many of them of the apparent size of Venus or Jupiter. Its velocity in reference to the earth's surface appeared to be from eight to twelve miles per second. The pyrotechnic display is said to have been transcendently beautiful, hardly equalled or surpassed by any previous occurrence of the kind. The cause of this brilliancy lay in the physical structure of the body, which will be detailed farther on.

The fragment which fell.—The only fragment of this bolide known to have fallen was one found on the farm of Mr. Morris, three miles northwest of Rochester, Indiana, lat. 41° , long. 86° . This farmer heard the explosion, and shortly afterward noticed a body strike the ground not far from him. There were six inches of snow upon the ground, and, on the following morning he found the stone, which had rebounded to a short distance from the place where it first fell, it not having penetrated the ground. The entire stone did not weigh four hundred grams, and as we have not heard of the fall of any other mass, it is reasonable to suppose that it was dissipated into very minute fragments and dust, as in the case of the Hesse stones and other similar falls.

The manner in which the molten matter of the exterior of many of these meteorites is swept over their surfaces, in shining streaks, covering freshly broken surfaces, show clearly that this disintegration is constantly and rapidly going on in these bodies during their passage through the air. I have in my collection many fine examples illustrating this fact.

Professor Kirkwood is of the opinion that this bolide never passed out of our atmosphere, which is in accord with my general view on this subject, viz: that a bolide rarely, if ever, gets entangled in our atmosphere without being entirely reduced to fragments or powder.

The stone has been broken up into many small fragments, of which I have fortunately secured a good portion. Others have been lost and a few have found their way into collections. With the exception of the largest specimen in my collection, weighing ninety-five grams, hardly any other fragment weighs over thirty grams. It is important to treasure these specimens, small as they are, for it is a remarkable stone of its type. It is of the pisolitic variety, very friable, of a gray color, easily crushed under the fingers into light powder (some of it to fine dust), and to small globules, some of them *perfectly spherical*, of which I

have specimens two millimeters in diameter. It resembles more closely the Aussun stone than any other I know of, although much more friable. This peculiar structure, so often seen in many parts of meteoric stones, has recently attracted much attention, Professor Tschermak, of Vienna, having recently published an interesting paper on the subject.*

The specific gravity of the stone, taken with several average specimens, is 3.55. There is nothing peculiar about the coating on the specimens I have examined; it is of a dull black and quite rough.

Chemical examination.—The stony part of the meteorite separated almost perfectly from the metallic part still contained a notable portion of troilite that could not be separated mechanically. The amount of sulphur found in that part of the meteorite indicated the amount of troilite present, viz: 3.31.

The stony material, when treated with chlorhydric acid over a water bath, affords soluble part 47.80 per cent, insoluble 52.20 per cent, and is constituted as follows:

	Soluble part, per cent.	Insoluble part, per cent.
Silica - - - - -	34.55	57.81
Iron protoxide - - - - -	27.75	11.04
Alumina - - - - -	trace	.23
Lime - - - - -	trace	5.31
Magnesia - - - - -	36.38	24.97
Chromium oxide - - - - -		.10
Soda - - - - -	.46	.84
	<hr/> 99.14	<hr/> 100.30

I separated some of the globules perfectly free from the intervening matrix, which is easily done by rubbing a piece of the stone between the fingers. Very minute specks of iron could be distinguished on them, and when pulverized and treated with chlorhydric acid, they gave about the same result as the matrix, viz: soluble, 46.80 per cent; insoluble, 53.20 per cent; and the magnesia in the soluble part was 34.48 per cent, showing clearly that they were merely concretions of the matrix of the stone.

The nickeliferous iron, which was separated mechanically, is composed of:

Iron - - - - -	94.49
Nickel - - - - -	4.12
Cobalt - - - - -	.51
	<hr/> 99.12

The quantity of iron was too small for an examination of the other constituents, as phosphorus and copper, but they were no doubt both present.

* Sitzungsab. Akademie der Wissenschaften, vol. lxxi, p. 661.—Wien.

Mineral constituents of the Stone.—Careful examination under the microscope of the broken surface, as well as of a section rubbed down very thin, show the stone to be composed of the unisilicates and bisilicates usually found in these bodies, mixed with nickeliferous iron and troilite; nothing like anorthite is distinguishable. The first two minerals constitute the bulk of the stone, and there is possibly more than one variety of each of these minerals present. The nickeliferous iron is quite abundant, although Professor Shepard states that from a casual observation he estimates it at one per cent; by the careful method adopted for separating it, I find in two average specimens over ten per cent. The particles of iron are very bright and lustrous, looking as if they were covered with plumbago, although there is no evidence of the presence of the latter mineral. The troilite is not detected so readily by the eye as it is by chlorhydric acid. One of the spherules was rubbed down to a thin section and examined by polarized light; and in this way it was found to contain both classes of silicates referred to, a fact, as already stated, sustained by chemical examination. I consider the mineral constituents of the Rochester stone to be about as follows:

Bronzite and pyroxene minerals.....	46·00
Olivine minerals.....	41·00
Nickeliferous iron.....	10·00
Troilite.....	3·00
Chrome iron.....	·15

2. *Warrenton (Missouri) Meteorite.*

About sunrise, on the 3d of January, 1877, five miles from Warrenton in the State of Missouri, lat. $38^{\circ} 50'$, long. $91^{\circ} 10'$, a sound was heard by certain observers similar to the whistle of a distant locomotive; or, as stated by others, like the passage of a cannon ball through the air. The sound came from the northwest, and became louder and louder to four observers near Warrenton. On looking up they saw an object falling, which struck a tree, breaking off the limbs, and then coming to the ground with a crash. The observers were fifty or sixty meters distant from the spot where it fell. On approaching the place they saw a mass of stone broken into a number of pieces. From the fragments they suppose it to have been originally of a conical form, and about eighteen inches in length. The snow was melted, and the frozen ground thawed near where it fell, but the pieces, although warm, were easily handled. The weight was estimated to have been about one hundred pounds; but, whether this estimate be correct or not, only about ten or fifteen pounds of fragments have been preserved, a good portion of which is in my possession, mostly in small fragments;

some specimens are in the cabinet of Yale College, and others scattered about among the inhabitants of the country where it fell.

As regards its temperature at the time of falling I would say that I have a specimen, which gives as it were a satisfactory record that it was not very hot when it struck the tree, for a portion of the fibers of one of the branches is adhering to the surface entangled in the rough crust of the stone, and these delicate fibers show not the slightest signs of having been heated. A fact to be noted in connection with the fall of this meteorite is that no explosion was heard, or any luminous phenomena produced, by its passage through the air after it was first noticed; this may be in part due to the fact that the fall happened at sunrise; but it was no doubt a meteorite well spent in its rapid motion through the atmosphere, and dropped quietly like an exhausted bird in its flight. Its direction, so far as made out, was from northwest to southeast.

Aspect of the Stone.—Studied by the various fragments that are under my observation, it differs in a marked degree, although pisolitic, from the one just described, and which fell only a few days previously. It has its own points of peculiar interest, and is not like any meteorite that I am familiar with, except the Ornans meteorite, which fell July 11th, 1868; and this it resembles closely in every particular, as may be seen by comparing my results with those of Pisani (*Comptes Rendus Acad. Sci.*, 1868, vol. ii, p. 663), although his method of recording the analytical results is different from mine, and the specific gravity, as made out by him, is higher than mine, which is not singular in different specimens of these porous bodies. Its crust is dull black, and quite thick; in many places, of several centimeters square, from two and one half to three and one half millimeters thick (the thickest I have ever seen), where the crust is a rough scoria that sometimes terminates abruptly on a smooth portion of the crust, and is doubtless produced by the melted matter on the surface being forced backward and opposite to the direction of the flight of the stone, being swept off one portion of the surface, and leaving this part smooth, and piled up behind it, in the form of a surface of scoria.

The interior of the stone has a very dark uniform ash color, and is soft and easily crushed; the latter fact accounts for its having broken into fragments as it struck the ground. Its specific gravity is 3.47, and the amount of metallic matter contained in it is small.

Chemical composition.—The stone pulverized and freed from metallic particles gave on analysis an amount of sulphur equal to 3.51 per cent of troilite; the amount of nickeliferous iron was small, being equal to 2.01 per cent. The stony minerals treated with chlorhydric acid gave—

Soluble in acid.....	80.40 per cent.
Insoluble in acid.....	19.60 per cent.

composed as follows:

	Soluble.	Insoluble.
Silica.....	33.02	56.90
Iron protoxide.....	37.57	10.20
Alumina.....	0.12	.20
Lime.....	trace	7.62
Magnesia.....	28.41	22.41
Soda.....	.07	1.00
Nickel oxide.....	1.54	
Cobalt oxide.....	.31	
Chromium oxide.....		.33
	<hr/> 101.04	<hr/> 97.66

I obtained chrome oxide thirty-three per cent, indicating 0.50 of chrome iron, if the chrome be present in that form. There is no way, however, by which I can decide this question, although it is probable, since the chrome is in the insoluble part; the oxide of nickel, with the exception of perhaps a minute portion, belongs to the composition of the soluble silicates.

The *nickeliferous iron* contained in this stone is very small in quantity. This on analysis gave

Iron.....	88.51
Nickel.....	10.21
Cobalt.....	.60
	<hr/> 99.32

Mineral constituents of the Warrenton Meteorite.—A microscopic examination did not give me any clear indications, for it is not possible to prepare a good section for observation. Its chemical examination, however, shows the usual uni- and bisilicates, of the olivine and bronzite and pyroxenic types. The most marked feature is the preponderance of the olivine minerals, constituting four-fifths of the mass. The proportion of the mineral constituents is about as follows:

Olivine minerals.....	76.00
Bronzite and pyroxenic minerals.....	18.00
Nickeliferous iron.....	2.00
Troilite.....	3.50
Chrome iron.....	.50

3. *Cynthiana (Kentucky) Meteorite.*

I have called this the Cynthiana stone, although it fell nine miles from that place, in Harrison county, Cynthiana being the nearest important point to the place where it fell.*

* I will take occasion just here to correct an error that I have seen in several catalogues, among them those of Vienna, the British Museum, and the Garden of Plants. These catalogues designate the meteoric fall described by me in 1858, as that of Harrison county, Kentucky: it should read Harrison county, *Indiana*.

At four o'clock P. M., on the 23d of January, 1877, a brilliant bolide was seen traversing Monroe county, Indiana, in a southeasterly direction, about thirty-five degrees above the horizon. The same bolide was observed by a number of persons in Decatur county, of the same State, lat. $39^{\circ} 27'$, long. $85^{\circ} 28'$, and it disappeared just as it seemed to touch the earth, apparently not more than a quarter of a mile distant. As will be seen, it fell about sixty miles distant from these places. It seemed to fall almost perpendicularly toward the earth's surface. I cannot learn that it was seen by any one in the State of Ohio, but suppose that it was. In the State of Kentucky it was seen over a considerable territory. The phenomena culminated in the usual noises heard in the heavens accompanying the approach of these bodies, and much consternation was produced among the inhabitants of the surrounding country. Fortunately one of the observers, an intelligent farmer (Mr. Cragmyle), heard a solid body strike the ground; he walked immediately to the spot, and dug the stone from a depth of thirteen inches, to which extent it had penetrated the ground. A few days after its fall and before it had become generally known, Professor Kirkwood wrote me a letter, stating what observations had been made in Indiana, and telling me to look out for a meteoric fall somewhere about the region where the stone did fall. I had, however, made the observations and secured the meteorite, before his letter arrived, but the stone had not yet been forwarded to me.

Character of the Stone.—It is wedge-shaped, with one portion of it very extensively and regularly pitted, while the rest is comparatively smooth. The crust is dull black, and, as it reached me, it was as perfect as when it fell. There was a fresh broken spot of two or three square centimeters, which, to a casual observer, would appear to have been made after the fall; but upon close examination, I saw that it had been made prior to the fall, and before the melted matter of the surface had entirely cooled, for a few small specks of this matter have been sprinkled on this broken surface, to which it firmly adheres, and the molten matter is running over one border of it. This could not have arisen from any fusion of that surface, which is too fresh and unaltered to have been heated to any high degree. The fracture was produced by the same cause that produced the pitting.*

The weight of the stone is six kilograms. It is of the harder brecciated variety, and when broken presents a mottled surface, identical with that of the Parnallee stone, which it resembles also in every other particular, the very pale yellow round spots,

* This is clearly and fully set forth by Professor Maskelyne, in the *Phil. Mag.*, for August, 1876.

sometimes five or six millimeters in diameter, are disseminated through the two alike; and so with the troilite, the globular structure in some parts, and a few specks of a black siliceous mineral; and, by a singular coincidence, the specific gravity of the part I tested is identical with that as made out by Maske-lyne, viz: 3.41. Under the microscope it presents the appear-ance described by the same author.

Chemical examination.—The stony material freed from metal-lic iron, consisted of—

Matter soluble in chlorhydric acid	56.50
Matter insoluble in chlorhydric acid	43.50

Some of the soluble part was composed of troilite, which I could not separate mechanically, but is deducted in the follow-ing analysis:

	Soluble part.	Insoluble part.
Silica	33.65	57.60
Iron protoxide	30.83	11.42
Alumina11	.43
Lime	trace	5.70
Magnesia	34.61	23.97
Chromium oxide38
Soda		1.24
	<hr/>	<hr/>
	99.20	100.74

The portions examined contained nickeliferous iron 5.93 per cent, consisting of:

Iron	90.64
Nickel	8.35
Cobalt73
	<hr/>
	99.72

Mineral constituents of the Cynthiana Stone.—The minerals in this stone are quite easily distinguished by the eye, but are very much more conspicuous under a moderate magnifying power, especially the round and distinct concretions of a light yellow bronzite. The troilite and metallic specks and fila-ments are also easily seen.

No attempt was made to separate the stony minerals in suffi-cient quantity for analysis; quantitative tests were made to distinguish their character. From the chemical examination previously made I deduce the following as about the propor-tion of the mineral constituents:

Olivine minerals	50.00
Bronzite and pyroxenic minerals	30.00
Nickeliferous iron	6.00
Troilite	5.50
Chromé iron52

There were no distinct crystals of minerals visible either to the unaided eye or with a lens.

4. *Remarks on the region where these meteorites fell.*

In the study of the three aerolites just described it is interesting to note the relation of the region where they fell to that of previous falls of recent date.

During a period of less than eighteen years there have been twelve falls of meteoric stones in the United States, of which specimens have been collected. All of these, with one or two exceptions, I have described in detail, and furnished specimens to various cabinets in this country and in Europe.

In grouping together these twelve falls and estimating the amount of meteoric matter accompanying them, I have been struck with the singular fact that eight of them, with over one thousand kilograms of matter, have occurred over the prairie regions of the West, not far from my home; and the extreme limits of these falls is within a region not exceeding one-eighth of the surface of the United States, east of the Rocky Mountains. It may be supposed that one reason for this may be that this region is more thickly populated than others, and consequently that there are more observers. This however is not the case, for the population is not much above the average of the country.

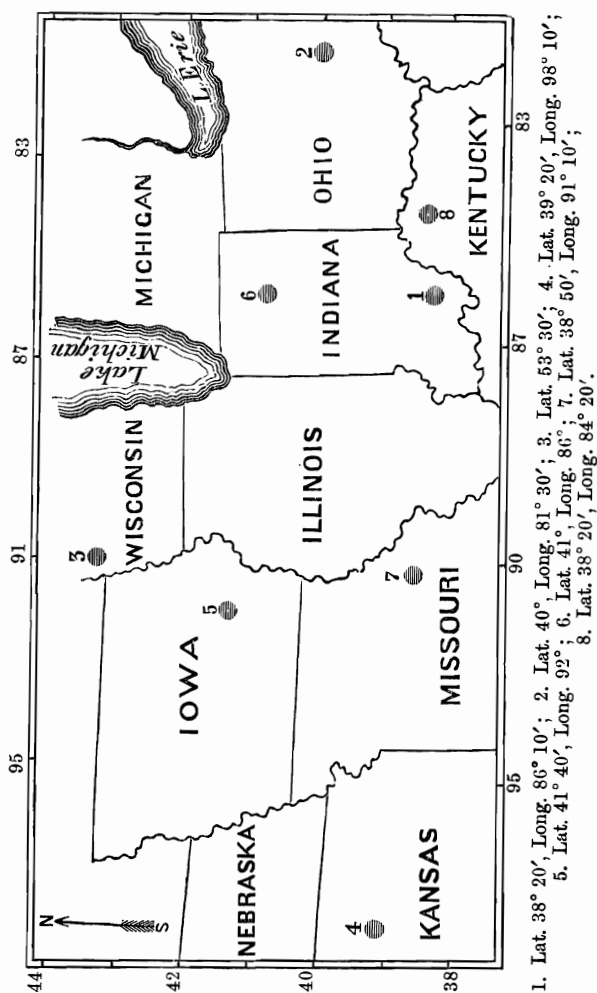
I have made a map of the region (see next page) where these eight falls occurred, which shows at a glance their relative positions. The accompanying table gives a few comparative details in relation to each of them.

No.	Time of Fall.	Place of Fall.	Lat.	Long.	Estimated Weight of Fall.	
1	28th March, 1859	Harrison Co., Ind.	38° 20'	86° 10'	1·	kilo.
2	1st May, 1860	Guernsey Co. (Concord), O.	40	81 30	500·	"
3	25th March, 1865	Claywater (Vernon Co.) Wis.	43 30	91	3·	"
4	Not known, 1874	Wacanda, Kansas,	39 20	98 10	40·	"
5	12th Feb., 1875	Iowa Co., Iowa,	41 40	92	500·	"
6	21st Dec., 1876	Rochester, Indiana,	41	86	40	"
7	3d Jan., 1877	Warrenton, Missouri,	38 50	91 10	10·	"
8	23d Jan., 1877	Cynthiana, Ky.	38 20	84 20	6·	"

Total, 1060·40 kilos.

There have been four other falls in the United States during the same period; but the aggregate weight of them is less than two kilograms. They occurred respectively. Nov. 28th, 1868, lat. 34° 30', long. 87°; Dec. 9th, 1868, lat. 34° 30', long. 87° 50'; Oct. 6th, 1869, lat. 32° 10', long. 85°; May 21st, 1871, lat. 44° 30', long. 69° 10'.

Again: in this region more bolides have recently been observed than in any other. Professor Kirkwood has described,



as seen by him and others, eight from July, 1876, to February, 1877, the stones from three of them are those described in this paper, the others left no evidence of their passage. By personal observation I have noted, in the last two or three years, three splendid bolides, that were seen to burst in the sky, but of which no fragments were found; these I have described, and still others have been described to me by several observers. It is a still more striking circumstance, that, in the past sixty

years, there have been twenty well noted falls of meteoric stones; and of these just one half have fallen within the region mapped by me as including the eight falls of the past eighteen years; and the weight representing them is nearly twelve hundred kilograms—an amount twenty times greater than that of the other ten falls scattered over various regions.

I have mentioned this singular fact not that it has any cosmical significance, but simply as a part of the record I keep of my observations and study of these curious links between heaven and earth. Before very long I hope to put together my more recent speculative studies in regard to these bodies.