The identity of the Cobija and Lampa meteoric stones.

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FROM an examination of thin sections of specimens in the British Museum (Natural History) labelled Cobija and Lampa and also from a consideration of the present distribution of these meteorites in the British Museum and in the Ward-Coonley collection in the Field Museum of Natural History, Chicago, Dr. G. T. Prior thought that there was strong evidence in favour of their identity. In his 'Catalogue of Meteorites' (1923, p. 95) he states with reference to the Lampa stone: 'Except that it is more oxidized, in characters it is very similar to Cobija, and may be identical with it since the information as to locality was obtained not from H. A. Ward but indirectly from the School of Mines, Santiago.' Dr. Prior subsequently handed me these meteorites for a chemical examination.

The Cobija Stone.

The Cobija stone was described by Professor Henry A. Ward,[1] and was acquired by him, during a visit in April 1905, from Professor Julio Laso, the Custodian of the Collections at the School of Mines at Santiago, Chile, who had found the specimen in 1892 on the Pampa of Santa Barbara, east of Cobija, province of Antofagasta. The dimensions of the stone were given as $14 \times 12\frac{1}{2} \times 11$ cm., one side and one end being somewhat flattened, and the original weight as 3,690 grams. The surface is described as dark brown, 'slightly tinged with reddish hue at the more oxidized places', the crust, which covers half the surface, appearing shining or varnished in places. A photograph of a section only is given. This section is roughly the same shape as the slice in the British Museum collection, almost identical in size, and similar in appearance.

There are two specimens of the Cobija stone in the British Museum, an end-piece obtained from H. A. Ward in 1905, which weighed 301 grams,

[1] H. A. Ward, Proc. Rochester Acad. Sci., 1906, vol. 4, p. 229.

and a slice 7 mm. thick, weighing 252 grams, obtained from Mrs. L. A. Coonley Ward in 1907. The white granular patches covering the polished surface would appear to be hollows filled with the polishing powder. Both specimens show in places the reddish-brown shining crust described by Ward, and the other details in his description would also apply.

A fractured surface shows a porous, fine-grained structure coloured brown by iron oxide. A polished surface shows the iron uniformly scattered through the stone in irregular grains together with subordinate troilite. Olivine and pyroxene occur both as irregular chondrules and also as rounded chondrules up to 5 mm. in diameter. A fibrous radiating structure can be observed in some of these latter, but they appear mostly to be granular. These chondrules have broken with the matrix on the fractured surface.

In thin sections, the crystals of olivine and pyroxene are seen to be fresh and well developed and appear as phenocrysts or grains in a groundmass of the nickel-iron, while the felspar forms a fine-grained mosaic or is interstitial in the olivine and pyroxene. The whole section is iron-stained, especially at the margin corresponding to the crust, where there has formed a reddish-brown cement between the crystal grains; in the interior, the crystals of olivine and pyroxene are considerably stained yellow in bands following cracks in the crystals. Small chondrules are fairly numerous both of the lamellar and fibrous forms; while crystalline-granular chondrules are present, but more obscure.

The microscopic section was prepared from the end-piece, and from the same piece some of the freshest material, weighing 14·0375 grams, was selected for analysis. Hydrostatic weighing of the larger specimen gave an uncorrected value of the specific gravity of 3·40. A more accurate determination of the specific gravity made on ten grams of material similar to that analysed, after expulsion of air by boiling, gave 3·580 as the corrected specific gravity.

A magnetic separation of the attracted and unattracted portions gave the following figures:

weight of attracted portion . .	2·3434 grams
weight of unattracted portion . .	11·5174 „
	13·8608

The complete quantitative analysis of this material was carried out on the lines established by Dr. Prior, and I am very greatly indebted to him for his help in manipulation and interpretation of results.

Chemical analysis of Cobija.

	Attracted.	Unattracted.	Bulk.	Unattracted Soluble in HCl.	Unattracted Insoluble in HCl.
Fe... ...	76·61	—	12·95	—	—
Ni... ...	7·30	—	1·24	—	—
Co ...	0·34	—	0·06	—	—
Fe... ...	0·63	4·23	3·68	[4·23]	—
S	0·36	2·42	2·10	[2·42]	—
SiO_2 ...	2·47	43·42	37·06	16·83	26·55
TiO_2 ...	—	0·15	0·13	—	[0·15]
Al_2O_3 ...	—	3·33	2·81	1·20	2·48
Fe_2O_3 ...	—	3·14	2·65	3·19	—
Cr_2O_3 ...	—	0·35	0·30	—	0·35
FeO ...	0·80	10·37	8·83	[6·57]	3·80
MnO ...	—	0·28	0·24	—	0·28
CaO ...	1·78	2·66	2·55	0 80	2·10
MgO ...	1·41	27·39	23·35	17·25	10·07
Na_2O ...	—	0·85	0·72	—	[0·85]
K_2O ...	—	0·17	0·14	—	[0·17]
H_2O ...	—	0·53	0·45	[0·53]	—
Insol. ...	7·65	—	—	—	—
	99·35	99·29	99·26	53·02	46 80

	Molecular proportion.	Cr.	Il.	Fe_2O_3.	Or.	Ab.	An.	Ol.	Pyr.
SiO_2 ...	0·617	—	—	—	6	66	30	221	294
TiO_2 ...	0·002	—	2	—	—	—	—	—	—
Al_2O_3 ...	0·027	—	—	—	1	11	15	—	—
Fe_2O_3 ...	0·017	—	—	17	—	—	—	—	—
Cr_2O_3 ...	0·002	2	—	—	—	—	—	—	—
FeO ...	0·123	2	2	—	—	—	—	77	45
MnO ...	0·003								
CaO ...	0·045	—	—	—	—	—	15	—	30
MgO ...	0·584	—	—	—	—	—	—	367	217
Na_2O ...	0·011	—	—	—	—	1	—	—	—
K_2O ...	0·001	—	—	—	1	—	—	—	—
H_2O ...	0·029								

Mineral composition.

Felspar	Orthoclase	0·56		
	Albite	5·76	10·49	
	Anorthite	4·17		
Pyroxene	$CaSiO_3$	3·48		
	$MgSiO_3$	21·70	31·12	
	$FeSiO_3$	5·94		
Olivine	Mg_2SiO_4	25·69	33·54	
	Fe_2SiO_4	7·85		
	Ilmenite	0·30		
	Chromite	0·48		
	Fe_2O_3	2·65		
	Troilite	5·78		
	Nickel-iron	14·25		
	H_2O	0·45		
		99·06		

The Lampa Stone.

The specimen of the Lampa stone in the British Museum weighs 200 grams and shows a certain amount of the external surface. It was acquired in February 1910 from Dr. C. G. Gilbert, who was left in charge of Ward's collection after his death in 1906.

The stone was described by Professor Farrington,[1] who states the following: 'Among a number of meteorites obtained by the late Professor Henry A. Ward in Chile in 1905, one was placed by Professor Ward in the hands of the writer for description. The only information given the writer by Professor Ward at that time was that the meteorite had been handed to him by some one at the School of Mines at Santiago. On corresponding with the School of Mines, the Director, Señor A. Orrego Cortes, kindly informed the writer that the meteorite had been found in the Sierra de Chicauma, near Lampa.' Cortes also informed him that a further 5–6 kilograms had been preserved. The stone received by Ward from Santiago measured 10×15 cm., but only a part of this, in two pieces, weighing 2·8 kilograms, was handed on to Farrington. Two photographs of these pieces are given. No mention, however, is made either of the date on which Farrington obtained the stone or as to whether the whole was returned to Ward after examination.

A recent letter from Professor Farrington gives a slightly different impression. He writes: 'For my account of Lampa I relied on the information given me verbally by Professor Ward, which seemed to be fully confirmed by the letter of Director Cortes. Professor Ward's death occurred soon after he had handed me the meteorite for description, so that there was no opportunity for further inquiry of him as to details of the transaction by which he secured the meteorite.'

With reference to the Lampa stone Dr. Gilbert wrote in a letter to Sir L. Fletcher that the 'record had been mislaid by Professor Ward and become completely obscured temporarily owing to his sudden death'. As it seemed possible that the specimen sent by Dr. Gilbert might not be a specimen of the stone described by Farrington, it was thought desirable to compare it with the original Lampa. Professor Farrington has kindly forwarded a piece weighing 555 grams for this purpose. It is the portion shown in the lower part of the photographs accompanying his description and is identical in character with the specimen sent by Dr. Gilbert.

[1] O. C. Farrington, Field Columbian Mus. Chicago, 1907, Publ. 122, Geol. Ser., vol. 3, no. 6, p. 115.

Farrington's description of the meteorite is not inapplicable to the Cobija stone, except for a system of cracks on part of the surface and other physical characters of the crust. The interior is compact and chocolate to reddish-brown in colour. The specific gravity, determined on a piece weighing 557 grams, was given as 3·4005.

The stone in the British Museum is an irregular fragment with a considerable amount of crust, which is of a reddish shiny appearance, and also possesses a system of cracks, which, however, scarcely penetrate into the stone. The interior on a fractured surface resembles the Cobija stone, but is of a more reddish-brown tint. Other physical characters and the microscopic appearance of a thin section agree with Farrington's description. Apart from a slightly deeper staining of the crystals by iron and the system of iron-stained veins at the surface, no distinction can be drawn from that of Cobija.

Hydrostatic weighing of the whole piece gave an uncorrected specific gravity of 3·45, while 11 grams of the least altered material, after removal of air-bubbles, gave a specific gravity of 3·572. An amount of 12·2854 grams of the best material was collected for analysis, and, after crushing and separating with the magnetic comb, gave the following results:

weight of attracted portion . .	2·0062 grams
weight of unattracted portion . .	10·0838 ,,
	12·0900

A partial chemical analysis gave the following results:—

	Attracted.	Unattracted.	Bulk.	Unattracted Soluble in HCl.	Unattracted Insoluble in HCl.
Ni + Co ...	7·58	—	1·26	—	—
SiO_2... ...	—	42·96	36·44	15·40	27·43
Al_2O_3 ...	—	3·75	3·18	1·51	2·24
Fe_2O_3 ...	—	5·66	4·80	6·13	—
FeO	—	10·30	8·74	[6·29]	4·01
CaO	—	2·58	2·19	0·85	[1·73]
MgO... ...	—	27·27	23·13	16·05	[11·22]
Insol. ...	7·30	—	—	—	—

For convenience, the following characters are further listed together to show the similarity between the two stones:—

	Cobija.	Lampa.
Specific gravity (of mass)	3·40	3·45
Specific gravity (selected material) .	3·580	3·572
Percentage of nickel-iron	14	—
Ratio of iron to nickel	$10\frac{1}{2}$	—
Ratio of MgO to FeO (in olivine) .	$4\frac{1}{2}$	$4\frac{1}{2}$
Ratio of MgO to FeO (in pyroxene)	5	5

These meteorites, then, both belong to the Ck group of Brezina and to the Cronstad type of Prior.

It will be noticed that the specific gravity of Cobija determined on a large mass is identical with the value given by Farrington for Lampa determined in a similar way.

It is curious that, if Ward obtained the Lampa stone in 1905, no mention was made of it in his account of Cobija, and also that Farrington in 1907 made no reference to Ward's account (published in 1905) of the meteorites obtained by him. The dimensions of the respective stones are, moreover, almost identical and the weights given are quite compatible. It is also a curious coincidence that the section shown in perspective in Farrington's paper is almost identical in size, though not in shape, with the section of Cobija in Ward's paper, and also with the section of Cobija in the British Museum.

A consideration of the distribution of these stones at the present time leads to rather interesting results:

	Cobija.	Lampa.
Chicago[1]	1,100 grams	886 grams
	120 ,,	555 ,,
British Museum . . .	301 ,,	220 ,,
	252 ,,	
Total known at present	1,773 ,,	1,661 ,,
Original weight . . .	3,690 ,,	2,800 ,,

The figure for the total weight (3,434 grams) of both stones, now in Chicago and London, falls short of the original Cobija weight, though only by 256 grams. If Farrington had 2·8 kilograms and definitely established them as Lampa, what has subsequently become of the rest weighing 2·2 kilograms? In his paper, Ward states that of the 3,690 grams, the original weight of Cobija, the largest piece, weighing 1,805 grams, was retained in the Ward-Coonley collection. This is comparable with the 1,773 grams for the total of the Cobija now identified. In a letter from Ward to Sir L. Fletcher in 1905 he says, with reference to the Cobija stone, 'I took it to cut and to send back half, which I did'. Unfortunately, I have been unable to ascertain whether any of the original Cobija is now in the School of Mines at Santiago.

The foregoing account supports Dr. Prior's conclusion that the only difference between the two meteorites is the more oxidized condition of

[1] O. C. Farrington, Catalogue of the Collection of Meteorites, 1916. Field Mus Nat. Hist. Chicago, 1916, Publ. 188, Geol. Ser., vol. 3, no. 10.

the Lampa stone, though satisfactory information as to the original locality of these stones is still lacking. Our knowledge, moreover, of the present distribution of these stones is very incomplete. Cobija and Lampa are situated 750 miles apart, so that there is no possibility of these localities being those of two stones of the same fall. The evidence suggests that Ward obtained two separate specimens of Cobija from the School of Mines at Santiago in 1905, but that one, which was subsequently described on insufficient evidence by Farrington as the Lampa stone, was mislaid at the time of his describing Cobija.