The Meteoric Iron of Tucson.

By L. Fletcher, M.A., F.R.S. (General Secretary),
Keeper of Minerals in the British Museum.

[Read March 18th, 1890.]

1. TWO large masses of meteoric iron, which have been removed from Tucson, are now preserved, the one at Washington, the other at San Francisco. According to Lippincott's Gazetteer, Tucson is "a post-town, capital of Pima County, Arizona, U.S.A., on the Rio Santa Cruz, and on the Southern Pacific Railroad, about 250 miles east of Yuma. It was founded in the year 1560 by the Jesuits. It contains a church, the Institute of St. Joseph, two free schools, a bank, a newspaper office, a court-house, a United States depository, many stores, and two flour mills. The population in 1880 was 7,007."

Le Conte.

2. Attention was called to the iron of Tucson by Dr. John L. Le Conte of Philadelphia, a distinguished entomologist, in an oral statement made by him at a meeting of the American Association for the Advancement of Science, held at Albany in August 1851. Two accounts of this statement have been published. According to the first and brief official account,[1] Dr. Le Conte, "while passing through the village of Tucson in the preceding February, had observed two large pieces of meteoric iron in use by the blacksmiths of the town as anvils." They were irregular in form; and although imbedded in the ground to make them steady for use, they were about three feet high. Notwithstanding the offer of a high price, "he was unable to get any bits broken from the anvils, but was guided to a cañon between two mountain-ridges in the immediate vicinity, from which both pieces had been taken, where the masses of the meteorites were so abundant as to have given name to the cañon."

In the second and more detailed report[2] of his statement no mention at

[1] *Proc. Amer. Assoc. for Adv. of Sci.*, p. 188.
[2] *Amer. Jour. Sci.*, 1852, ser. 2, vol. 13, p. 289.

all is made of a visit to the cañon, and it is implied that no such visit took place: it is there stated that the pieces "were brought from a valley in a small mountain-chain about forty miles south-east of Tucsan (*sic*), east of the road leading to Tuvaca (*sic*). In this valley, fragments similar to those seen and of various sizes *were said to be* abundant. From the occurrence of this metal, the valley was called *Canada de Hierro* or *Iron Valley*. Silver mines of great richness are very numerous in that vicinity: the metal occurs as sulphuret, with galena and blende, and also in the native form."

3. Did Le Conte really visit the original site of the iron, or is he merely recording hearsay statements? By the following considerations we are led to infer that his oral statement was initially mis-reported, and that no visit was made by him to the *Iron Valley*.

Le Conte was informally attached to Major Emory's party,[1] which was engaged in the survey of the western part of the boundary between the United States and Mexico, and he spent eighteen months in California. Seeing that he was "passing through" Tucson in February 1851, and that he attended the meeting at Albany in August of the same year, it seems certain that his information about the iron was got during his journey home from California.[2] His stay at Tucson would thus probably last only a few hours; and if it had been otherwise he would have been able, by continued appeal, to overcome the indolence of the blacksmiths, and to get the fragments he desired. It is extremely improbable that an entomologist would have turned aside from his route many miles merely to see the masses *in situ*: he must have had less curious companions who would have objected to the delay: while a journey without an escort as defence from the Indians was then extremely dangerous. And if he had ventured so far out of the track he would not have returned without securing an illustrative specimen, and would have given a description of the mode of occurrence and the distribution through the valley. As a matter of fact his reference to the Tucson iron was only a casual one, made after hearing Professor Shepard read a paper relative to a meteoric stone which had fallen at Deal in New Jersey more than twenty years before.

We may thus conclude that the later was the more correct version of Le Conte's original statement, and that he was merely recording information given to him at Tucson.

---

[1] *Smithsonian Report for* 1851, p. 53.

[2] *Amer. Jour. Sci.*, 1854, ser. 2, vol. 18, p. 369.

Bartlett.

4. A year later, in July 1852, the two large masses were seen at Tucson by John Russell Bartlett,[1] then the United States Commissioner for the delimitation of the United States and Mexican frontier.

One, a ring-shaped mass, of which he gives a figure, was in use as an anvil in the blacksmith's shop. He writes as follows :—" It was found about 20 miles distant towards Tubac, and about 8 miles from the road, where we were told are many larger masses. There is another mass within the garrison grounds, of which I did not take a sketch. With much labour Dr. Webb broke off a fragment of this meteorite for the purpose of analysis."

Parke and Shepard.

5. In November 1854,[2] Professor Shepard gave a description of some small fragments, the largest not more than a quarter of an ounce in weight, which had been sent by Lieutenant John G. Parke, of the United States Topographical Engineers, on his return from Sonora. Parke had just been engaged in the survey for a railroad across the continent, and had chipped off the fragments while at Tucson in February 1854 : he was told that there were three masses, though only the two larger ones were seen by him. According to information supplied by Parke " they were found in a cañada of the Santa Rita Mountain, about 25 or 30 miles to the south of Tucson. Two of them were shown to us by the Commandante, both being used as anvils. One lies within the *presidio*, and is of a very peculiar form, being annular and somewhat like a seal-ring of huge proportions. Its exterior diameter is about 3½ feet: its interior about 2 feet. It weighs nearly 1,200 lbs. The other piece is in front of the Alcalde's house. It weighs about 1,000 lbs. and has an elongated prismatic form, serving well the purposes of an anvil. It is partially buried in the soil, but has two feet of its length projecting above the ground. The Alcalde and Commandante would not consent to our removing the masses, even if we had had the means."

The position of the Sierra de la Santa Rita is shown in the map[3] ac-

---

[1] Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora and Chihuahua. New York, 1854, vol. 2, p. 297.

[2] *Amer. Jour. Sci.*, 1854, ser. 2, vol. 18, p. 369. Reports of Explorations and Surveys for a railroad from the Mississippi River to the Pacific Ocean: (Senate Documents): 1855, vol. 2, containing *inter alia* a report by J. G. Parke on Explorations between Doña Ana and Pimas Villages, p. 7.

[3] Reports of Explorations, &c. 1861; vol. 11.

companying the report of the survey made by Parke; it is on the eastern side of the road, and north of Tubac.

Lawrence Smith.

6. Others of the fragments were sent by Parke to Professor Lawrence Smith,[1] and were analysed by him. The historical particulars given by Smith are quoted from information sent to him by Bartlett, and are identical with those published shortly afterwards in Bartlett's work.

Genth.

7. In April 1855[2] Dr. F. A. Genth, of Philadelphia, gave the results of analysis of some pieces of a specimen of the Tucson iron: the specimen had been presented to the collection of the Academy of Natural Sciences of Philadelphia by Dr. Heermann. Though Dr. Genth gave no history of the specimen, there can be no doubt that it was one of the fragments referred to by Parke, for Dr. A. L. Heermann[3] was the naturalist attached to that section of the Survey of the Pacific Railroad Route, on which Parke was engaged, and both were at Tucson together.

Michler.

8. The Tucson iron was seen by Lieutenant Michler[4] during a visit made in June 1855: he merely states that "a fine specimen of meteoric iron brought from the Santa Rica is to be seen at Tucson, and is used as a blacksmith's anvil. It is massive and quite malleable." Michler, who also belonged to the United States Topographical Engineers, was in charge of a surveying party under Emory, the successor of Bartlett, in connection with the United States and Mexican boundary: his party was encamped close to Tucson for nearly a month, and during that time received every attention and civility from Captain Garcia, who commanded the place. According to Michler, Tucson was then "inhabited by a few Mexican troops and their families, together with some tame Apache Indians. It is very prettily situated in a fine fertile valley at the base of the Sierra de Santa Catarina." From Tucson Michler went on to Los Nogales, sixty-nine miles to the south of it: "the road lay in the valley of

---

1 *Amer. Jour. Sci.*, 1855, ser. 2, vol. 19, p. 161. (The greater part was read before the Amer. Assoc. Adv. of Sci. in April 1854.)

2 *Proc. Ac. Nat. Sc. Phil.*, 1856, vol. 7, p. 317.

3 *Ibid.*, p. 129; *Smithsonian Report for* 1854, p. 84.

4 *Rep. of the U.S. and Mex. Bound. Sur.* (W. H. Emory), 1857, vol. 1, part 1, p. 118.

the Santa Cruz as far as the Rancho de las Calabazas between high mountains. On the east are the Santa Catarina, with its top covered with lofty pines, and the Santa Rita rich in minerals: and on the west are the Sierra Rica and the Sierra Atacosa." Calabazas is shown on the maps as on the side of Tubac more remote from Tucson: the distance by road from Tucson to Tubac is 48½ miles, from Tubac to Calabazas 13 miles.

Comparison of the above statements.

9. Owing to the surveys of the Mexican boundary and Pacific Railroad Route, the masses of iron at Tucson were thus seen and noticed within the short space of the four years, 1851-55, by Le Conte, Bartlett, Parke and Michler, but the original site was visited by none of them: their information as to its position is hearsay, and was doubtless communicated in turn to each of them, either by the Mexican Commandante or the Tucson blacksmiths: their statements are in all probability merely different versions of a single original. According to their various accounts the site is about 40 miles south-east of Tucson, and east of the road leading to Tuvaca (Le Conte): about 20 miles distant towards Tubac and about 8 miles from the road (Bartlett): about 25 to 30 miles south of Tucson in the Santa Rita Mountain (Parke): in the Santa Rica (Michler).

10. (1) All these statements agree in placing the site to the south of Tucson: (2) the three which specify the distance agree tolerably well with each other: (3) as according to Michler the Santa Rita is east of the road leading to Tubac, the only two which specify the side of the road agree in making it east (Le Conte and Parke): (4) the only disagreement is thus presented by Michler's statement that the iron was brought from the Santa Rica, for Sierra Rica is said by him to be on the west of this road. It will be conceded, however, that Rica is here a misprint for Rita: the two words appear close together in Michler's report, rendering such a misprint easy; this view is confirmed by the remark that Michler in the preceding sentence mentions, not Santa Rica, but Sierra Rica and Santa Rita: indeed the association of the words Santa and Rica (Holiness and Riches) is an unlikely one, while that of Santa and Rita is not uncommon. Further we may add that Michler speaks of Santa Rita as being rich in minerals, which accords with the character given to the locality of the cañon in the second version of Le Conte's statement.

11. We infer that in the years 1851-5 it was stated by the Mexican Commander of the fort at Tucson that the masses had been brought from a cañon in the Santa Rita, that the cañon was reached by travelling along the road from Tucson towards Tubac for a distance of 20 or 30 miles, and by then turning off in an easterly direction for about 8 miles: further, that the district was rich in silver minerals.

Irwin and Ainsa.

12. When the survey was concluded (1856) the boundary between the United States and Mexico was transferred about seventy miles to the south of Tucson, and the town passed into the possession of the United States. Soon afterwards, in 1857, Dr. B. J. D. Irwin, Surgeon in the United States Army, who was stationed at Fort Buchanan, south of Tucson, found the annular mass in one of the by-streets half buried in the earth; and, no person claiming it, he publicly announced that he took (nominal) possession of it with the intention of forwarding it to the Smithsonian Institution. In 1860 the mass was sent, by the agency of Mr. Agustin Ainsa as far as Hermosillo, and later to Guaymas, a port of Sonora in the Gulf of California: in 1863 it was taken to San Francisco by Jesus M. Ainsa, and thence by Santiago Ainsa to the Smithsonian Institution at Washington by way of the Isthmus of Panama.

In a letter dated Sept. 5, 1863, sent to Mr. Henry, the Secretary of the Smithsonian Institution, Dr. Irwin[1] says:—"The only history I can give you is a vague one, as there is no written record of its advent in Tucson. The old inhabitants of that place all agree that it was brought thence from the Santa Catarina mountains, which lie to the north of Tucson, about midway between the Rio San Pedro and that town. It was brought in by the military stationed at the old *presidio*, where it remained until after the withdrawal of the Spanish garrison. It was then taken into town, set up on end, and used as a kind of public anvil for the use of the inhabitants. The smaller one was used in a blacksmith's forge for similar purposes." "The people of Tucson all agree that a shower of these meteorites fell in the Santa Catarina mountains some two hundred years ago, and I have been told that there were plenty of them remaining in the mountains. I never was in the immediate portion of the mountain-range where they report the specimens are to be found, so I cannot vouch for the correctness of their reports."

13. In another letter, dated August 26, 1863, sent likewise to Mr. Henry in response to an inquiry for information, Mr. Santiago Ainsa makes the following statements[2]:—"The history of this aerolite we have from our grandmother, Doña Ana Anza de Islas, daughter of Don Juan Bautista Anza, our great-grandfather. The Jesuit missionaries had the

---

[1] *Smithsonian Report for* 1863, p. 85. [2] *Ibid.*, p. 86.

earliest knowledge of this curiosity. There were various theories entertained about it; but it was generally believed to proceed from some iron-mine in the vicinity, which belief holds to this day in Sonora. In an expedition made by Don Juan Bautista Anza, then 'Gran Capitan de las Provincias del Occidente,' about the year 1735, to the country about Tucson, he was induced to visit the aerolite, and he undertook the work of transporting it to Spain. The place where it was found is called *Sierra de la Madera*, on a spot called *Los Muchadios*. Through the want of proper means and the bad state of the roads (having to carry it to San Blas, then the nearest port of entry) the work of transportation was given up, and they were satisfied to take it as far as Tucson."

14. In another part of the same Report[1] the name of the place is given by the Secretary, on the basis of Mr. Ainsa's letter, as *Los Muchaches*, in the *Sierra Madre*. As both statements are founded on the same letter, one or other or both of the words *Muchaches* and *Muchadios* must be the result of an error of printing, and inspection of the written words makes it clear that the variation could very easily arise in such a way: as *Muchadios* is not given in the Spanish dictionary, and *Muchachos* is the ordinary Spanish word for "boys," and as the names of Mexican localities have generally a simple Spanish interpretation, it is most satisfactory to regard both as misprints, and to take the *ch* of one version and the *os* of the other, thus adopting *Los Muchachos* as the correct spelling. On the other hand *Sierra Madre* is probably a misinterpretation of *Sierra de la Madera*: it is clearly not a mere misprint. Sierra Madre (or Mother Range) is the name given to one of the principal mountain-ranges, extending for hundreds of miles through Mexico and the United States: and in his interpretation of the Ainsa letter, Mr. Henry would appear to have taken the unknown name *Sierra de la Madera* to be merely another mode of writing *Sierra Madre*. Such a term would be too wide in its signification to have had any utility in the indication of a locality. But there is a common Spanish word *Madera* meaning *timber*: so that *Sierra de la Madera* might be a name given to any well-timbered mountain-range. That such a name would, up to 1855 at least, be peculiarly appropriate to the range on the east of the road leading from Tucson to Tubac is evident from the description given by Michler:—"On the east are the Santa Catarina, with its top covered with lofty pines, and the Santa Rita rich in minerals." In 1777, according to the Tucson archives,[2] there was an abundance of excellent pine in the Sierra de Santa Rita itself.

[1] *Ibid.* p. 56.

[2] *Reports of Explorations and Surveys, &c.*, 1857, vol. 7, appendix C.

15. This view is fully confirmed by a statement read by Professor Whitney[1] at San Francisco on July 20, 1863. He quotes a memorandum furnished by "Mr. James M. Ainsa," which, though identical in its general information with the letter dated August 26, 1863, sent by Mr. Ainsa direct to Mr. Henry, is so far distinct from it as to be an undoubtedly independent document. *Los Muchachos* is not mentioned at all, but the name of the mountain-range appears as *Sierra de la Madera.*

Comparison with the previous statements.

16. *Sierra de la Madera* is not mentioned on any accessible map, and Ainsa himself gives no information as to whether the site is north or south of Tucson. Still his letter would indirectly suggest that the place is to the north of Tucson, since he states that the iron was being transported to the port of San Blas, and therefore southward. Irwin, for his part, directly states that the masses were brought from the north of Tucson.

The only explanation which will bring into harmony these two statements and that which has reached us through Le Conte, Bartlett, Parke and Michler, seems to be the following:—As regards Ainsa's statement: the transportation to San Blas was a matter of difficulty, so much so that it was eventually abandoned; hence the masses may have been found to the south of Tucson, transported to the Tucson and Tubac road, and afterwards along it in the direction opposite to that of San Blas, either when the idea of transport had been finally given up, or when it was decided to wait for better means of carriage; the masses in such case being taken northwards and preserved in the neighbouring *presidio* of Tucson. As for Dr. Irwin, a glance at the wording of his statement makes it probable that he was merely told by the inhabitants of Tucson that the masses had been brought from the Santa Catarina mountains, and that he himself added the information that the mountains are to the north of Tucson, about midway between the Rio San Pedro and that town. In fact the only Sierra de Santa Catarina mentioned in various maps is in the position thus indicated by Irwin. But a reference to Michler's report shows that, at least in 1855, the term Sierra de Santa Catarina was by some persons differently applied: Michler speaks of Tucson as being "very prettily situated in a fine fertile valley at the base of the Sierra de Santa Catarina," and in describing his journey from Tucson to Tubac says that "the road lay in the valley of the Santa Cruz between high mountains. On the east are the Santa Catarina and the Santa Rita."

[1] *Proc. Calif. Ac. Nat. Sc.*, 1863, vol. 3, part 1, p. 48.

Further, on more than one map the Sierra de Santa Catarina is marked as extending from the north side of Tucson to the south of Tubac.[1] The information given by Irwin is thus not inconsistent with the former statements, if we may assume that he had misapprehended what was intended to be meant by the term "Santa Catarina mountains."

Velasco.

17. The correctness of the above arguments is established by the following paragraph from a work published by Velasco[2] in the year 1850, a date antecedent to that of any of the publications above referred to; as Velasco's work is not easily accessible the paragraph is also given in the original Spanish:—[3]

"Between the presidio of Tucson and Tubac is a mountain-range called Sierra de la Madera and (a pass called) Puerto de Los Muchachos. In it are seen enormous masses of native iron, and many have rolled to the foot of the said sierra. One of the masses of a moderate size was transported to Tucson, and has stood for many years in the *plaza* (square) of the said presidio."

Scarcely a single map gives any information relative to the region adjacent to Tucson and Tubac: but in Stieler's Atlas the southern part of the range on the eastern side of the road between Tucson and Tubac is designated Sierra de la Santa Rita, and a pass running in an easterly direction at the north side of this sierra is marked as Puerto de los Muchachos. The map is based on the observations of Captain A. W. Whipple, of the United States and Mexican Boundary Commission: he travelled through the Puerto de Los Muchachos in 1853, and his route is indicated in Parke's map already referred to.

Whitney.

18. Professor Whitney of San Francisco (who cites an English translation of Velasco's work, published in 1861), summarising the contents of various letters sent to him, said on February 19, 1866[4]:—

---

[1] e.g. *Nueva Mapa de Mexico*, 1866. Pub. por Colton & Co., New York, U.S.A.

[2] *Noticias Estadisticas del Estado de Sonora, &c.* By Jose Francisco Velasco. Mexico, 1850, p. 221.

[3] "Entre el presidio del Tucson y Tubac, hay una sierra que llaman de la Madera y puerto de los Muchachos. En ella se ven masas enormes de fierro vírgen, y muchas están rodadas al pié de dicha sierra. De aquellas masas de fierro llevaron una mediana al Tucson, la cual hace muchos años cesiste tirada en la plaza de dicho presidio."

[4] *Proc. Calif. Ac. Nat. Sc.*, 1866, vol. 3, part 3, p. 241.

"It is stated by several persons who have visited southern Arizona, among whom Dr. Horn may especially be mentioned, that it is universally believed, and vouched for by apparently trustworthy explorers, that there are many large masses of iron near the summit of the range next east of Tucson."

19. One odd conclusion follows from the above; namely, that Dr. Irwin was actually stationed in the immediate neighbourhood of the true locality: for Fort Buchanan is on the eastern side of the Tucson and Tubac road, and about 30 miles from Tucson: indeed, it appears to be approached from the Tucson and Tubac road through the Puerto de los Muchachos itself. Hence it would seem that he was only prevented from finding any remaining masses by an unlucky misapprehension of the term "Santa Catarina mountains."

Removal of the masses from Tucson.

20. We have already seen that one of the two large masses, the ring-shaped one figured by Bartlett, was removed from Tucson in 1860, and deposited in the hall of the Smithsonian Institution at Washington in 1863. The other was taken possession of by General James H. Carleton, and sent to San Francisco in the year 1862:[1] Carleton was in command of the Column from California; he presented the mass to the City of San Francisco as a memento of the march of his Column, and asked that it might be "placed upon the Plaza, there to remain for the inspection of the people and for examination by the youth of the city for ever." It was, however, deemed advisable to keep the specimen in a safer and drier place, and it is now in the hall of the Pioneer Society.[2] A figure of the mass, prepared from a photograph sent to him by Professor Whitney, has been published by Haidinger[3].

Form and Dimensions.

21. The dimensions of the ring-shaped mass now at Washington are given by Whitney[4] as follows:—

---

[1] *Proc. Calif. Ac. Nat. Sc.*, 1863, vol. 3, part 1, p. 33.
[2] *Mineral Resources of the United States for* 1883-4 (Williams), p. 290.
[3] *Sitz. Ak. Wien.*, 1863, vol. 48, part 2, p. 303.
[4] *Proc. Calif. Ac. Nat. Sci.*, 1863, vol. 3, part 1, p. 49.

"Greatest exterior diameter	49 inches.
Least exterior diameter	38 inches.
Greatest width of central opening	$26\frac{1}{2}$ inches.
Least width of central opening	23 inches.
Greatest thickness at right angles to plane of ring... ...	10 inches.
Width of thickest part of the ring	$17\frac{1}{2}$ inches.
Width of narrowest part	$2\frac{3}{4}$ inches.
Weight estimated by Ainsa as	1,600 lbs."
An inscription on the specimen now gives the weight as ...	1,400 lbs.

The form of the mass now at San Francisco is described by Whitney as follows:—

"Shape irregular, but in general that of a flattened elongated slab; length, 49 inches; average breadth, 18 inches; thickness varying from 2 to 5 inches. Weight, 632 lbs."

Supposed difference in the characters of the masses.

22. There has been a certain amount of discussion as to whether the two masses are not essentially different in their characters. By a curious coincidence they were both in San Francisco at the same time, and Professor Whitney had the opportunity of directly comparing them. He reports as follows:[1]—

"On examining with a magnifying glass a fractured surface of the ring-shaped iron, it was seen at once to be different in composition from the Carleton meteoric iron, and my conjecture that Professor Smith was mistaken in supposing that he analysed a fragment from the mass figured by Mr. Bartlett was confirmed. It is now almost certain that Messrs. Brush and Smith did analyse fragments of the same mass (the Carleton one)."

23. Though there may still be some doubt as to which mass Professor Smith's fragments were taken from, the doubts which had arisen in the mind of Whitney were the result of a misunderstanding. Smith reproduced the figure of the ring-shaped mass as sketched by Bartlett, who had furnished him with information relative to the iron before the actual publication of the "Personal Narrative": hence Whitney inferred[2] that Smith's analysis was made on the fragments mentioned in Bartlett's work, and those appear to have been got by Dr. Webb from the second mass

---

[1] *Ibid.*, p. 49.
[2] *Ibid.*, p. 34.

(the Carleton one) in the garrison grounds, though Bartlett's statement is wanting in precision. But a reference to Smith's paper shows that this was not the case: the fragments were obtained, not from Webb or Bartlett, but from Parke, who in the report sent to Professor Shepard failed to indicate from which mass they had been taken. Lawrence Smith appears to have been under the impression that they were taken from the ring-shaped mass, and it is possible that he may have received direct information from Parke to that effect.

24. Baron von Richthofen, who was in San Francisco at the time that the ring-shaped mass was in the city, also supported the view of Whitney in a letter published by Haidinger:[1]—"Brush calls attention to the striking agreement of his analysis of the Carleton iron with an analysis made by Lawrence Smith of an iron from Tucson. A comparison of the two meteorites leaves however scarcely a doubt that Bartlett knew both, and that both analyses have been made on pieces of the Carleton mass. The ring-shaped mass has so different a mineral composition that we must infer an important difference in the chemical constituents. Schreibersite and olivine are not observable in it, while on the other hand there is a large number of white and apparently crystalline grains which look like a felspar. Whitney and I came to the conviction that they may be anorthite."

25. After examination of the etched faces, Brezina says:—"The Ainsa iron presents a certain similarity with the Carleton iron, yet not sufficient to allow of their being placed together without further investigation."[2]

The masses are products of a single meteor.

26. With regard to this point, the above history of the Tucson iron is sufficient to establish beyond reasonable doubt that both masses have been brought to Tucson from the same valley, and have resulted from a single meteor. It must be remembered that the observations of Whitney and Richthofen were merely preliminary ones, made on rough fractured surfaces of the masses, and that the fragment of the annular mass available for examination by Brezina weighed only 8 grams, and had probably been more or less hammered at Tucson during its removal from the block. In the British Museum there are now good fragments of both masses, one of them sent from San Francisco many years ago through

---

[1] *Sitz. Wien. Ak.*, 1863, vol. 48, part 2, p. 306.

[2] *Die Meteoriten-sammlung in Wien*, 1885, p. 71.

Professor Whitney, and the other from Washington more recently through Dr. F. W. Clarke. They have been lately polished, and the identity of their essential characters is now manifest: and this identity is one of characters extremely rare in meteoric irons. Masses of iron, like those of Krasnojarsk and Breitenbach, having numerous disconnected pores filled with stony matter, are not frequent among meteorites; but in the case of both of the Tucson masses not only is this a characteristic feature, but in each of them the grains of included silicate are on a much smaller scale than those included in other irons of the same type. The included grains are crystalline, and are identical in aspect. One of the sections is 75 mm. long, and has a width increasing from zero to 50 mm.; the other is 40 mm. long and has a width varying between 44 and 70 mm. Most of the included grains, thousands in number, are only one or two-tenths of a millimeter in diameter, but there are a few of which the thickness reaches a millimeter: their distribution is generally irregular, but in one part of each section they are arranged in parallel slightly curved lines, and are elongated in the same direction. Irregular fields, sometimes 5 or even 8 mm. in diameter, appear at first sight to be free from enclosures, but the presence of microscopic grains is indicated by the punctuation which becomes visible when the polished face is examined with the aid of a lens. No Widmanstätten figures were formed when the polished faces were etched with bromine-water, but over the whole extent of both sections there became visible an irregular network of yellow metallic lines, resembling tænite or schreibersite, and round each enclosure, large or small, was seen a linear margin of the same material.[1]

As it is impracticable to give a special name to every separate mass of a meteoritic fall, the names of Irwin-Ainsa iron, Ainsa iron, Signet iron, Tucson-Ainsa iron, Carleton iron and Tucson-Carleton iron may therefore be advantageously dropped from scientific literature, and the masses be designated simply as Tucson iron.

27. It is thus of trivial importance whether the fragments sent to Shepard, Genth and Smith, were got from the one or the other mass, for different parts of the same mass may present as great variations of mineral constitution as distinct masses belonging to the same fall: the fragment sent to Brush was taken from the mass now at San Francisco.

Specific Gravity.

28. The specific gravity, according to Shepard, is 6·66: according to Smith 6·52, 6·91, 7·13 for three different fragments; his chemical examination was made on the last, which appeared to be the most compact

[1] See also G. Rose's *Beschreibung der Meteoriten zu Berlin;* 1864, p. 150.

and free from stony particles: the specific gravity of a fragment, as determined by Brush, was 7·29.

Chemical analyses made by Shepard, Smith, Genth, and Brush.

29. The examinations made by Shepard, Smith, Genth, and Brush, leave some doubt as to the true nature of the stony matter.

1. After the solution of the metallic portion in *aqua regia*, Shepard found a residue consisting partly of a mealy powder and partly of small ovoidal grains, some of them milk-white, some perfectly limpid, others milky on one side and limpid on the other, and therefore all probably belonging to a single mineral species: he was led to regard the mealy powder as of the same nature as the ovoidal grains, and to infer from general resemblance that the silicate was likely to be identical with that of the Bishopville stone to which he had given the name of *chladnite* (but which is now known as enstatite).

2. Smith separated some few particles of the stony matter mechanically, and from its general appearance when seen with a lens, and from the easy solubility in acids when it yielded silica and magnesia, decided that it was undoubtedly *olivine*. Like Shepard he points out that some of the silicate is in a pulverulent condition.

3. Genth reports as follows:—" On evaporation of the solution by nitric acid, and subsequent moistening of the dry mass by hydrochloric acid, all the substances were taken up excepting a small residue of siliceous matter. This partly dissolved on boiling with carbonate of soda, leaving a residue which I took for a felspathic mineral: the quantity obtained, however, was too small for further examination; the small quantities of alkalies, lime and alumina (in the bulk-analysis) speak in favour of this view, and indicate that the residue insoluble in carbonate of soda is *labradorite*, a mineral which is partly decomposed by acids. The silica, soluble in carbonate of soda, results undoubtedly from the decomposition of *olivine*.'

4. Brush, after examination of the residue left behind when the metallic portion had been dissolved out by nitric acid, gave a description of the ovoidal grains which perfectly agrees with that of Shepard, but remarked that their behaviour before the blowpipe very much resembled that of *olivine*. He further reported as follows:—

" For the quantitative examination a fragment weighing 4·3767 grams was treated with *aqua regia*, and after solution of the iron the whole was evaporated; on approaching dryness, gelatinous silica separated, showing that the silicate had been, partially at least, decomposed by the acid.

After heating until the silica was rendered insoluble, it was repeatedly treated with acid and evaporated, so as to insure the oxidation of all the schreibersite ; and finally the soluble part was taken up with hydrochloric acid, and on dilution separated from the silica and insoluble residue. The insoluble residue, containing free silica and undecomposed silicate, was perfectly white and free from all traces of schreibersite. It weighed 0·1855 grm. It was fused with carbonate of soda, and the silica and bases determined in the usual manner. It yielded :—

SiO_2	0·1590
FeO	0·0054
Al_2O_3	minute trace
CaO	0·0028
MgO	0·0168
	0·1840."

Analytical results.

30. It will be convenient to insert here the following complete analytical results of Smith, Brush, and Genth :—

	Smith.	Genth. I.	Genth. II.	Genth. III.	Brush.
Fe	85·54	83·47	not est.	83·64	81·65
Ni	8·55	9·44	8·69	9·85 (Ni + Co)	9·17
Co	0·61	0·42	0·37		0·44
Cu	0·03	0·008	not est.	not est.	0·08
P	0·12	0·10	not est.	0·15	0·49
Al_2O_3	trace	trace	trace	trace	trace
CaO	...	0·46	0·55	not est.	1·16
MgO	2·04	2·59	2·03	2·15	2·43
Na_2O	...	not est.	not est.	0·174	...
K_2O	...	not est.	not est.	0·098	...
Cr_2O_3	0·21	not est.	not est.	0·50	...
SiO_2	3·02	2·89	not est.	4·17 (SiO_2 + Labradorite)	3·63
Labradorite (?)	...	1·05	not est.		...

Deductions from the analytical results.

31. Whatever the true nature of the stony matter, the grains included in the iron are obviously very different in size; and unless the action of the acid has been very prolonged the larger grains, whatever their nature, may escape complete decomposition: hence an opinion that the residual silicate is more difficultly decomposed than olivine, based solely on the incomplete decomposition of the stony matter by the acid, must in any case be received with caution.

a. "The general resemblance" and the "presence of decided traces of magnesia in the acid solution," relied upon by Shepard as supporting the view that the stony matter is possibly identical with that of the Bishopville stone, are obviously characters of no great weight.

b. Smith considered the stony matter to be olivine: his experiments undoubtedly prove that the particles, separated by him mechanically, differed from the Bishopville silicate in being easily decomposed by acids: still he only proved the presence of magnesia and silica as constituents, and left it undecided whether more than one kind of stony material is included in the iron.

c. Genth inferred from his experiments that the stony matter consists largely of olivine, but that there is an appreciable proportion of a felspathic material, probably labradorite. The first inference is based on the amount of silica set free through the action of the acid; the second on the presence of material undecomposed by the acid, and on the small quantities of alkalies, lime and alumina found in the acid solution. The presence of labradorite cannot, however, be regarded as established by him: in the first place, no evidence is adduced that the undecomposed material differs from that which has been decomposed; and in the second place, if the alkalies and lime found in the acid solution had been due to labradorite, they would have been accompanied by more than a trace of alumina.

d. In fact, Brush (who was probably unaware of Genth's analysis) came to the conclusion that the undecomposed silicate, obtained in the course of his own examination, was olivine. His analysis of the mixed silica and undecomposed silicate was imperfect in that a separation of the two substances was not made: still the numbers obtained are of value in deciding on the nature of the residue. The constituents are those of either olivine or bronzite, and are not those of a felspar. If the substanc be an olivine ($2R''O.SiO_2$), the amount of silica combined with the base will be 0·0188, and the composition will be as follows :—

	Undecomposed Silicate.		Olivine of Fogo I. (Deville).[1]	Olivine of Imilac (von Kobell).[2]	Olivine of Krasnojarsk (Berzelius).[3]
	Determin'd Weights.	Percentage Composition.			
SiO_2 ...	[0·0188]	[42·92]	40·19	40·79	40·86
FeO ...	0·0054	12·33	15·27	12·10	11·72
MnO ...	...	...	2·27	...	0·43
CaO ...	0·0028	6·39	5·12	...	...
MgO ...	0·0168	38·36	35·70	47·05	47·35
Al_2O_3 ...	trace	trace	0·80	0·02	...
	[0·0438]	[100·00]	99·35	99·96	100·36

It must be remembered that according to this calculation the percenta composition of the undecomposed material is based on the analysis of on 0·0438 grams.

The similarity of the numbers thus obtained to those which characteri certain terrestrial and meteoritic olivines will be obvious from the abo table.

32. The bulk-analyses made by Smith, Genth and Brush, all indica that a basic silicate is present : the proportion of the lime and magne to the silica is alone sufficient to prove the presence of a silicate mo basic than enstatite ; and as the stony matter certainly contains ferro oxide as well as lime and magnesia, the basicity of the stony matter considerable. Hence, we may take it that there is absolutely no dou that the stony matter consists very largely, at least, of olivine ; and th so far there is no valid proof of the presence of any other kind of silica

If there is only one kind of silicate (an olivine) present, its compositi can be determined from each of the bulk-analyses ; and the results oug to correspond with each other and with that deduced for the undecompos residue analysed by Brush.

---

1 *Zeitsch. d. deutsch. geol. Gesell.* 1853, vol. 5, p. 693.
2 *Corresp. Bl. zool. min. Vereines in Regensburg*, 1851, p. 112.
3 *Pogg. Ann.* 1834, vol. 33, p. 134.

The following results are obtained by calculation :—

	Smith.	Genth.	Brush.
SiO_2 ...	34·87	36·58	35·94
MgO ...	23·56	28·61	24·06
FeO ...	[41·57]	[24·94]	[28·52]
CaO ...	—	6·46	11·48
Na_2O ...	—	2·15	—
K_2O ...	—	1·26	—
	100·00	100·00	100·00

The numbers differ considerably, but are deduced from analyses which are evidently incomplete : in the analysis made by Brush the alkalies were probably not looked for, owing to the insufficiency of the material: the same may be said of Lawrence Smith's analysis, with the addition that the lime, also having escaped notice, has been either lost, or weighed along with the iron or magnesia.

Mineralogical interpretation of the analytical results.

33. It seemed that in the case of analyses made by such experienced chemists as Lawrence Smith, Genth and Brush, it ought to be possible, notwithstanding the differences in their numerical results (§ 30), to find a mineralogical interpretation which will agree with the analyses within the ordinary limits of experimental error: we have to remember that the meteoritic fragments are mixtures of different minerals, and that the proportions of the latter may be more or less variable.

34. The following is offered as a satisfactory solution of this problem :—

(*a.*) The meteorite is a mixture of nickel-iron, olivine, schreibersite and chromite : the composition of the nickel-iron being :—

Iron	89·89
Nickel	9·58
Cobalt	0·49
Copper	0·04
	100·00

and that of the olivine :—

			Oxygen.	
FeO	... ...	24·07	5·35	19·44
MgO	... ...	27·37	10·85	
CaO	... ...	8·67	2·48	
Al_2O_3	... ...	trace	...	
Na_2O	... ...	2·15	0·55	
K_2O	... ...	1·26	0·21	
SiO_2	... ...	36·48	...	19·44
		100·00		

The schreibersite and chromite, which are relatively small in quantity, may be assumed to have the average composition indicated by the formulæ Fe_2 Ni P (Fe 55·53, Ni 29·09, P 15·38) and $FeO{\cdot}Cr_2O_3$ (FeO 32·11, Cr_2O_3 67·89).

(*b.*) The proportions of the mineral constituents vary throughout the masses: this is obvious to the unassisted eye, and the extent of the variation is shown by the differences of specific gravity: for the fragments analysed by Lawrence Smith and Brush, and the fragment I. analysed most completely by Genth, the proportions were as follows:—

		Smith.	Genth.	Brush.
Nickel-iron	...	90·64	90·03	86·24
Olivine	...	8·29	8·60	10·05
Schreibersite	...	0·77	0·64	3·18
Chromite	...	0·30	0·73	0·53
		100·00	100·00	100·00

35. The agreement of the calculated and observed results is shown in the following tables:—

LAWRENCE SMITH.

	Nickel-iron.	Olivine.	Schreibersite.	Chromite.	Total.	Calculated.	Observed.	Differences.
Fe	81·48	1·55	0·43	0·08	83·54	85·54	85·54	0
O	..	0·44	..	0·02	0·46	0·47	..	..
Ni	8·68	..	0·22	..	8·90	9·11	8·55	−0·56
Co	0·44	..	..	..	0·44	0·45	0·61	+0·16
Cu	0·04	..	..	..	0·04	0·04	0·03	− ·01
P	..	..	0·12	..	0·12	0·12	0·12	0
Cr_2O_3	..	..	..	0·20	0·20	0·21	0·21	0
MgO	..	2·27	..	..	2·27	2·33	2·04	− ·29
CaO	..	0·72	..	..	0·72	0·74	..	..
Na_2O	..	0·18	..	..	0·18	0·19	..	..
K_2O	..	0·10	..	..	0·10	0·10	..	..
SiO_3	..	3·03	..	..	3·03	3·10	3·02	− ·08
Total ..	90·64	8·29	0·77	0·30	100·00	102·40	..	..

GENTH.

	Nickel-iron.	Olivine.	Schreibersite.	Chromite.	Total.	Calculated.	Observed.	Differences.
Fe	80·93	1·42	0·35	0·18	82·88	83·47	83·47	0
O	..	0·40	..	0·05	0·45	0·45	..	..
Ni	8·62	..	0·19	..	8·81	8·87	9·44	+0·57
Co	0·44	..	..	..	0·44	0·44	0·42	— ·02
Cu	0·04	..	..	..	0·04	0·04	0·01	— ·03
P	..	..	0·10	..	0·10	0·10	0·10	0
Cr_2O_3	..	..	..	0·50	0·50	0·50	0·50	0
MgO	..	2·07	..	..	2·07	2·09	2·59	+ ·50
CaO	..	0·65	..	..	0·65	0·66	0·46	— ·20
Na_2O	..	0·16	..	..	0·16	0·16	0·17	+ ·01
K_2O	..	0·10	..	..	0·10	0·10	0·10	0
SiO_2	..	2·76	..	..	2·76	2·78	2·89	+ ·11
Undecomposed	..	1·04	..	..	1·04	1·05	1·05	0
Total ..	90·03	8·60	0·64	0·73	100·00	100·71	..	..

BRUSH.

	Nickel-iron.	Olivine.	Schreibersite.	Chromite.	Total.	Calculated.	Observed.	Differences.
Fe	77·52	1·88	1·77	0·13	81·30	81·65	81·65	0
O	..	0·54	..	0·04	0·58	0·58	..	..
Ni	8·26	..	0·93	..	9·19	9·23	9·17	—0·06
Co	0·42	..	..	..	0·42	0·42	0·44	+0·02
Cu	0·04	..	..	..	0·04	0·04	0·08	+0·04
P	..	..	0·48	..	0·48	0·48	0·49	+·01
Cr_2O_3	..	..	..	0·36	0·36	0·36	trace	..
MgO	..	2·75	..	..	2·75	2·76	2·43	— ·33
CaO	..	0·87	..	..	0·87	0·88	1·16	+ ·28
Na_2O	..	0·21	..	..	0·21	0·21	..	..
K_2O	..	0·13	..	..	0·13	0·13	..	..
SiO_2	..	3·67	..	..	3·67	3·69	3·63	— ·06
Total ..	86·24	10·05	3·18	0·53	100·00	100·43	..	..

(Since the whole fragment analysed by Brush weighed 4·3767 grams, the composition of the stony matter is based on the analysis of 0·4399 grams.)

Summary.

36. The differences in the statements of Le Conte, Bartlett, Parke, Michler, Irwin, and Ainsa, relative to the original site of the meteoritic masses of Tucson, are all such as might easily result from simple errors of printing or interpretation: the masses have been known for centuries: they were found in a pass called *Los Muchachos*, which is between Tucson and Tubac, and is on the eastern side of the road: other masses of various sizes are said to be still in the pass. The results of the analyses made by Smith, Genth and Brush, show that, besides small proportions of schreibersite and chromite, there is a varying proportion (8 to 10 per cent.) of stony matter included in the nickel-iron: they are consistent with the stony matter being a lime-olivine, having approximately the per-centage composition FeO 24·07, MgO 27·37, CaO 8·67, Na_2O 2·15, K_2O 1·26, and SiO_2 36·48, and with the nickel-iron being composed of Fe 89·89, Ni 9·58, Co 0·49 and Cu 0·04.