The Breece, New Mexico, meteoritic iron.

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Introduction.

THE literature of meteoritics contains little information about the unusual Breece meteorite. This iron appears to be mentioned only in museum accession reports and catalogues of meteorite collections,[1] and the sole information supplied by these references consists of the approximate date of find (1921), the approximate weight (50 to 51 kg.), the approximate place of discovery, near Breece, McKinley County, New Mexico, in latitude 35° 18′ N., longitude 108° 18′ W., and the classification (Om). At the time of the discovery the hamlet of Breece[2] was the centre of a small lumbering industry, since moved SW. and SE. into more heavily forested areas, and today it has few inhabitants. The find consisted of a single well-preserved mass which was purchased in its entirety from an unnamed source by the Field Museum of Chicago approximately ten years after the iron was discovered.

The Heaston Collection of New Mexico meteorites at the University of New Mexico contains an interesting end-piece (fig. 1) weighing 920 grams sawn from the single mass which comprises the Breece find. The maximum dimensions of this specimen in three directions at right angles are 14·5 × 7·1 × 2·3 cm. This end-piece, registration number IOM–11 in the Institute of Meteoritics, the University of New Mexico, is the

[1] Ann. Rep. Field Mus. Nat. Hist. Chicago, 1932, for 1931, vol. 9, p. 133. H. H. Nininger, Our stone-pelted planet, Boston and New York, 1933, p. 158; The Nininger collection of meteorites. Mines Mag. Colorado School of Mines, 1933, vol. 23, pp. 6–9, 12 (p. 2 of reprint, 747 grams). [M.A. **5**–400, 405.] M. H. Hey, Second appendix to the catalogue of meteorites . . . British Museum. London, 1940, p. 24. [M.A. **7**–534.] A. L. Coulson, A catalogue of meteorites . . . Indian Museum. Mem. Geol. Surv. India, 1940, vol. 75, p. 57. [M.A. **8**–54.] S. A. Northrop, Minerals of New Mexico. Bull. Univ. New Mexico, 1942, no. 379 (Geol. Ser., vol. 6, no. 1), p. 186. [M.A. **8**–357, **9**–131.] S. H. Perry, The metallography of meteoric iron. Bull. U.S. Nat. Mus., 1944, no. 184, p. 167, pl. 47. [M.A. **9**–290.] F. C. Leonard, A catalog of provisional coördinate numbers for the meteoritic falls of the world. Univ. New Mexico Publ. Meteoritics, 1946, no. 1, p. 41. [M.A. **10**–171.] S. H. Perry, Meteorite collection of Stuart H. Perry . . . 1947, p. 3 (1487 grams, donated to University of Michigan).

[2] Breece is shown in the U.S. Geol. Surv. Topographic map of the state of New Mexico, edition of 1925, and on the U.S. Geological map of New Mexico, by N. H. Darton, edition of 1928; both maps 1 : 500,000.

subject of the mineralogical and chemical investigations reported in the present paper. This specimen, with its hackly fracture, presents evidence that the original 51-kg. mass was only a fragment of a larger mass which disrupted during transit through the atmosphere. Because of this

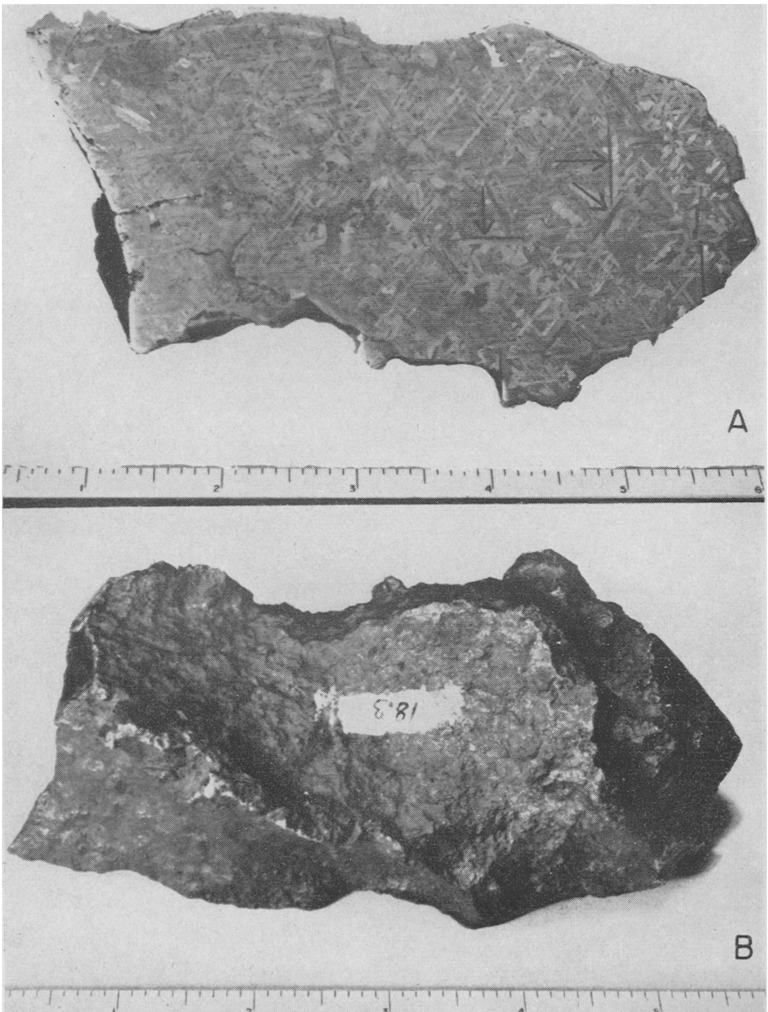

Fig. 1. Breece, New Mexico, siderite. A. Macro-etched surface; arrows point to cohenite lamellae. B. Exterior surface. $\times\frac{2}{3}$ (scale of inches).

evidence, an effort has been made to discover additional masses of the fall. Information supplied by Mr. Herbert Dick and Mr. L. E. Roderick of Albuquerque, New Mexico, and in particular by Mr. Charles Allen, a mineral collector of Trinidad, Colorado, leads to the apparently well-substantiated existence of a second fragment of the meteorite found in 1941 at one of the logging camps near Breece. Several searches with drag magnets and meteorite detectors have been made in the areas designated by these informants, but no additional finds were made. At the moment it must be presumed that the 51-kg. mass sold to the Field Museum constitutes the only fragment recovered and recognized from this fall.

Macroscopic examination.

The external crustal surface of the Breece meteorite (fig. 1B) is typical of most iron meteorites. The colour is dark brown to black, and the surface exhibits ample evidence of piezoglyphs, pressure markings produced during flight through the earth's atmosphere. The crustal coating ranges from vanishingly thin to a maximum thickness of 0·5 mm. The oxidation of the meteorite is limited to the surface and along cracks which penetrate into the interior of the iron (fig. 1A). Otherwise the meteorite is exceedingly well preserved; and, from this observation, it may be assumed that the fall did not antedate the find by many years.

The sawn surface of the meteorite was polished and macro-etched (fig. 1A). The metallographic structure is revealed to be that of an octahedrite. Lamellae of kamacite range in thickness from 0·6 to 1·2 mm., although some short lamellae have local thicknesses up to 1·8 mm. Because the greatest proportion of kamacite bands falls in the range of 0·6–1·0 mm., the Breece meteorite is classified in the division of siderites (Si), class octahedrites (O), subclass medium octahedrite (Om). The kamacite bands are in three systems forming good equilateral triangles; apparently the cut was made parallel to an octahedron plane. The kamacite bands are bordered by taenite lamellae which are, for the most part, much thinner than the kamacite. The angular interstices are filled with plessite fields, which, macroscopically, are triangular in form.

Another type of lamellae appears prominently in the macro-etch (fig. 1A, arrows). These lamellae are finely developed and either parallel to or perpendicular to kamacite bands. They average about 0·8 mm. in thickness and attain a maximum length of 1·8 cm. These lamellae in the Breece meteorite were noted by Perry (loc. cit., 1944) and referred to by him as Reichenbach lamellae. He says (p. 17): 'In octahedral irons troilite is occasionally observed in the form of scattered plates or lamellae with a definite cubic orientation unrelated to the octahedral pattern.' Farrington says the Reichenbach lamellae form 'parallel to the faces of a cube or dodecahedron' (p. 100),[1] but contradicts this later (pp. 143, 150) by saying they form parallel to the cube. A similar arrangement of schreibersite parallel to planes of the dodecahedron is referred to by Farrington (pp. 100, 150) as the Brezina lamellae of Cohen. Dr. L. J. Spencer (personal communication), has pointed out that in the rhombic dodecahedron orientation traces of (110), (101), (011) and their opposite faces are parallel to octahedral edges, and traces of $(1\bar{1}0)$, $(\bar{1}01)$, $(0\bar{1}1)$ and their opposite faces are perpendicular to octahedral edges on the face (111), while cube traces are all parallel to octahedral edges. Inasmuch as these lamellae in the Breece meteorite are both parallel and perpendicular to the octahedral edges, they are presumed to be parallel to the rhombic dodecahedron. The lamellae figured by Perry (pl. 47), on a section of Breece approximately parallel to (111), are also parallel and perpendicular to octahedral edges; but when referring to them as Reichenbach lamellae (p. 167) no mention is made of either troilite or cohenite.

Several of these lamellae were isolated and subjected to three separate qualitative chemical analyses. In all three cases abundant carbon was obtained, and sulphur was completely absent. In two of these analyses phosphorus was absent, while the third showed a trace. The complete chemical analysis of the Breece siderite (table I) also shows phosphorus to be absent and confirms the presence of carbon, though the small amount of carbon would indicate that the analysed fragment contained at best but a small lamella. These analyses suggested that the lamellae are composed of cohenite. A quantitative analysis of another cohenite lamella is shown in table II. The results remove any possible doubts as to the nature of these lamellae. These same lamellae were observed in the microscopic examination of small polished sections. Immersion for 90 seconds in boiling alkaline sodium picrate, prepared by dissolving 12·5 g. of sodium hydroxide in 50 c.c. of water and adding 2 g. of picric acid, darkened the lamellae and confirmed that they are cohenite.

Cohenite is conventionally regarded as a rare meteoritical mineral. It has been reported from the Magura, Bendegó, Wichita County, Beaconsfield, Canyon Diablo, Cosby's Creek, and several other iron meteorites (Perry, loc. cit., 1944, p. 22). In physical appearance

[1] O. C. Farrington, Meteorites, their structure, composition, and terrestrial relations. Chicago, 1915.

cohenite is identical with schreibersite, and distinguished from it with difficulty. The above test with boiling alkaline sodium picrate is the most diagnostic test for cohenite. In truth, it is to be expected that a more universal application of this etch test to polished sections would reveal that cohenite is more common than it is now believed to be.

The absence of sulphur in the lamellae makes the designation of Reichenbach lamellae inapplicable to this structure, and, as the presence of schreibersite appears doubtful at best, the term Brezina lamellae is equally inapplicable. These lamellae are similar physically to both the Reichenbach and Brezina lamellae, but the comparisons must be confined to structural relations only.

Microscopic examination.

Two slices of the Breece, New Mexico, siderite were mounted in bakelite, polished, etched with nital for 15 seconds, and studied with the metallographic microscope.

The microscope study shows that the external zone of alteration is extremely small, and that the interior of the meteorite, except along fractures, is free from alteration. From the unaltered appearance of the kamacite, taenite, and plessite, it may be assumed that the interior of the meteorite did not become appreciably heated during the flight through the atmosphere. Heating and the resultant fusion crust were confined to a thin outer zone.

The meteoritical components present are kamacite, taenite, plessite, cohenite, and troilite. The principal constituent is kamacite, the alpha nickel-iron alloy. In the macro-etched specimen the kamacite displays a characteristic sheen which changes as the surface is rotated. On the well-polished sections the kamacite is tin-white and occurs either as narrow, tapering lamellae bounded by very fine, fairly regular taenite and usually in a field of dense plessite (fig. 2); or it occurs as broad plates of two types: (1) apparently structureless, and (2) granular. Some of the latter type of kamacite show several sets of well-developed Neumann lines. Because Neumann lines can be obliterated in the laboratory upon heating, their presence is further confirmation that the siderite did not become heated in the interior.

Taenite, the gamma nickel-iron alloy, occurs usually as fine, fairly continuous bands bounding the kamacite lamellae (fig. 2) and forming the distinctive Widmanstetter pattern. Taenite also occurs as highly irregular patches. These patches range in appearance from entirely taenite, through taenite with some interior plessite (the 'fleckig' or 'spotted' taenite), to dense plessite with a border of taenite, the result of an incomplete separation of kamacite and taenite. In these taenite-plessite patches the plessite becomes increasingly denser towards the centre of the patch.

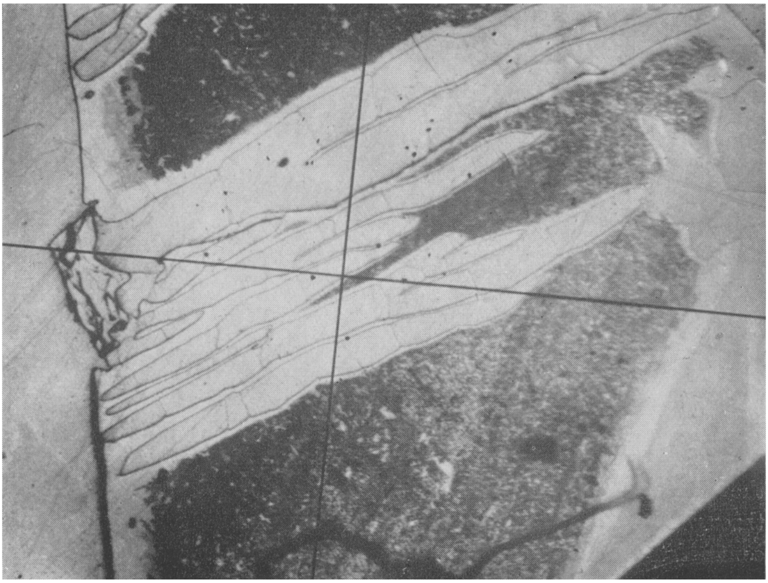

FIG. 2. Breece, New Mexico, siderite. Kamacite lamellae bounded by narrow taenite and surrounded by dense plessite. An irregular grain of brittle cohenite shows near the left-hand edge of the photomicrograph. × 125.

Most of the plessite on the polished sections is of the dense variety. Under high magnification the dense plessite can be seen to be composed of minute taenite particles embedded in a mesostasis of kamacite. These fields occupy the spaces formed by the lamellae of kamacite and taenite in octahedral arrangement.

In the polished sections cohenite generally appears as narrow, tin-white, brittle bands concentrated along the boundaries of contiguous kamacite plates, but occasionally an irregular grain of cohenite can be seen (fig. 2). That these are cohenite, and not schreibersite, was confirmed again by the boiling alkaline sodium picrate test.

Troilite occurs as tiny, irregular grains associated with the kamacite plates. In the Breece meteorite the troilite is typically brownish in colour.

Chemical analyses.

A portion of the Breece meteorite was removed from the mass, etched, and studied with a microscope to be certain it was representative of the meteorite. A chemical analysis was made by Dr. E. L. Martin, Department of Chemistry, the University of New Mexico, and the results are shown in table I. The analysis is in agreement with that of a normal medium octahedrite, though possibly a little higher in nickel than usual.

An analysis of one of the cohenite lamellae was made by Carl W. Beck. The results are shown in table II, and are consistent with the formula R_3C for cohenite where R = iron, nickel, and cobalt.

TABLE I. Chemical analysis made on 1·743 grams of the Breece siderite.

	%		
Fe	89·87	Specific gravity ...	7·93
Ni	9·26	Molecular ratio $\frac{Fe}{Ni}$ ...	10·20
Co	0·89		
S	0·11	Molecular ratio $\frac{Fe}{Ni+Co}$	9·34
C	0·03		
P	0·00		
Cl	0·00		
Cu	0·00		
	100·16		

TABLE II. Chemical analysis made on 0·4764 gram of cohenite.

	%	Molecular ratios.	
Fe	91·35	1·6356	3·054 (Fe + Ni + Co)
Ni	1·64	0·0279	
Co	0·11	0·0019	
C	6·54	0·5450	1·000
	99·64		
Specific gravity	7·37		

Summary.—The investigation of the Breece, New Mexico, siderite shows it to be a medium octahedrite (Om) composed chiefly of kamacite with lesser amounts of taenite bands and plessite fields. The most interesting constituent is cohenite as well-defined lamellae in the unusual arrangement similar to the familiar Reichenbach and Brezina lamellae.