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The Meteorites of Uwet, Kota Kota, and Angela: re-determinations of nickel and iron in the Baroti and Wittekrantz meteoric stones.[1]

(*With Plates V and VI.*)

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[Read June 16 and November 10, 1914.]

1. The Meteoric Iron of Uwet, Southern Nigeria.

EARLY in 1905 a small fragment of a meteoric iron from Uwet in Southern Nigeria was received at the Imperial Institute from Mr. John Parkinson, the Principal of the Mineral Survey then proceeding in Southern Nigeria. The fragment was part of a large mass which was held in great veneration by the natives of Uwet (lat. 5° 17′ N., long. 8° 15′ E.), a town on the Calabar river, about 23 miles north by west of Calabar. Later, further particulars of the meteorite were communicated to the Imperial Institute by Mr. E. D. Simpson. According to Mr. Simpson's report, dated March 30, 1907: 'About eighty years ago a meteorite fell at Uwet causing considerable consternation. A large hole was noticed but was not probed. The same day a second fell which is the one in question. In this case it was dug up and preserved. No further details are remembered. The time of year was about June or

[1] Communicated by permission of the Trustees of the British Museum.

Fig. 1.

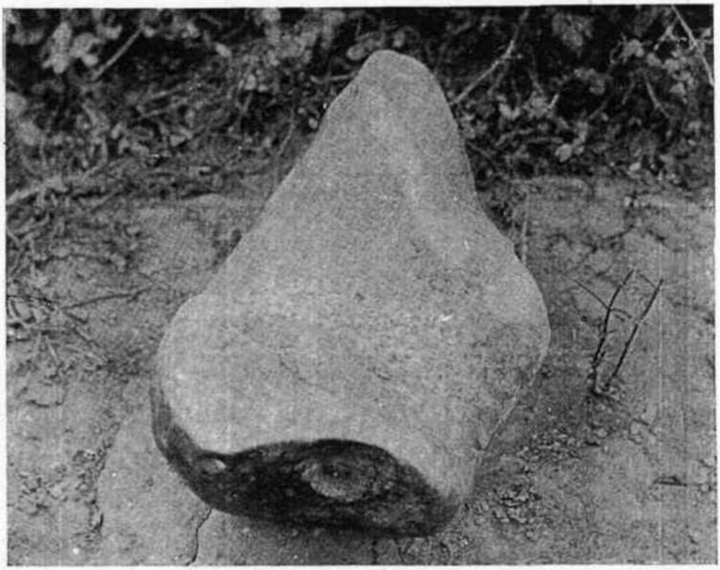

Fig. 2.

G. T. Prior: The Meteoric Iron of Uwet, Southern Nigeria.

May—the end of the tornado season. The stone is not "juju," but is bound up in the general welfare of the town. In 1903 it was removed from Uwet. Smallpox, however, broke out and devastated the town, which was attributed to its absence. The stone was returned to Uwet, since when, I am informed, the town has been entirely prosperous.'

The mass was of irregular shape, as shown in the photographs (Plate V, figs. 1 and 2). Mr. Simpson gave the following measurements: circumference, lengthways 3 ft. 6 in., breadthways 1 ft. 9 in.; length about 1 ft. 3 in.; breadth about 9 in. The weight was estimated to be 120 lb.

At the suggestion of Dr. L. Fletcher, at that time Keeper of the Mineral Department of the British Museum, to whom the fragment had been submitted for examination, request was made by the Director of the Imperial Institute, Prof. W. R. Dunstan, to the authorities in Southern Nigeria that, after friendly arrangement with the natives, a corner should be sawn off the meteoric iron for preservation and examination. This request was acceded to, and a portion of the meteorite weighing about 20 lb. was forwarded to the Imperial Institute. In February 1908, through the kindness of Prof. Dunstan, the mass was transferred to the British Museum as a donation from the Governor of Southern Nigeria.

Physical Characters.

The specimen sawn from the original mass was a roughly conical piece having a height of about 4 inches and an oval base of 6 to $6\frac{3}{4}$ inches diameter. Its surface is smooth and rounded, and is only partially covered with a thin black film of oxide. The iron is bright, shows no signs of weathering, and is free from large inclusions. On the polished surface of the base are seen about ten small inclusions of troilite, the largest of which does not exceed 16 mm. in length and 4 mm. in breadth. Schreibersite (rhabdite) is distributed uniformly over the slice in fine needles up to a centimetre in length. These are mostly parallel to one direction, but a few occur parallel to a direction nearly at right angles, and a third set of shorter needles, still less prominent, at an angle of about 24° with the direction of the first set. Etching with bromine of a small polished slice of the iron developed Neumann lines to perfection. The slice was densely covered with sets of fine parallel lines. Two sets are most prominent, traversing the slice from side to side and inclined to each other at about 30°. One of these is inclined to the main set of schreibersite needles at an angle of about 54°, and the other is parallel to the shorter needles. A third set of shorter etched lines in places cuts the first two sets at angles of about 80° and 70° respectively, and a fourth set, much less distinct, can be faintly distinguished cutting the third set at about 26°. The iron thus belongs to the normal hexahedrite group, of the type of Braunau.

The density of a piece of the iron, weighing about 20 grams and as free as possible from troilite, was 7·862.

Chemical Composition.

For the chemical analysis, about 8 grams of the iron free from troilite was dissolved in aqua regia, filtered from a slight residue of carbonaceous matter and divided into five equal portions. In one of these portions the nickel was determined by precipitation with dimethylglyoxime; in another the iron was separated from the nickel and cobalt by a double precipitation with sodium acetate, and the nickel from the cobalt by means of dimethylglyoxime. The result of the analysis is as follows:

Fe	93·36
Ni	5·78
Co	0·75
Cu	nil
P	0·25
Carbonaceous matter ...	0·03
	100·17

The meteoric iron of Uwet is a hexahedrite of the Braunau type, showing, on etching, well-marked Neumann lines, and having a chemical composition approximating to $Fe_{14}Ni$, and a density of 7·862.

2. The Meteoric Stone of Kota Kota, Marimba district, British Central Africa.

In 1905, besides the meteoric iron from Uwet, the Imperial Institute received from Africa a stone said to be of meteoric origin. The specimen was sent by the Acting Commissioner for British Central Africa, who stated that it fell some years previously in the Marimba district, British Central Africa, where it was found by the District Commissioner, and that the original stone had since been broken up by the natives. Through the kindness of Prof. Dunstan, the specimen was transferred to the British Museum as a donation from Mr. A. J. Swann, the magistrate of the Marimba district, who had obtained the specimen from the natives. According to information supplied by Mr. Swann in answer to inquiries made by Dr. Fletcher, some natives with whom he was conversing about meteorites in order to ascertain if any were known to them, said: 'There was a large one in our district, but that, as it was God's stone and came from the air, it was kept a secret by a Chief and protected.' Mr. Swann was a year in trying to locate the stone, but at last succeeded in inducing two natives to make a journey of 95 miles to fetch it. They returned with the specimen lashed to a pole and said that it was only a piece of the original stone which fell. Nothing would induce them to touch it, and when Mr. Swann suggested that it was simply an ordinary piece of country rock they said: 'Master, do not disbelieve us. We have done our journey as you must know, and that stone is a piece of the great stone which every one knows fell near our villages but which is not to be taken away by any one. We went because you say you are not afraid of our spirits. Take care of it.' The precise locality in the Marimba district where the stone fell was given by Mr. Swann as Kota Kota, Lake Nyasa (lat. 12° 55′ S., long. 34° 18′ E.).

The specimen, which weighs 333 grams, is much weathered and rusted, but has the appearance of being a nearly complete stone rather than a fragment broken from a larger one. It is of irregular shape and shows on certain faces traces of the original black fused crust. One smooth corner where three somewhat concave faces meet is preserved intact, but the other corners of the stone have been broken off and show a 2 mm. thick layer of hard rust. Small sharply defined chondrules are seen projecting from the surface in several places. A thin slice shows numerous small sharply defined chondrules and sections of pyroxenes in a rusted matrix. Most of the larger chondrules are of fibrous radiating rhombic pyroxene, but the smaller ones consist mainly of grains of a pyroxene which shows a well-marked longitudinal cleavage and between crossed nicols a lamellated structure like a plagioclase felspar, and is thus similar to the pyroxene (γ) described by Prof. H. L. Bowman as occurring in the Chandakapur meteoric stone.[1] The stone probably belongs to the group of spherulitic chondrites and in character is distinct from the meteoric stone of Mt. Zomba, British Central Africa, a locality about 150 miles south of Kota Kota. Owing to the weathered and rusted condition of the stone no chemical analysis was made, as it would have been of little value.

[1] H. L. Bowman, Mineralogical Magazine, 1910, vol. xv, p. 355.

3. The Meteoric Iron of Angela, Santa Catalina, Iquique, Chili, and its probable identity with La Primitiva.

In 1904 the British Museum[1] became possessed of a mass of meteoric iron weighing 4,065 grams which had been sent to Mr. Martin Hardie, of London, by his uncle Mr. William Hardie in Iquique, Chili. According to Mr. W. Hardie's letter, the mass of iron 'was found in the jaws of one of the crushers of the Angela Nitrate Co., Ltd., at the Oficina Angela, and was picked out in time to save broken plates. It had been carted a distance of half a mile along with the caliche or raw material from which nitrate of soda is produced. It must have been embedded in a mass of caliche, for it had a little caliche sticking to it. . . . The Oficina Angela is an establishment for producing nitrate of soda from the caliche extracted from its surrounding grounds inside a half circle with a radius of two miles, more or less. . . . The aerolite was picked up half a mile from the "maquina" or plant, which is situated in the district of Santa Catalina, Tarapaca, at a distance of 41 miles by the Nitrate Railway line from Pisagua, and, as the crow flies, 40 miles N.E. from Iquique.' In 1906 and 1911 two other masses of the same meteoric iron weighing respectively 1,480 and 4,341 grams were obtained by the Museum from the same source.

Physical Characters.

The three masses are all of very irregular shape, with jagged pieces of iron projecting from the main mass (see Plate VI, fig. 1). This structure appears to be due to the fact that in each case the iron is honeycombed by schreibersite, which in one piece is estimated to amount to nearly a quarter of the mass. Etching with bromine of a polished surface of the iron gives it a satiny appearance, but develops no Widmanstätten figures, nor typical Neumann lines, though in parts faint indication of parallel lines and of curved lines like finger-prints can be observed with the lens. The iron is therefore an ataxite.

The density of a piece of the iron, weighing about 10 grams and as free as possible from schreibersite, was 7·892.

Chemical Composition.

A chemical analysis of the iron, as free as possible from schreibersite, gave the following numbers under I; under II for comparison is given the result of the analysis of La Primitiva made by O. Sjöström.[2]

[1] In the British Museum 'Introduction to the study of Meteorites,' 10th edition, 1908, this iron is referred to as 'Angelas (Oficina), Chili.'

[2] E. Cohen, 'Meteoreisen-Studien VI.' Ann. Naturhist. Hofmus. Wien, 1897, vol. xii, pp. 122–123.

	I. Angela.	II. La Primitiva.
Fe	95·03	94·72
Ni	4·52	4·72
Co	0·65	0·71
Cu	—	trace
C	trace	0·03
S	—	0·02
P	trace	0·18
	100·20	100·38

The result of the investigation shows that the Angela meteoric iron is an ataxite having a comparatively low percentage of nickel and characterized by its extraordinary richness in schreibersite. In these characters and in its chemical composition it appears to be identical with La Primitiva, the iron described by Cohen.[1] La Primitiva (lat. 19° 57′ S., long. 69° 50′ W.) is another of the nitrate works near Iquique and distant from the Angela (lat. 19° 48′ S., long. 69° 58′ W.) works about 12 miles. Photographs of etched polished surfaces of the two irons (Plate VI, figs. 2 and 3) show their similarity and the remarkable intergrowths of schreibersite.

4. Chemical Analysis of Meteoric Stones: re-determinations of Nickel and Iron in the Baroti and Wittekrantz Meteorites.

In a previous paper on the Baroti and Wittekrantz meteorites (this vol., p. 22), a simplified method of analysis of meteoric stones is described. For such analyses in which the extreme of accuracy was not required, it was thought that the separation of iron and nickel by repeated precipitation of the iron with ammonia would give sufficiently exact results and the introduction of large amounts of sodium acetate into the solutions be avoided. Almost immediately after the publication of that paper, however, it was found that the separation of the iron and nickel by means of ammonia had been by no means complete, and that it could not be made so even after as many as six or seven precipitations.[2] Accordingly in

[1] E. Cohen, loc. cit.

[2] C. Friedheim (Sitz-Ber. Akad. Berlin, 1888, p. 345) has stated that six or seven precipitations are necessary for absolutely complete separation; L. H. Borgström, that three or four may suffice if the solution after the addition of ammonia be kept for one to two hours on the water-bath. My experience suggests that by ammonia a really complete separation is scarcely possible.

the description of the method of analysis given in the previous paper, for the ammonia method of separating iron and nickel should be substituted the more accurate method of a triple (or even fourfold) precipitation with sodium acetate[1] or ammonium formate,[2] and subsequent precipitation with ammonia. The use of dimethylglyoxime,[3] although convenient for the precipitation of nickel, has the disadvantage that the cobalt passes into the filtrate with the iron, from which it would have to be subsequently separated. This reagent, however, may be used with advantage for the separation of the nickel and cobalt after the iron has been removed by sodium acetate, or for the precipitation and estimation of the nickel in a separate portion of the original solution.

In the case of the Baroti and Wittekrantz meteorites, in order to test the purity of the ferric oxide obtained in the analyses of the attracted portions after repeated precipitation with ammonia, it was brought into solution and treated for the separation of iron and nickel by the sodium acetate method. In both cases considerable amounts of nickel were found in the filtrates. The new determinations for the 'attracted portions' are:

	Baroti.	Wittekrantz.
Fe	67·20	56·75
Ni	10·35	8·82
Co	0·37	0·20

and in the 'unattracted portion' of Wittekrantz: Fe (in the nickel-iron), 0·31; FeO, 16·00; total, 100·43. Introducing these corrections, the bulk analyses and the mineral composition become (*see* p. 134):

It is probably the case that in many analyses of meteoric stones the nickel has been under-estimated, especially when the ammonia method of separation from the iron has been used. The proportion of iron to nickel in most chondritic meteorites therefore probably approximates more closely to 6 : 1 than to the 10 : 1 suggested in a previous paper (this vol., p. 38).

[1] L. Fletcher, Mineralogical Magazine, 1901, vol. xiii, p. 11.

[2] As advocated by L. H. Borgström, Bull. Comm. Géol. Finlande, 1903, vol. iii, p. 73.

[3] Zeits. Anal. Chemie, 1908, vol. xlvii, p. 162.

Bulk Analyses.

	Baroti.	Wittekrantz.
SiO_2	39·64	41·12
TiO_2	0·16	0·17
Al_2O_3	2·40	2·54
Fe_2O_3	0.44	0·48
Cr_2O_3	0·18	0·36
FeO	13·99	14.73
MnO	trace	0.15
CaO	1·79	2·12
MgO	24.71	25·40
Na_2O	0.91	1·16
K_2O	0·04	0·14
P_2O_5	0·25	0·16
H_2O	0.17	0·16
FeS { S	2·47	1·26
FeS { Fe	4·32	2·20
Fe	7·70	7·10
Ni	1·19	1·11
Co	0·04	0.02
	100·40	100·38

Mineral Composition.

Baroti.			Wittekrantz.			
147 $Na_2O.Al_2O_3.6SiO_2$	7.70	10·25	187 $Na_2O.Al_2O_3.6SiO_2$	9·81	11·95	Felspar.
4 $K_2O.Al_2O_3.6SiO_2$	0·22		15 $K_2O.Al_2O_3.6SiO_2$	0·83		
84 $CaO.Al_2O_3.2SiO_2$	2·33		47 $CaO.Al_2O_3.2SiO_2$	1·31		
27 $FeO.Fe_2O_3$		0·63	30 $FeO.Fe_2O_3$		0·70	Magnetite.
20 $FeO.TiO_2$		0·31	21 $FeO.TiO_2$		0·32	Ilmenite.
12 $FeO.Cr_2O_3$		0·27	23 $FeO.Cr_2O_3$		0·52	Chromite.
$\frac{17}{3}$ $Ca_3 2PO_4.CaO$		0·56	$\frac{11}{3}$ $3Ca_3 2PO_4.CaO$		0·37	Apatite.
179 $CaSiO_3$	2·08	30·38	296 $CaSiO_3$	3·48	26·60	Bronzite.
534 $FeSiO_3$	7·03		437 $FeSiO_3$	5·77		
2127 $MgSiO_3$	21·27		1742 $MgSiO_3$	17·40		
675 Fe_2SiO_4	13·77	42·12	768 Fe_2SiO_4	15·66	47·95	Olivine.
2025 Mg_2SiO_4	28.35		2304 Mg_2SiO_4	32·29		
FeS		6·79	FeS		3·46	Troilite.
Fe	7·70	8·93	Fe	7·10	8·23	Nickel-Iron.
Ni	1·19		Ni	1·11		
Co	0·04		Co	0·02		
H_2O		0·17	H_2O		0·16	Water.
		100·41			100·26	

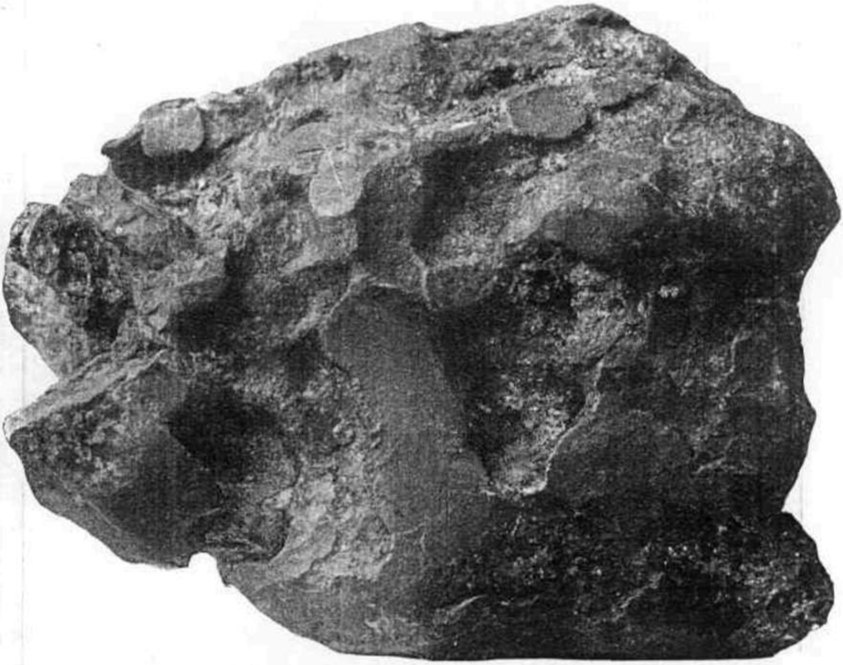

Fig. 1.—Meteoric Iron of Angela, Chili. ($\frac{4}{5}$ natural size.)

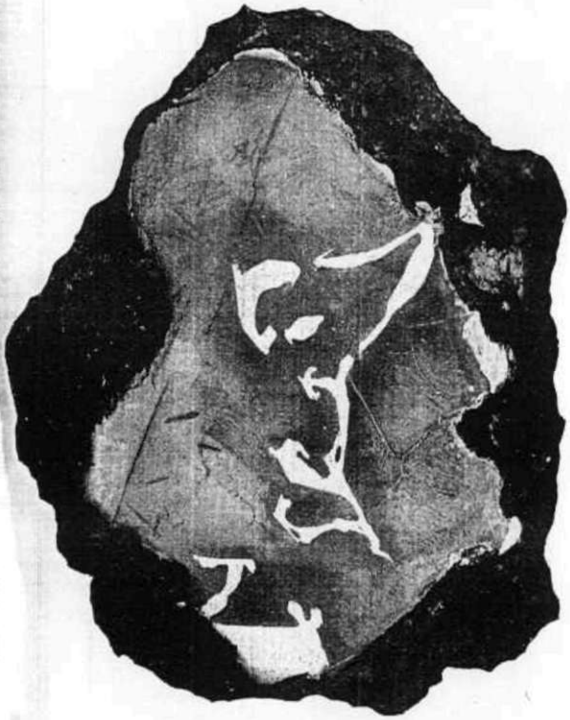

Fig. 2.—Etched surface of the Angela Meteoric Iron showing Schreibersite. (Natural size.)

Fig. 3.—Etched surface of the La Primitiva Meteoric Iron showing Schreibersite. (Natural size.)

G. T. Prior: The Meteoric Iron of Angela, Chili.