Immediately under the metallic fusion crust is a 10-20 μ thick carburized zone. The reason for this is, no doubt, that the metallic melt, produced from the carbon-rich meteorite, had sufficiently high carbon activity to carburize a thin surface layer, even if the time was short. Upon cooling, this zone developed the usual bainitic-martensitic structures. It may also be observed how the bluish-gray taenite of the interior, in the α_2 zone changes to a yellow-etching taenite. An adjacent, 10 μ wide kamacite zone has simultaneously transformed to martensite, proving that carbon has redistributed itself by diffusion from the taenite ribbons. The microhardness of the martensitic areas is as high as 375, in contrast to 190 of the normal, heat-affected α_2 zone.

Bahjoi is structurally and chemically a typical group I iron, closely related to, e.g., Odessa and Toluca.

Specimen in the U.S. National Museum in Washington:
497 g endpiece (no. 1807, 7 x 5 x 3 cm)

Bald Eagle, Pennsylvania, U.S.A.
41°12'N, 77°7'W

Medium octahedrite, Om. Bandwidth 0.80±0.15 mm. Distorted Neumann bands.

Group IIIB. 9.41% Ni, 0.52% Co, 0.27% P, 18.1 ppm Ga, 37.1 ppm Ge, 0.018 ppm Ir.

HISTORY

A mass of 3.2 kg (7 lbs, 1 oz) was discovered in 1891 on the east side of Bald Eagle Mountain, seven miles south of the Park Hotel, Williamsport, in Lycoming County. "At this point the mountain comes down to the edge of the Susquehanna River, a road bed for the Philadelphia-Erie Railway having been cut in the mountain side. Numerous transverse depressions occur in the mountain side and some of these are filled with loose sandstone, varying in size from a few cubic inches to several cubic feet in volume." In one of these depressions some Italian laborers, while excavating stones for a stone-crusher, found the mass in a bed of loose stones about 2 m deep. When several attempts to break it or cut it with a cold chisel failed, the mass was discarded. Some weeks later it was donated to Bucknell University, where it was described by Professor W.G. Owens (1892) who also contributed the exact data quoted above on the circumstances of discovery. On modern maps the locality is seen to be seven miles west-southwest rather than south of Williamsport. The corresponding coordinates are given above.

Ward (1902b) borrowed the mass for examination and cutting. He provided a photograph of the exterior and a photomacrograph of an etched slice, and assumed the meteorite to be quite unique in shape as well as in structure. Ward (1904a: plate 7) reprinted the photograph of the slice. Farrington (1915: 47) and Stone & Starr (1967) reviewed the literature. The latter also presented three new photographs of the exterior, demonstrating how the meteorite strikingly resembled a small deformed or club foot. Noting that the meteorite was for a while feared lost in the Bucknell Museum fire of August 27, 1932 (it was recovered intact), they speculated that the difference between the original weight and the current weight might be due to the evaporation of water from the specimen or by some damage from the fire. This is, however, not the case. The cumulative weight of known samples cut from the Bald Eagle mass is 3,005 g, see below. If we assume a loss of 2 g per cm^2 cut and polished section we will have to add (5 x 4) + (8 x 12) x 2 = 232 g, and this brings us reasonably close to the reported original weight, which was 7 lbs, 1 oz, equal to 3.3 kg (Owens 1892). However, 7 lbs, 1 oz is only 3.2 kg.

COLLECTIONS

Bucknell University Museum, Lewisburg, Pennsylvania (2,639 g), Chicago (300 g), Berlin (51 g), London (15 g of filings).

Figure 300. Bald Eagle. Main mass in the Bucknell University Museum, Lewisburg, Pennsylvania. Scale bar 30 mm.

BALD EAGLE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore 1969, pers. comm.	9.56	0.52	0.27									
Scott et al, 1973	9.25								18.1	37.1	0.018	

DESCRIPTION

As noted by previous authors, the mass resembles a small human foot, deformed and tapering to a point at one end. The flat face corresponding to the sole measures 16.5 x 8 cm, and the distance from the heel to the tapering upper point is 14 cm, or 10 cm if measured perpendicularly to the sole. A slice of 300 g, measuring 16 x 8 x 0.5 cm, has been cut parallel to the sole (Chicago, Me no. 23), and another slice of 51 g, measuring 5 x 4 x 0.5 cm has subsequently been cut obliquely through the heel (Berlin, no number). Finally, the tip of the tapering end, representing only a few grams, also has been detached. The surface is covered with irregular regmaglypts, 10-20 mm across, and the state of preservation is much better than assumed by previous authors. Fusion crusts albeit weathered, may be distinguished in several places. A scar near the tip of the toe appears to be the groove made by a schreibersite lamella which partially burned out in the atmosphere; such features are common in Chupaderos and Grant. In other places there are a few marks from a sledge hammer and chisel, as reported by Owens (1892).

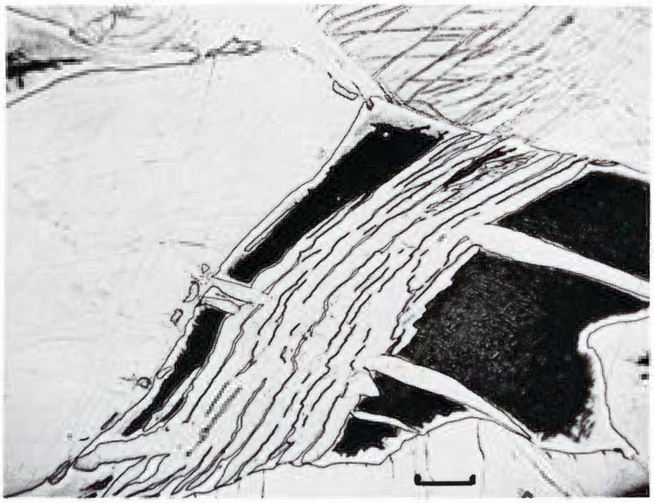

Figure 301. Bald Eagle (Chicago no. 1006). A general view of the distorted structure. Both kamacite and taenite are coldworked in space. Etched. Scale bar 200 μ.

Figure 302. Bald Eagle (Chicago no. 1006). The schreibersite crystal (S) has been broken and shear-displaced, but the metallic matrix was sufficiently ductile to accommodate the strains without fissuring. Etched. Scale bar 50 μ.

Etched sections display a medium Widmanstätten structure of undulating, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.80±0.15 mm. The lamellae are often violently twisted and give etched surfaces the appearance of tangled yarn. The kamacite shows mixtures of distorted Neumann bands and indistinct ϵ-structure and is clearly coldworked by deformation. Taenite and plessite cover about 40% by area. Common structures are fields with tarnished taenite rims, transition zones of martensite-bainite developed parallel to the bulk Widmanstätten structure, and interiors of duplex $\alpha + \gamma$, either black-etching and optically unresolvable, or clearly resolvable as 1-2 μ γ-blebs in cellular kamacite. All plessite forms are deformed contemporary with the kamacite.

Schreibersite occurs as cuneiform or pointed crystals up to 30 x 2 mm in size. It is further present as 10-60 μ wide grain boundary veinlets and as 5-30 μ irregular blebs inside some open-meshed plessite fields. Rhabdites are apparently absent. There are peculiar 10-20 μ wide schreibersite particles which occur as island arcs of 10-20 μ outside many taenite and plessite bodies. Similar arrangements are known in, e.g., Kouga Mountains, Bear Creek and Narraburra. Several of the larger schreibersite crystals have nucleated and grown upon euhedral chromite crystals, 50-150 μ across, or upon rounded phosphate crystals, 50-100 μ across. Most of the minerals are brecciated and shear-displaced. Some schreibersite crystals are hacked up in short bars, each of which is displaced 5-10 μ relative to neighboring fragments.

Troilite was mentioned by Ward (1902b) as 25 x 2 mm bodies filling "two diagonal fissures" in the sole. A reexamination of the specimen shows that the minerals are schreibersite with 1-1.5 mm wide rims of swathing kamacite. They are normal precipitates from the high temperature austenite phase and not fissure-fillings. Troilite is present elsewhere, e.g., as a 0.3 x 1 mm nodule with a 0.2 mm thick schreibersite rim.

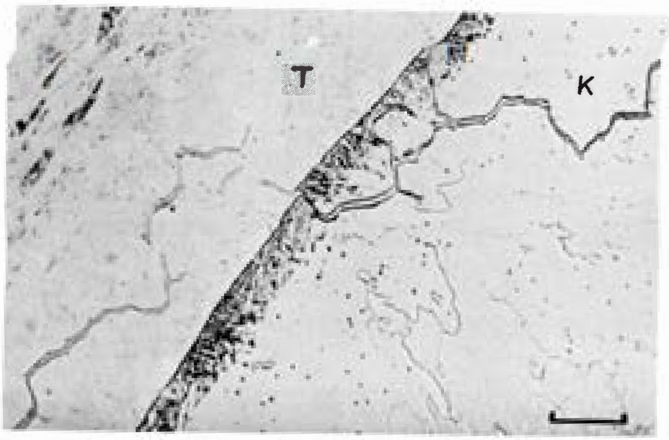

Figure 303. Bald Eagle (Chicago no. 1006). From the heat-affected α_2 zone. A zigzagging phosphide melt penetrates the high-temperature austenite grain boundaries of taenite (T) and kamacite (K). Etched. Scale bar 20 μ.

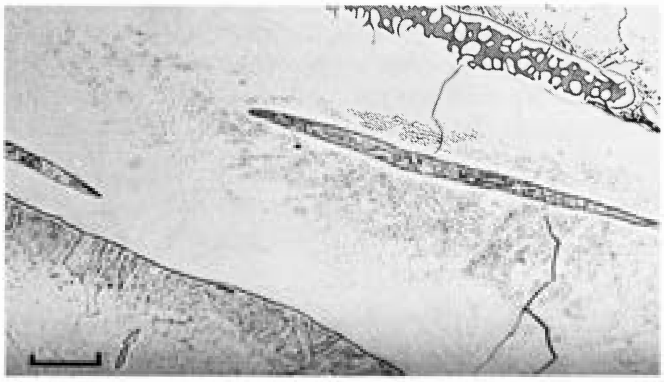

Figure 304. Bald Eagle (Chicago no. 1006). As Figure 303. A schreibersite crystal at the kamacite-taenite interface has completely melted during the atmospheric passage. Etched. Scale bar 50 μ.

The fusion crust has lost its oxidic part, but patches of up to 150 μ thick fused dendritic metal have survived. Under the fusion crust is a 2-3 mm thick heat-affected zone of α_2, and the exterior part of this contains micromelted phosphides. The serrated α_2 grains are relatively small, 10-30 μ across, presumably because they have formed from a severely coldworked kamacite matrix. The tarnished taenite has lost its color in the rim zone and etches clear yellow. A 10 μ wide dark zone along the yellow taenite indicates that carbon rapidly diffused during the atmospheric flight from taenite to kamacite, which was also austenitic when the diffusion occurred. Upon cooling, bainitic-martensitic reaction products developed and now stand out as a dark-etching zone.

Bald Eagle is a severely coldworked mass in which both metal and inclusions are distorted and brecciated. The deformations are clearly of cosmic nature and unassociated with the activity of the finders. The exterior undamaged shape and the well-preserved α_2 zone support this conclusion. Bald Eagle is closely related to Oroville, Joe Wright Mountain, Turtle River and Smith's Mountain and is a normal member of group IIIB.

Balfour Downs, Western Australia

22°57'S, 120°46'E

Coarse octahedrite, Og. Bandwidth 1.30±0.25 mm. Neumann bands. HV 190±10.

Group I. 8.39% Ni, 0.52% Co, 0.25% P, 59 ppm Ga, 194 ppm Ge, 2.0 ppm Ir.

HISTORY

A mass of 2.4 kg was found 1962 by a stockman on the Balfour Downs sheep station, about 85 km east-southeast of Roy Hill. According to the *Times Atlas*, 1967, Vol. 1, Balfour Downs has the coordinates given above, but the exact locality of the meteorite find is not known. Through N.R. Beresford, of Cloncurry, Queensland, the mass was obtained for the Australian Meteorite Expedition in 1963, and was described briefly by Wiik and Mason (1965). Two photomacrographs were presented by McCall and de Laeter (1965).

COLLECTIONS

Washington (911 g), New York (754 g), R.N. Beresford (151 g), Perth (147 g), Sydney (139 g).

DESCRIPTION

The angular mass has average dimensions 11 x 8 x 6 cm, and deep, irregular cavities which appear to be the original regmaglypts modified somewhat by terrestrial weathering. Most of the surface is pockmarked by 2-3 mm wide, shallow depressions which are typical corrosion pits. The fusion crust is not preserved, but the heat-affected α_2 zone is present locally as a rim zone up to 1 mm wide; it is estimated that, on the average, only 1-2 mm have been lost to weathering.

Etched sections display a beautiful Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) lamellae with oriented sheen and a bandwidth of 1.30±0.25 mm. Neumann bands exist in profusion. Locally, particularly around the larger schreibersite crystals, grain growth has created almost equiaxial α-grains, 3-5 mm in diameter. The microhardness is 190±10, decreasing to a minimum of 155±5 at the transition to the rim zone, which itself has a hardness of 185±10 (hardness curve type II). Comb plessite occupies about 25% by area, but acicular, martensitic and pearlitic plessite fields are also very common and well developed in this meteorite. The width of the γ-lamellae of the pearlite ranges from 0.2 to 2 μ. Locally these are considerably spheroidized. Haxonite may occur as intimate intergrowths with these types of plessite.

Schreibersite is common as 25-50 μ wide grain boundary precipitates; 5-10 μ thick rhabdite prisms occur everywhere in the α-lamellae. Still finer rhabdites, ~ 1 μ thick are located upon the subboundaries of the α-phase. A few large, angular skeleton crystals of schreibersite, typically 3 x 3 mm, occur scattered in the sections. At least half of them are built around complex aggregates of silicate, troilite and graphite grains, and it appears that these "insoluble impurities" have acted as nuclei for the phosphides, which without the heterogenous nuclei could not have precipitated so early nor grown to such proportions,

BALFOUR DOWNS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wiik & Mason 1965	8.39	0.52										
Wasson 1970a	8.39								56.4	194	2.0	
De Laeter 1972									62.1			

when the overall phosphorus content of the alloy is as low as 0.25% P, a result established by point counting of sections totaling 120 cm^2.

Cohenite is present as 50-200 μ rims around some of the larger schreibersite inclusions. They are anisotropic, monocrystalline and display a few fissures. Incipient decomposition to α-iron plus graphite is taking place along the fissures. The microhardness of the cohenite rim is 1,080 and of the large schreibersite crystals 900, a usual difference of 150-200 units.

Subangular, brecciated silicate grains, 50-200 μ in diameter, occur locally and are always embedded in a complex mixture of polycrystalline (1 μ grains) troilite and graphite with "horsetail" extinction. It appears that all possible combinations of graphite in troilite, troilite in silicate, silicate in troilite, and so on, occur in these aggregates. 20-50 μ spherulitic to angular graphite, i.e., "cliftonite," colonies occur *in* the schreibersite, *in* the cohenite and as rims between the silicate and the schreibersite. As mentioned, schreibersite envelops the whole complex and constitutes 80-90% by area of the total aggregate. Swathing, cellular kamacite, 1.5-4 mm wide, surrounds the aggregates.

Balfour Downs, with about 8.4% Ni, might be expected to be a medium octahedrite related to, e.g., Drum Mountains or Coopertown, but as the structural analysis shows, it is in fact a close relative to such coarse meteorites as Bischtübe and Toluca. An independent line of evidence for this conclusion is provided by the Ga-Ge-Ir data of Wasson.

Specimen in the U.S. National Museum in Washington:

911 g endpiece (no. 3202, 9 x 5 x 4.5 cm)

Ballinger, Texas, U.S.A.

Approximately 31°44'N, 99°57'W; 550 m

Coarse octahedrite, Og. Bandwidth 2.6±0.6 mm. Neumann bands. HV 164±8.

Group I. 6.54% Ni, 0.51% Co, 0.26% P, 84.5 ppm Ga, 326 ppm Ge, 2.1 ppm Ir.

HISTORY

A small mass of 1,250 g was purchased by Nininger from a mineralogist in Colorado, and it was described with an analysis and three photomacrographs (1929a). No particulars are preserved of the history, but the meteorite is supposed to come from Ballinger, Runnels County, Texas,

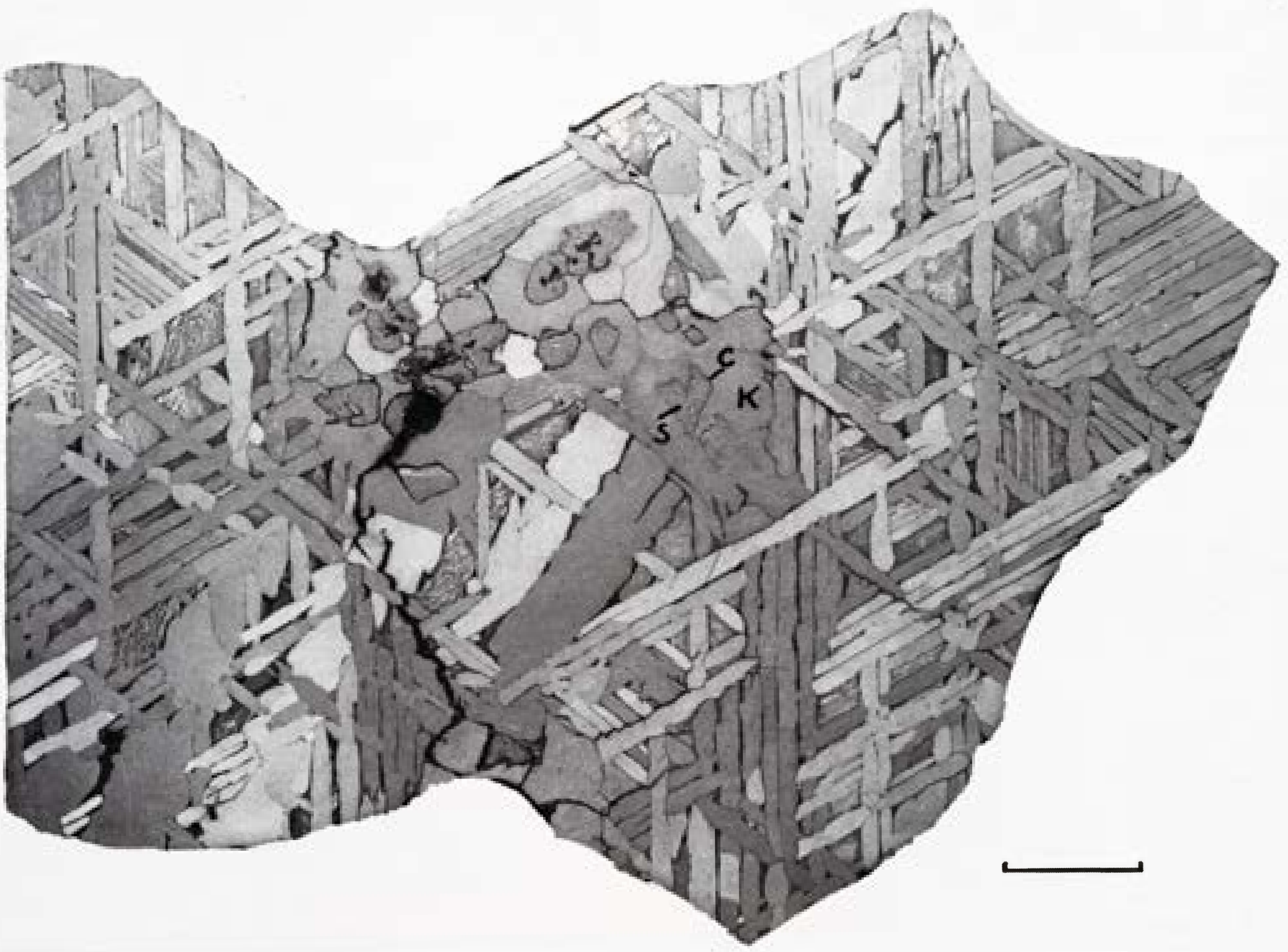

Figure 305. Balfour Downs (U.S.N.M. no. 3202). The endpiece after deep-etching. Conspicuous are the schreibersite skeleton crystals (S) with narrow cohenite rims (C) and very wide swathing kamacite rims (K). Scale bar 10 mm. S.I. neg. 1060A.

which has the above coordinates. Nininger & Nininger (1950, plate 11; 1952, plates 3 and 4) gave additional photographs of cross sections, which show the irregular mixture of octahedral and granular structures quite well.

COLLECTIONS

Washington (459 g), Chicago (108 g), Harvard (89 g), University of Texas (80 g), New York (74 g), Tempe (58 g), London (56 g). Adding the material spent in cutting and analyzing we arrive close to the original weight of the mass.

DESCRIPTION

The irregular, angular mass had average dimensions of 8 x 7 x 6 cm and weighed 1,250 g. It is covered by a crust of 0.5-1 mm terrestrial oxides, and on sections it is seen that the corrosion penetrates to the center along most grain boundaries. The fusion crust and the heat-affected α_2 zones have been removed by weathering.

Etched sections show a confusing arrangement of Widmanstätten structure mixed with more or less equiaxial grains 5-20 mm in diameter. A close inspection shows, however, that the mass originally was a single austenite crystal, since the few preserved taenite and plessite fields (see, e.g., Nininger 1952a, plate 4 which shows a plessite field, and not a schreibersite crystal as stated) all line up and thereby trace the orientation of the parent austenite crystal.

The width and length-width ratio of the Widmanstätten lamellae may be given as 2.5 mm and 6 respectively, but the variation is tremendous, due to late grain growth. Some favorably oriented α-lamellae have expanded over the neighboring fields, and in the process a few intercalated and still not resorbed taenite and plessite fields have become engulfed. The taenite ribbons are 20-100 μ thick, while the plessite areas may be double that size and have comb-plessitic or acicular interiors. Among most of the parallel α-lamellae hardly a trace of taenite is found. The small austenite content is in harmony with the analytical nickel value; below 6.5% Ni, retained austenite becomes rare. Neumann bands are well developed and form a seat for numerous, very fine precipitates of phosphides. The micro-segregation of nickel and phosphorus along the bands has created a chemical potential sufficient to start selective corrosion. The microhardness of the kamacite is 164±8; it is generally well annealed, except locally in coldworked areas where the hardness increases to about 200.

Schreibersite occurs as scattered skeleton crystals, e.g., 3 x 4 and 8 x 1 mm with a hardness of 875±25. Point counting showed a total of 0.16% P in the visible inclusions. Since the bulk chemical analysis showed 0.25% P (Hawley in Nininger 1929), there appears to be about 0.1% P as microscopic inclusions and in solid solution in the α- and γ-phases. The schreibersite skeleton crystals apparently precipitated directly from the austenite phase. After some growth, they nucleated ferrite and became completely enveloped in 5-10 mm swathing kamacite. Inclusion-poor areas transformed in the regular way to Widmanstätten lamellae, and later, competitive growth between these and

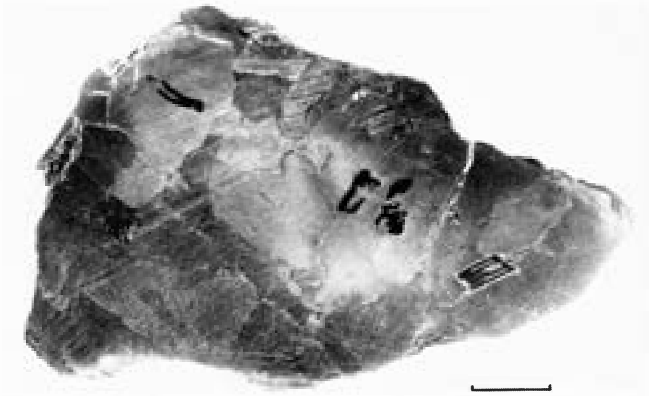

Figure 306. Ballinger (U.S.N.M. no. 824). The endpiece after deep-etching. Conspicuous are skeleton crystals of schreibersite (black) with their narrow "cohenite" rims (bright) and wide rims of swathing kamacite. Scale bar 10 mm. S.I. neg. 1651B.

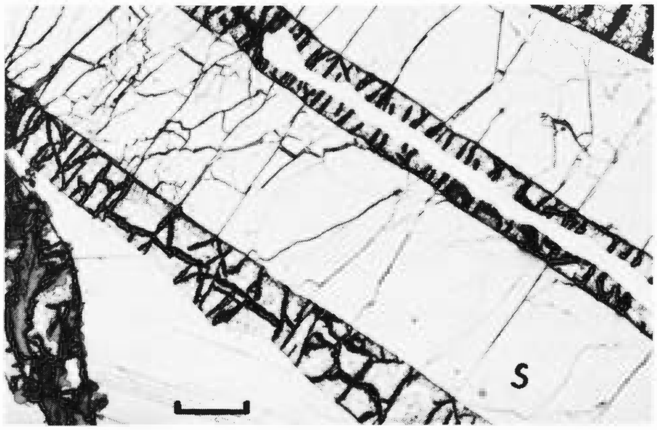

Figure 307. Ballinger. Detail of schreibersite (S)-"cohenite" aggregate. The cohenite is almost entirely decomposed to granulated ferrite and lamellar graphite. Etched. Scale bar 200 μ. Courtesy of R.S. Clarke.

BALLINGER – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hawley in Nininger 1929	6.54	0.48	0.26	900			700					
Hawley 1939	6.54										6.9*	
Henderson & Perry 1954	6.89	0.54										
Wasson 1970	6.19								84.5	326	2.1	

*Includes all platinum metals.

the swathing kamacite created the peculiar structure we see now. Schreibersite of late origin is present as 50-100 μ grain boundary veinlets, often corroded and hard to recognize. All schreibersite is monocrystalline, but brecciated, as are the common rhabdites. These are 5-20 μ thick tetragonal prisms that often are broken and displaced 1-5 μ along the Neumann band shear planes.

Troilite has been reported, but in this study was not observed on a total of 65 cm^2 sections. A large schreibersite crystal on an old deep-etched section appeared to be enveloped in a 0.1 mm wide cohenite rim, but the preparation of the large slice was not good enough for a conclusive identification of the cohenite. Roy S. Clarke, Jr. (personal communication, 1971) has repolished this sample. He identified cohenite as a 0.1-0.2 mm wide rim around the schreibersite, and further noted that the cohenite was under decomposition to graphite and ferrite.

Ballinger is structurally related to such group I irons as Wichita County, Campo del Cielo, Seeläsgen, and Seymour. Its gallium-germanium-iridium content might indicate a relationship with Zacatecas; that is, however, a polycrystalline mass with numerous disseminated, small troilite bodies, so a direct structural relationship does not exist. Much more interesting is Ballinger's possible relationship to Wichita County. The two masses tally well in all major and minor metallographical features, the partial decomposition of cohenite is common to them, and the chemical analyses agree within the margin allowed for analytical error. Unfortunately, the places of find of the two masses are known only inaccurately, and the small Ballinger mass may easily have been transported a long distance. The identification of the two meteorites as a paired fall therefore rests on rather meager evidence, and it is advised that they be kept apart until further work may look for methods that independently support the conclusion that the masses are fragments of a paired fall or, alternatively, that it is possible to positively discriminate between them.

Specimen in the U.S. National Museum in Washington:
459 g endpiece (no. 824, 7.5 x 4.5 x 4 cm)

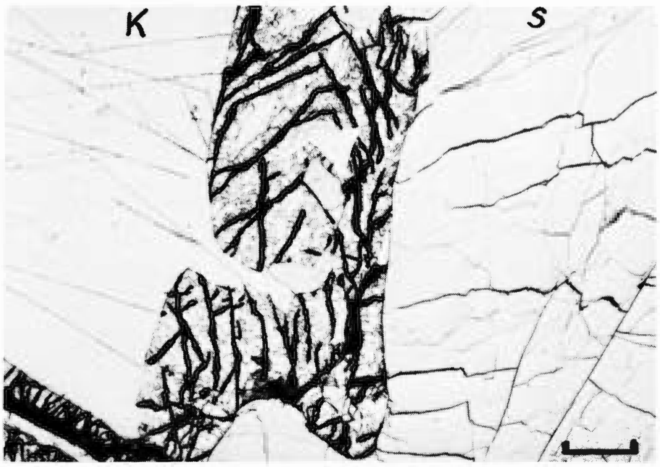

Figure 308. Ballinger. Detail of Figure 306. Kamacite (K), schreibersite (S) and decomposed cohenite in between. Etched. Scale bar 200 μ. Courtesy of R.S. Clarke.

Ballinoo, Murchison River, Western Australia
27°42'S, 115°46'E

Plessitic octahedrite, Opl. Spindle width 0.07±0.02 mm. HV 155±5.

Group IIC. 9.86% Ni, 0.57% Co, 0.5% P, 0.3% S, 39 ppm Ga, 94 ppm Ge, 9 ppm Ir.

HISTORY

A mass of 42.9 kg resembling a huge flattened potato was found in 1893 by a shepherd, George Denmack, on the water-wash of a tributary of the Murchison River, about 10 miles south of Ballinoo (Ward 1898). The coordinates as given by Ward (1904a), 26°30'S, 116°30'E, were considered erroneous by McCall (1965b), who suggested that the probable place of find was 10 miles south of Ballinyoo Springs at the above coordinates. Ward figured the mass and ascribed the peculiar, circular grooves on the otherwise smooth surface to troilite having been worn away to a greater depth than the iron surrounding it; whether this was by ablation in the atmosphere or by terrestrial corrosion and erosion was not stated. Ward cut the specimen in slices, and it is one of the better distributed meteorites. Cohen (1898c; 1905) grouped the iron with Bacubirito, Salt River, Tocavita and others, and presented micrographs in the Atlas (Brezina & Cohen 1886-1906, plate 29). Merrill (1916a), Perry (1944) and Axon (1961) presented macro- and micrographs.

Buchwald & Munck (1965: 14, 70) proposed to call this particular meteorite type a plessitic octahedrite, in order to distinguish it from both the ataxites and the finest octahedrites. Buchwald (1971d) discussed the low $^3He/^4He$ ratio found by Bauer (1963) and showed that it might be associated with cosmic annealing evident in the microstructure. In addition, he presented two photomicrographs.

COLLECTIONS

Chicago (11.0 kg), London (3.52 kg), New York (3.32 kg), Perth (2.4 kg), Harvard (2.28 kg), Vienna (1,725 g), Washington (1,412 g), Paris (599 g), Helsinki (431 g), Vatican (369 g), Sydney (357 g), Budapest (327 g), Calcutta (302 g), Stockholm (276 g), Leningrad (233 g), Amherst (154 g), Tübingen (150 g), Bonn (109 g), Yale (75 g), Tempe (66 g), Strasbourg (46 g), Prague (43 g), Sarajevo (41 g), Ottawa (31 g), Copenhagen (10 g).

SELECTED CHEMICAL ANALYSES

Wasson (1969) proposed to combine Ballinoo with six other irons of similar composition, i.e., Perryville, Kumerina, Tocavita, Salt River, Wiley and Unter Mässing, to form a new group IIC.

DESCRIPTION

The maximum dimensions of the mass before cutting were 34 x 27 x 11 cm (Ward 1898). The exterior is generally smooth, with overall preservation of the meteorite being very good. In many places a magnetite crust with thin striae and small warts from the last stages of atmospheric

Figure 309. Ballinoo (Vienna G 6474). The 0.6 cm thick slice shows a heat-affected α_2 zone with minute cracks and a softly outlined cavity (to the left) after an ablated troilite nodule. A large and several small troilite bodies are seen in the interior. Etched. Scale bar 30 mm.

penetration is preserved, and underneath it laminated, dendritic, metallic ablation layers are present in 0.1-1 mm thicknesses. Shallow cylindrical pits, 10-17 mm across and 2-20 mm deep, indicate where troilite nodules were partly or wholly removed by ablational melting during flight. The heat affected α_2 zone is 2-6 mm wide, and melted schreibersite is generally found in the exterior half of this zone. The microhardness reaches a maximum of 275±25 in the metallic fusion crust and drops to 210±10 in the outermost α_2 zone, where some phosphorus has passed into solid solution from the phosphide melts and thereby increased the strength of the α_2 phase. The inner parts of the α_2 zone have a hardness of 180±15, the hardness of phosphorus-poor α_2 (hardness curve type III).

Polished sections exhibit a microscopic Widmanstätten structure where α-spindles, typically 70 μ wide and 700 μ long, are evenly distributed. The ferrite of the spindles shows subgrain boundaries, but no Neumann bands; it is apparently in an arrested state of recrystallization and grain growth, with a microhardness of 155±5, corresponding to well-annealed material.

Schreibersite is extremely common: first as evenly distributed slender lamellae, typically 5 x 0.05 mm, with a 0.1 mm rim of swathing kamacite; second as 25 μ nodules in all the kamacite spindles; third as a discontinuous rim around and as fragments dispersed in the troilite nodules. The schreibersite is anisotropic, monocrystalline, and surrounded in a rather unusual way by a garland of tiny schreibersite islands about 1 μ in diameter, formed by secondary reheating in a similar way as seen in, e.g., Roebourne.

Troilite occurs as nodules of all sizes. Point counting of 270 cm^2 sections shows 1.3% sulfide by area, corresponding to about 0.3% S. A closer inspection of three nodules of 1, 12 and 16 mm diameter shows that they are extremely fine-grained, polycrystalline mixtures with a grain size of less than 2 μ. Sulfide, ferrite, austenite and phosphide are all present in varying amounts, and a 20 μ grain of chromite is locally embedded. The immediate surroundings of the nodules are penetrated by sulfide veinlets, creating a spongy network of metal and sulfide. The troilite evidently was melted by a shock wave. Fine

BALLINOO – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Sjöström in Cohen 1898	9.87	0.60	0.48	200	300		600					
Lovering et al. 1957	10.06	0.54				59	253		44	91		
Moss & Bothwell in Hey 1966	9.8											
Smales et al. 1967						66	233	<1	33	100		
Wasson 1969	9.72								39	94.4	9.0	
Crockett 1972											8.3	13

phosphate grains such as are observed in Wiley appear to be absent in Ballinoo.

The plessitic matrix is broken up in unusually well-defined alpha and gamma particles of about 1-2 μ width, and the taenite rim confining the α-spindles is often discontinuous. The "spheroidisation" of the plessite probably occurred at the same gentle temperature rise as the ferritic recrystallization that eliminated the Neumann bands. Although shock probably occurred at some time, as indicated by the troilite morphology, shock alone probably could not provide sufficient time for diffusion of the amount observed. The plessite texture resembles in many respects what is present in such different irons as Maria Elena, Oscuro Mountains and Reed City, meteorites that all are estimated to have suffered considerable cosmic reheating.

Ballinoo's structure corresponds well with the structure of the other group IIC meteorites (Salt River and Tocavita are, however, considerably altered due to heating by man), and group IIC appears to be a well-founded group.

Specimens in the U.S. National Museum in Washington:

1,254 g slice (no. 254, 19 x 9 x 1.1 cm)
158 g part slice (no. 3284, 5 x 5 x 0.8 cm)

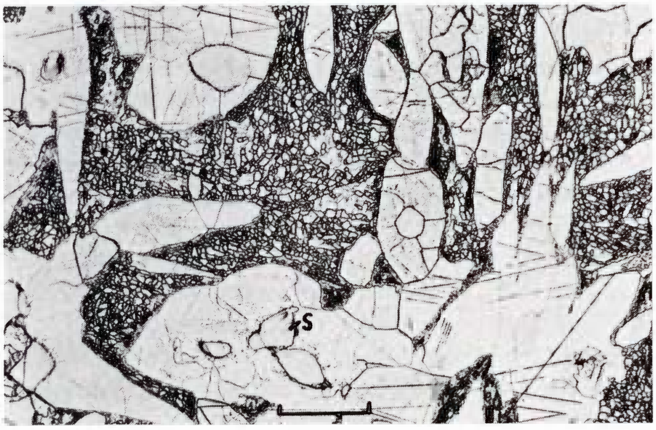

Figure 310. Ballinoo (Copenhagen no. 1898, 745). All the larger kamacite areas have been nucleated by and grown around schreibersite crystals (S). Etched. Scale bar 200 μ.

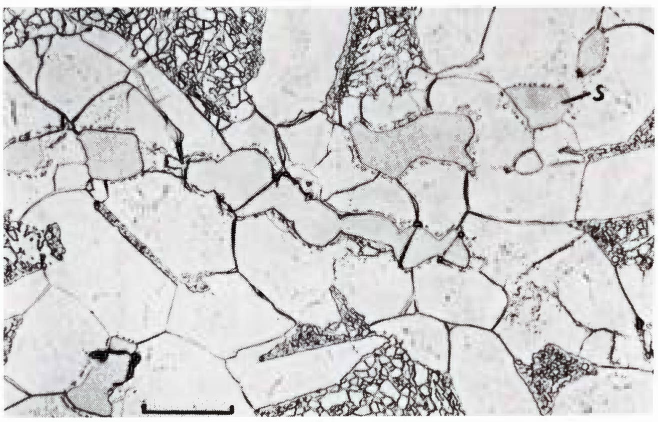

Figure 311. Ballinoo (Copenhagen no. 1898, 745). Due to annealing in space, the schreibersite crystals (S) have exsolved numerous tiny taenite particles. Etched. Scale bar 100 μ.

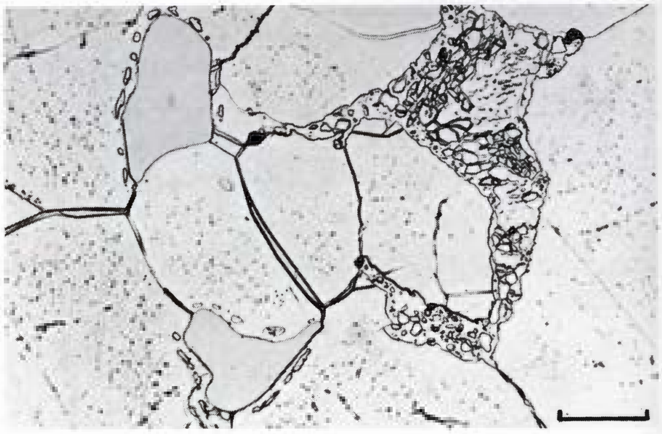

Figure 312. Ballinoo (Copenhagen no. 1898, 745). A spheroidized plessite field to the right, and two schreibersite crystals, surrounded by minute γ-particles. Etched. Scale bar 40 μ.

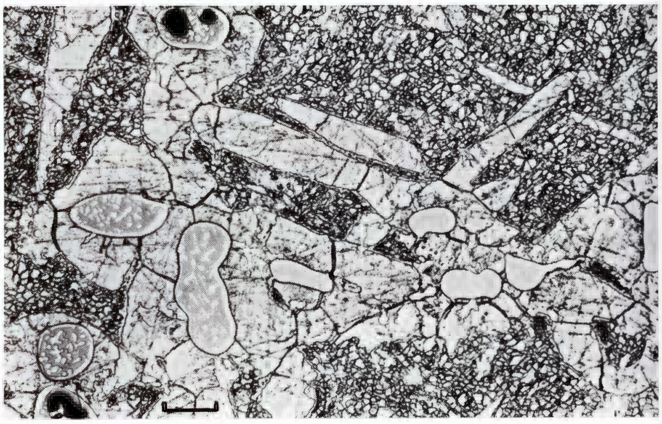

Figure 313. Ballinoo (Copenhagen no. 1898, 745). Detail of the heat-affected zone. All schreibersite crystals have been briefly melted and now display dendrites in eutectic melts. Etched. Scale bar 50 μ.

Baquedano, Antofagasta, Chile
23°20'S, 69°50'W

Medium octahedrite, Om. Bandwidth 1.20±0.20 mm. Twisted Neumann bands. HV 235±20.

Group IIIB. 8.79% Ni, 0.24% P, 20.4 ppm Ga, 42.8 ppm Ge, 0.11 ppm Ir.

HISTORY

A weathered mass of about 22 kg was found near the railway junction Baquedano in the Atacama Desert. The meteorite was acquired by Harvard University in 1930, where it was described and analyzed by Palache and Gonyer (1932). The coordinates of Baquedano as given in the *Times Atlas* map of Chile (1957: plate 118) can be seen above. Spencer (Mineralogical Abstracts 5: 158) speculated that it might be a transported mass belonging to one of the other masses from this region. After the preparation of this manuscript, a paper by Schaudy & Wasson (1971) discussed Baquedano and its relationships with other Chilean octahedrites. They provisionally listed Baquedano as an independent fall, a conclusion which I also had arrived at after my structural study. See further Las Salinas.

COLLECTIONS

Harvard (22.0 kg), Washington (864 g).

DESCRIPTION

The disc-shaped mass with average dimensions of 31 x 21 x 10 cm somewhat resembles the scaly head of a reptile. This is due partly to the form, but particularly to the corrosion pits which are so typical for irons exposed for any length of time to the environment of the Chilean desert. The pits are numerous and of about equal size, 4-6 mm in diameter and 1-2 mm deep. They are partly filled with reddish-brown limonite and/or caliche. Occurring on all sides of the meteorite, they are rough and sharp on one side and somewhat smoothed on the opposite. The explanation invariably given for the pitted irons of Chile is sand erosion, but this is difficult to visualize. Sand erosion would be more likely to produce semi-smooth surfaces on iron base materials, or at most only large-scale smooth, shallow depressions. Furthermore, as most of the pits mentioned are partly filled with well-adhering oxides, a conclusion that corrosive action created them seems most likely. It is speculated that the salt-saturated air of the Atacama region plays a decisive role in the peculiar development of Chilean corrosion features. Corrosion has removed all traces of the heated α_2 rim zone.

The Widmanstätten structure is well developed as long lamellae ($\frac{L}{W} \sim 20$) with a bandwidth of 1.20±0.20 mm. Traces of the pattern are faintly seen on the corroded surface. The ferritic matrix shows abundant Neumann bands, but these are curved, bent and twisted. The ferrite

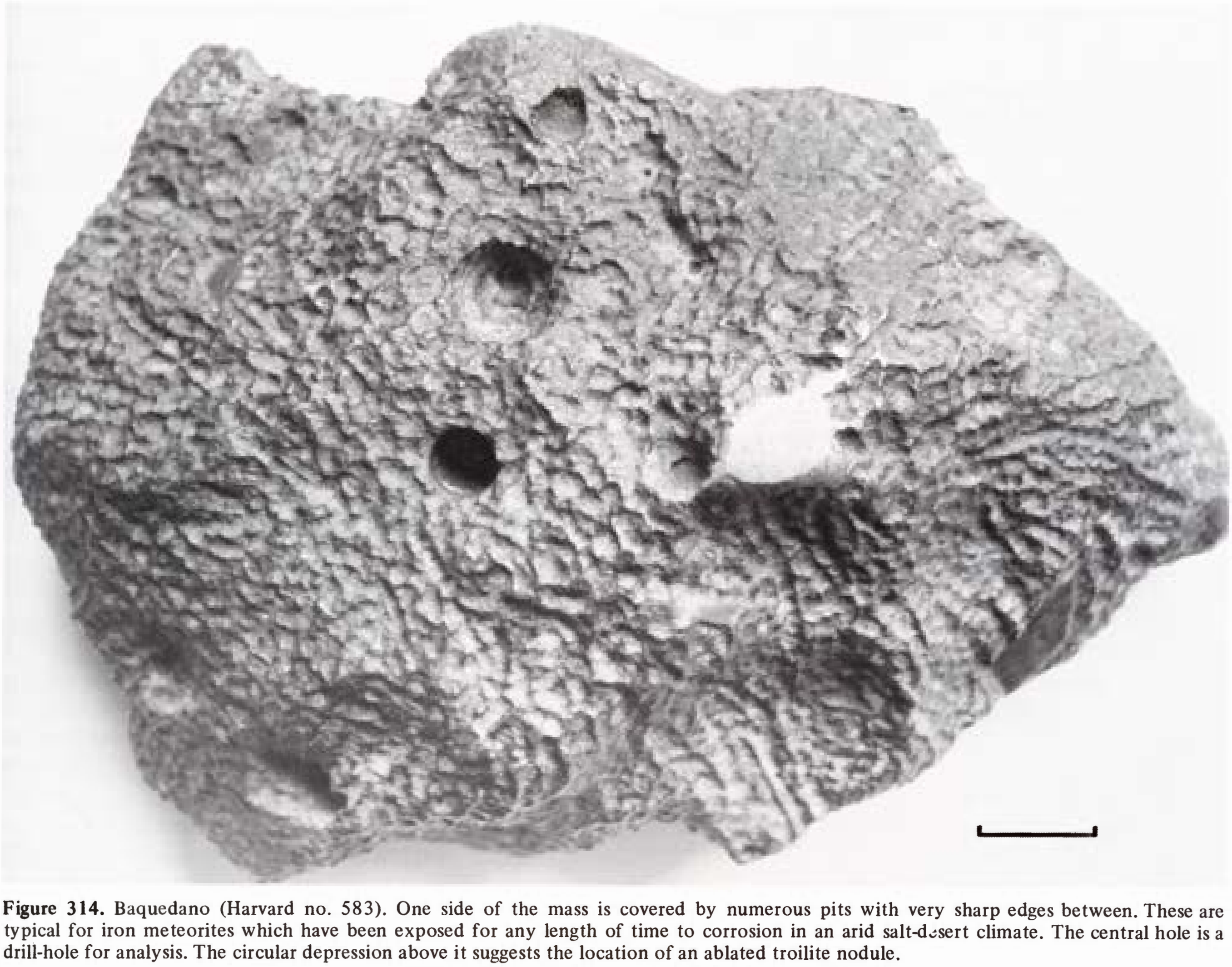

Figure 314. Baquedano (Harvard no. 583). One side of the mass is covered by numerous pits with very sharp edges between. These are typical for iron meteorites which have been exposed for any length of time to corrosion in an arid salt-desert climate. The central hole is a drill-hole for analysis. The circular depression above it suggests the location of an ablated troilite nodule.

BAQUEDANO – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Palache & Gonyer 1932	8.82	0.15	0.24		500		300					
Schaudy & Wasson 1971	8.76								20.4	42.8	0.11	

The cobalt determination is no doubt too low; expectations would be about 0.50%.

also shows lenticular deformation bands; the linear elements of the Widmanstätten pattern are locally bent, and the inclusions may be faulted about 10 μ in an irregular way. After the Neumann-band-producing shock event, another more gently plastic deformation, which acted over a period of time, presumably took place. The hardness varies from 210 to 260 in accordance with the visible deformation. Subgrains in the ferrite are clearly marked, with many precipitates of less than 1 μ decorating them. Locally it may be seen that the grain boundaries recently migrated, leaving their precipitates behind. Plessite is common as open-meshed micro-Widmanstätten structures. The taenite interior, with a hardness of 340±20, is locally decomposed to brown-etching martensite that is oriented parallel to the bulk Widmanstätten pattern.

Schreibersite is common, first as angular, millimeter-sized monocrystalline nodules located centrally in the larger kamacite lamellae, and also as 20-50 μ grain-boundary precipitates. These are sometimes deposited as an island series in front of the receding taenite. There are no rhabdites in the ferrite, but etching characteristics lead to the impression that the ferrite is loaded with ultrafine precipitates less than 0.2 μ in diameter. Troilite is scarce: only one 8 mm nodule and a few 10-25 μ blebs were observed; these were subdivided by parallel 1 μ thick daubreelite plates. The scattered Reichenbach lamellae, typically 50 x 3 x 0.05 mm in size, are very characteristic and crisscross large etched surfaces.

Baquedano belongs to a certain group of medium octahedrites within group III, of which Bartlett, Cleveland, Drum Mountains, Thule and Trenton are prominent members; structurally they are particularly characterized by the presence of thin Reichenbach lamellae. A comparison with the other octahedrites of Northern Chile shows that, although Baquedano is distantly related to Ilimaes, Joel's Iron and Sierra Sandon, there are sufficient structural and chemical differences to single Baquedano out as an independent fall.

Specimen in the U.S. National Museum in Washington:
864 g endpiece (no. 856, 13 x 8 x 3 cm)

Barbacena, Minas Gerais, Brazil
21°13'S, 43°56'W

Two oxidized masses of 6.1 and 2.9 kg were found in 1918 (Oliveira 1931). The material was inadequately described by Curvello & Ferreira (1951) who classified it as a fine-finest octahedrite with about 10.5% Ni. Photomicrographs indicate that Barbacena is a plessitic octahedrite, Opl. While the main masses in Ouro Preto (School of Mines) apparently contain sufficient unoxidized material for a description, the distributed samples, e.g., 33 g in the British Museum, are no more than limonitic lumps with virtually no preserved metal.

It is possible that some specimens of this meteorite are mislabeled, e.g., the 700 g sample no. 297 in Rio de Janeiro, but the present author has so far been unable to penetrate the confusing evidence.

Barraba. See Bingera

Barranca Blanca, Atacama, Chile
28°5'S, 69°20'W

Anomalous. Polycrystalline kamacite aggregate with troilite nodules. Neumann bands. HV 178±8.

Anomalous. 7.99% Ni, 0.65% Co, 0.15% P, 0.9% S, 21 ppm Ga, 65 ppm Ge, 5 ppm Ir.

HISTORY

A mass of about 12.5 kg was found in 1855 by a muleteer, Vincenti Avila, close to "Barranca Blanca, a refuge from the terrible tempests of the Andes, between Copiapo and Catamarca" (Fletcher 1889). It is not quite clear where this rest place may be found. In early catalogs, e.g., Fletcher's "A Guide to the collection of meteorites in the Department of Mineralogy in the British Museum" 1877-1888 editions, the meteorite was listed under the synonym San Francisco Pass, which is about 200 km northeast of the locality which Fletcher (1889) stated might be the place of find, on a more southern route across the Andes. The coordinates given above are based on Fletcher's map. Little has been written on this very interesting iron, and only one photomicrograph (Perry 1944: plate 42) has been published.

COLLECTIONS

Main mass (11.6 kg) in British Museum, Tempe (189 g), Washington (84 g), New York (73 g), Vienna (66 g), Harvard (27 g), Chicago (16 g). Allowing for loss by cutting and a few other distributed specimens, the original mass seems to have weighed about 12.5 kg and not 11.3 kg as stated by Fletcher (1889).

DESCRIPTION

The somewhat flattened, ham-shaped mass has average dimensions of 23 x 22 x 8 cm. Shallow regmaglypts are indistinctly seen. About one-half of the mass is covered with sharp-rimmed pits, generally 3-5 mm across and 1-2 mm deep; the opposite half is somewhat smoother and less corroded. The pits are no doubt due to the special Atacama environment, where corrosion creates extensive pitting. It is, however, not absolutely certain whether the pits formed on the side exposed to the atmosphere only, or on the side buried in the soil. The first possibility appears to be the most acceptable. An examination of the main mass and a comparison with meteorites as different as Baquedano, Iquique and Filomena indicate that the corrosive attack is only slightly influenced by the structure and chemical composition of the iron.

A heated rim zone from the atmospheric penetration is preserved as an α_2 border up to 4 mm thick. Corrosion has removed parts of it, hollowing it and creating small crater-formed pits. Locally, a 0.5 mm wide crack is filled with several generations of ablation melted metal (HV

370±30). The first layer to solidify was relatively poor in oxides; the last had many globules of dendritic oxide-sulfide intergrowths with about 1 μ cells. A crack like this is a natural point of attack for corrosion, becoming wider and deeper with terrestrial weathering. The heat-affected α_2 zone has a hardness of 210±15, and the unaffected interior has a hardness of 178±8. In a transitional zone, just below the α_2 zone, the hardness is only about 160, an indication of recovery during the atmospheric flight (hardness curve type II).

Polished and etched sections show a unique structure of irregular, mostly isometric, 5-50 mm kamacite grains, in and between which are rounded and wedge-shaped taenite and troilite bodies. Neumann bands are abundant, and their directions are helpful in tracing the limits of individual ferrite units. An estimate of the amount of the different phases on a 40 cm^2 slice (Tempe, no. 536.1) yielded 4% troilite, 9.5% taenite-plessite, 86% kamacite and less than 0.5% of chromite, schreibersite and phosphates. No trace of gross Widmanstätten structure was present, so it would be misleading to classify Barranca Blanca as an octahedrite.

The ferrite (HV 178±8) is beset with a confusing array of subboundaries, the majority of which are concentric or subparallel and wavy, resembling growth rings or contour lines of a map. They are decorated by less than 0.5 μ precipitates that have partly pinned them in position. Taenite occurs as independent bodies of variable orientation, quite different from the uniformly oriented taenite fields of normal octahedrites. The taenite and plessite fields show internal boundaries that apparently are relics of the grain boundaries in the precursor taenite-sulfide aggregate. A fully developed field is conspicuous by the absence of the clear yellow rim zone that is usually present; it is an

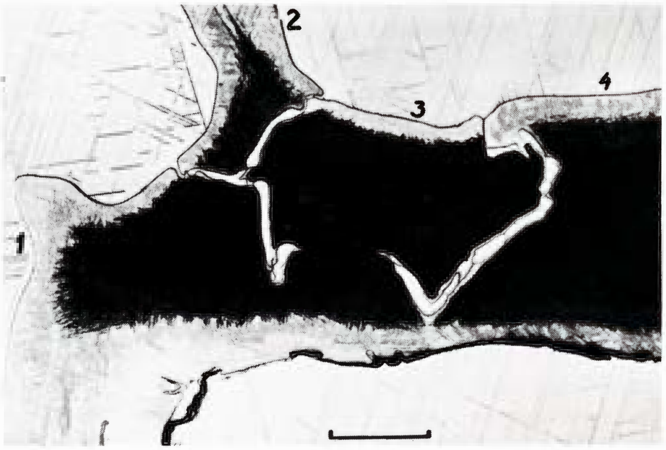

Figure 315. Barranca Blanca (Tempe no. 536.1). A detail of Figure 75. The four taenite-plessite fields are differently oriented because they were once part of four different precursor taenite grains. Kamacite has by late grain growth become almost uniformly oriented, as indicated by the Neumann bands. Etched. Scale bar 400 μ.

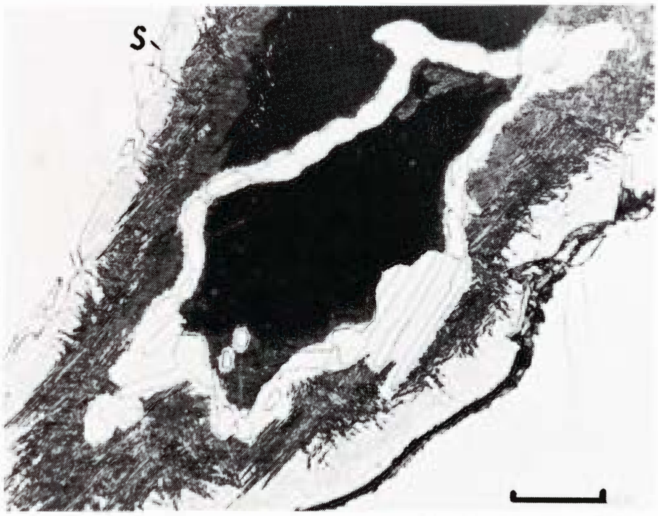

Figure 316. Barranca Blanca (Tempe no. 536.1). A central black taenite crystal surrounded by kamacite with Widmanstätten start. A few schreibersite particles (S) are also seen. Etched. Scale bar 200 μ.

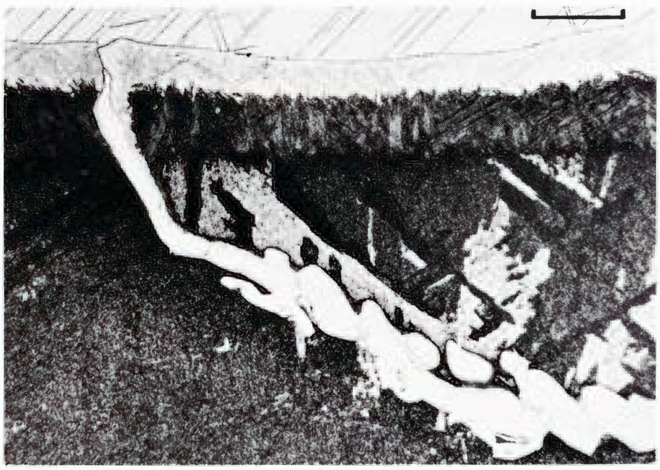

Figure 317. Barranca Blanca (Tempe no. 536.1). A detail of the grain boundary between two original taenite crystals. The grain boundary nucleated ferrite (white), and a few schreibersite particles also precipitated. Etched. Scale bar 200 μ.

BARRANCA BLANCA – SELECTED CHEMICAL ANALYSES

References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Fletcher 1889	8.01	0.65	0.15		1300	+	+					
Smales et al. 1967					16	<5	362	<1	20	66		
Wasson & Kimberlin 1967	7.96								22.1	63.9	4.9	

The phosphorus determination is in harmony with the phosphide content. The bulk sulfur content is estimated to be 0.9%.

indication that the nickel content of the rim is lower than usual, probably below 30%. Instead there is a light-etching martensitic zone (HV 260±10) followed by a darker-etching similar zone (HV 320±20). In the largest fields there is a central, rather homogeneous core of dark-etching martensite developed along the $\{111\}$ directions of the parent austenite (HV 295±20).

The 0.5-2 mm rounded, unoriented nodules of troilite scattered all over the sections are very conspicuous. They are mono- or polycrystalline aggregates, which show multiple twinning in the form of lenticular sparks. Their abundance, about 4% by area, corresponds to 0.9% S in the meteorite. Schreibersite occurs as infrequent 100 x 10 μ bodies, mostly situated in or near the taenite-kamacite interface. Rhabdites were not observed. Daubreelite is not present, but several 50-100 μ chromite grains were seen.

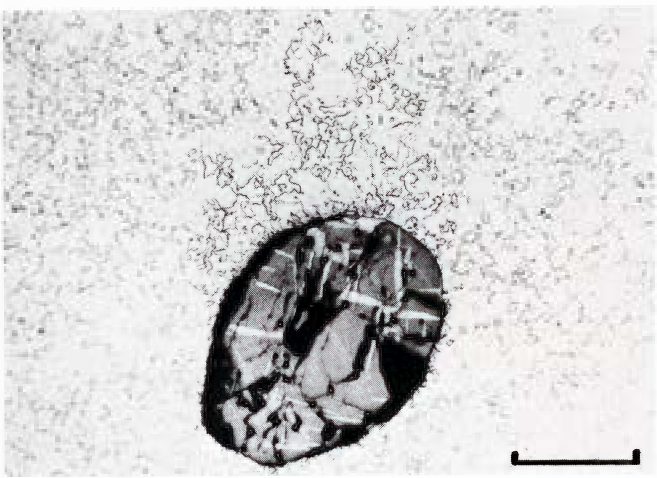

Figure 318. Barranca Blanca (Tempe no. 536.1). A troilite nodule with multiple twinning. It happens to be situated in the heat-affected α_2 zone, but the brief atmospheric reheating did not alter it. Etched. Slightly crossed polars. Scale bar 400 μ.

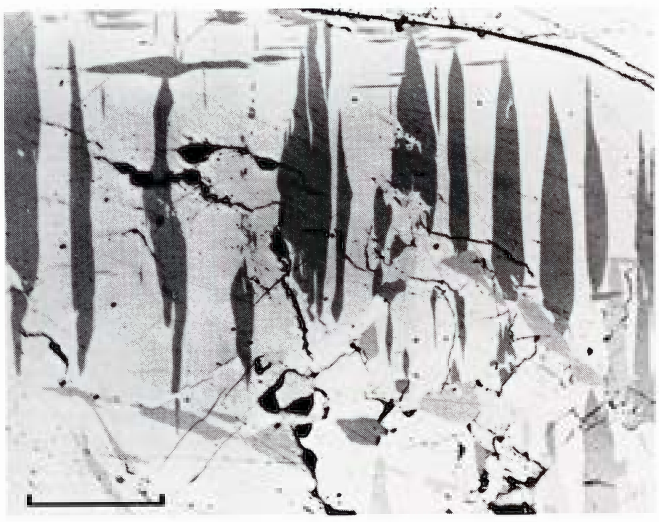

Figure 319. Barranca Blanca (Tempe no. 536.1). A detail of another troilite nodule, showing multiple twinning from mild deformation. Etched. Slightly crossed polars. Scale bar 100 μ.

Due to the low bulk phosphorus content, 0.15%, hardly any schreibersite rims are present on the troilite nodules. A few yellowish-green 30-200 μ grains were noted in association with chromite and troilite. Bild (1973, personal communication) has identified them as farringtonite.

The structure may be interpreted as the result of a sintering action that was not intense enough to homogenize the mass completely and create one large austenite crystal. Instead, a polycrystalline 2-5 mm aggregate of austenite grains with troilite nodules and veins was formed; each of these austenite units transformed independently to ferrite upon cooling. It is suggested that the transformation started around the sulfide nodules, which acted as heterogeneous nuclei for a rim of swathing kamacite; this then gradually increased in size until it stopped at neighboring growth fronts. Late grain growth allowed some favorably situated ferrite grains to grow out of proportion to the others. Lastly, a mild shock detached the mass from its surroundings, thereby creating the Neumann bands and the twins in the troilite.

Barranca Blanca is an anomalous iron outside the structural classification scheme; it may be unique or turn out to be somewhat related to such irons as Elga, Colomera, Glenormiston, Kodaikanal and Weekeroo. Structurally, it has an interesting parallel in Waterville, with approximately the same nickel content but due to a larger amount of troilite and a higher cooling rate, developed somewhat differently. In particular, part of the retained taenite in Waterville decomposed homogeneously to a genuine Widmanstätten structure.

After this examination had been completed, a paper by Axon & Faulkner (1970) appeared, giving more details on Barranca Blanca. It was particularly based on microprobe studies but supported the above observations and conclusions in all major respects.

Specimen in the U.S. National Museum in Washington:
84 g corner piece (no. 743, 4 x 2 x 2 cm)

Bartlett, Texas, U.S.A.
30°50′N, 97°30′W

Medium octahedrite, Om. Bandwidth 1.10±0.20 mm. ε-structure. HV 260±15.

Group IIIA. 8.78% Ni, 0.47% Co, about 0.3% P, 20.6 ppm Ga, 46 ppm Ge, 0.72 ppm Ir.

HISTORY

A rounded mass of 8.59 kg was plowed up about 1935 on the Molly Benson farm, 8 km west of the town of Bartlett, Bell County. It was placed along a fence line. Later, however, Willard Wiederspahn, having read an article on meteorites in a popular magazine, realized that the mass might be a meteorite and brought it in 1938 to the University of Texas, where it was cut and described with pictures by Bullard (1940). Bartlett was recently included in Brett & Henderson's (1967) discussion on lamellar troilite in iron meteorites.

COLLECTIONS

University of Texas, Austin (two endpieces, of about 4 and 2.8 kg), Washington (670 g).

DESCRIPTION

The mass has average dimensions of 19 x 16 x 9 cm and weighs 8.59 kg. Sections through the mass are shaped somewhat like a map of Africa, from which a rough impression of the external shape may be gained. It is weathered only superficially; the fusion crust, composed of iron oxides and dendritic metal, is preserved in many places.

Etched sections show a medium Widmanstätten structure with little oriented sheen and a bandwidth of 1.10±0.20 mm. The main reason for the dull appearance is that the kamacite was transformed by moderate shock pressures above 130 k bar to the hatched ϵ-structure. The hardness curve through the heat-affected zone to the unaltered interior is of type I, with exterior HV = 190±10, minimum HV = 170±10 and interior HV = 260±15. Plessite fields are abundant, either as comb plessite that repeats the octahedral pattern, or as martensitic and fine-grained, duplex $\alpha + \gamma$ fields.

Schreibersite is dominant as slender plates, typically 25 x 3 x 0.5 mm. In some of these are found small troilite inclusions, 0.5-1 mm in diameter, but no large troilite nodules were observed. Schreibersite further occurs as 25-50 μ wide grain-boundary precipitates and as 5-10 μ irregular blebs in the interior of the comb plessite. Rhabdites are very common as ultrafine precipitates, $<1\ \mu$, in the ferrite. Because the larger, primary schreibersite lamellae are arranged somewhat haphazardly, perhaps as Brezina lamellae parallel to $\{110\}_\gamma$, and are surrounded by asymmetric 1-2 mm wide zones of swathing kamacite, the Widmanstätten structure appears to be "messy," with too many directions. Point counting of the phosphides led to an estimate of 0.3% P for the bulk content of phosphorus.

Locally, thin lamellae, 10 x 3 x 0.05 mm, which seem to be troilite, stretch a few millimeters between schreibersite crystals that are normally enveloped in irregular rims of swathing kamacite. The exact morphology and mineralogy could not be examined, since the slice was large and therefore had a relatively rough finish. The crystals occur at about one per 40 cm^2.

A small near-surface section displayed a fusion crust composed of a 50 μ thick magnetite melt underlain by a 50-100 μ thick, cavernous, metallic melt, which had occasional inclusions of the magnetite. Several of the near-surface schreibersite plates evidently melted and were sucked out during atmospheric flight, since their cavities have been partly filled with dendritic, oxide-type melts to a depth of at least 1 mm. Similar selective burning out of the low-melting minerals is common, but rarely studied because corrosion rapidly destroys the delicate structures.

Under the fusion crust is a 2-3.5 mm thick heat-affected α_2 zone. Here it is possible to make some general observations on the original partition of phosphorus and carbon between the α- and the γ-phase. It is evident that an important reason for the thorns that develop upon rapidly reheated taenite is a high, local phosphorus concentration in the taenite, apparently high enough to create tiny wedges of melt in the high-temperature austenite boundaries, which form a network 10-25 μ in diameter. Carbon may also be concentrated in the thin, exterior layers of the taenite and plessite, but it diffuses rapidly away from this zone upon reheating in the atmosphere, without creating melt-pools.

Bartlett is structurally and chemically closely related to Spearman, Baquedano, Cleveland, Drum Mountains and Trenton, and is in many respects intermediate between phosphorus-poor medium octahedrites such as Henbury and Casas Grandes and phosphorus-rich medium octahedrites such as Grant and Chupaderos.

Specimen in the U.S. National Museum in Washington:
670 g slice (no. 1371, 16 x 11 x 0.8 cm)

Basedow Range. See Henbury (Basedow Range)

Batesville. See Joe Wright Mountain

Bear Creek, Colorado, U.S.A.

39°38'N, 105°20'W; 2400 m

Medium octahedrite, Om. Bandwidth 0.60±0.10 mm. ϵ-structure. HV 275±20.

Group IIIB. 9.95% Ni, 0.54% Co, 0.7% P, 2% S, 18.8 ppm Ga, 32.8 ppm Ge, 0.06 ppm Ir.

The fragment known as Jefferson (page 309) is a part of Bear Creek.

BARTLETT – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Gonyer in Bullard 1940	8.88	0.47	0.22									
Wasson 1968, pers. comm.	8.68								20.6	46.0	0.72	

HISTORY

A weathered mass, estimated to weigh 225 kg (500 lbs), was found in 1866 at 2,400 m altitude on the eastern slope of the Rocky Mountains (Shepard 1866). The locality was a deep gulch near Bear Creek, Jefferson County, about 40 km west of Denver (Henry 1866; Preston 1902b); on a modern map this corresponds approximately to the coordinates given above. The mass was secured by Shepard, who deposited the main mass of 160 kg under the name Aeriotopos in the Amherst Collection (Shepard 1872a). It was analyzed by Smith (1867) and by Jackson (1867), who also stated that his fragment "had been heated in a forge fire in order to cut it more easily." Bear Creek was again described by Cohen (1905) and by Nininger (Goldberg et al. 1951). Brezina & Cohen (Atlas 1886-1906: plate 38), Perry (1944) and H.H. & A.D. Nininger (1950: plate 13) gave photographs of etched slices. Axon (1961) observed the close similarity to Narraburra Creek, and Thode et al. (1961) included Bear Creek in their investigation on sulfur isotope abundances. Reed (1965a,b; 1969) examined the composition of the metallic phases and of the phosphides.

COLLECTIONS

Amherst (160 kg), Denver (35 kg endpiece), London (4.4 kg), Tempe (4.2 kg), Washington (275 g), Göttingen (235 g), Yale (156 g), Chicago (129 g), New York (116 g), Chicago (17 g).

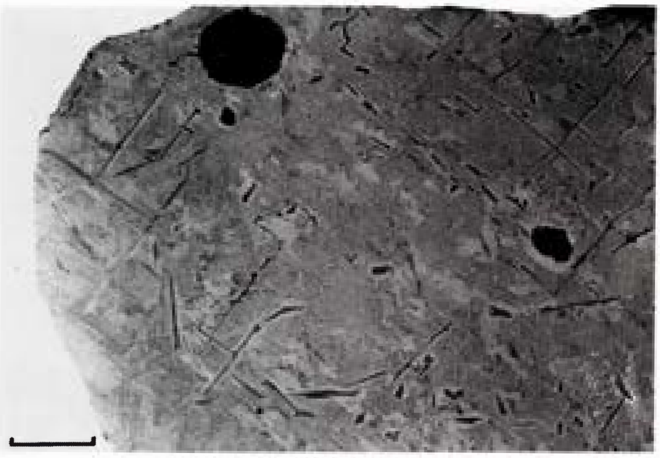

Figure 320. Bear Creek (Tempe no. 352.1). A typical group IIIB medium octahedrite with Brezina lamellae of schreibersite and large troilite nodules, all with conspicuous rims of swathing kamacite. Etched. Scale bar 30 mm.

DESCRIPTION

The irregular mass had approximate maximum dimensions of 55 x 35 x 25 cm and weighed perhaps 225 kg. The main mass in Amherst measures about 35 x 32 x 25 cm and weighs 160 kg. It is heavily weathered and covered by 0.1-1 cm thick, limonitic crusts. Locally, the corrosion penetrates along {111} planes, whereby the surface separates in octahedral fragments. The numerous, large troilite nodules are situated flush with the surface or raised slightly above the adjacent, more rapidly weathering metallic matrix. Such development indicates that several centimeters of the meteorite's skin has been lost by weathering and that the mass must be of high terrestrial age. The corrosion resistance of the troilite nodules appears to be related to their crystal size and homogeneity. When, as here in Bear Creek, the nodules are monocrystalline and homogeneous, they weather slowly, considerably more slowly than the metallic matrix. If, on the other hand, they have been altered by shock-melting to a microcrystalline aggregate of sulfide and metal, and possibly daubreelite and phosphide, they disintegrate more rapidly, probably because the finely dispersed metal phase corrodes rapidly.

The Widmanstätten structure is well developed, showing straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 0.60±0.10 mm. The kamacite displays an acicular ϵ-structure due to shock pressures of the order 200 k bar. Subboundaries of the ferrite phase are clearly seen, although the hatched ϵ-structure is superimposed; the hardness is 275±20. Taenite and plessite cover about 40% by area, and are developed in a very characteristic way, typical of many group IIIB irons (e.g., Bella Roca, Narraburra and Smith's Mountain). The plessite is an open-meshed, cellular to acicular aggregate of 25-100 μ kamacite, separated by taenitic wedges and ribbons of somewhat smaller dimensions. The interior of the swollen taenite wedges is decomposed to martensite, and this is, as usual but here easily observed, arranged in platelets parallel to the macroscopic Widmanstätten pattern (HV 380±30). The taenite rims around the plessite fields are frequently discontinuous (HV 340±20). In the ferrite phase in front of the taenite borders there is a garland of 10-20 μ wide, angular schreibersite bodies; locally they are still in contact with the taenite, but most are separated from the taenite by 5-10 μ wide ferrite channels, whereby the whole arrangement produces the impression of an "island arc."

BEAR CREEK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Goldberg et al. 1951	10.02	0.67							17.5			
Lovering et al. 1957	10.14	0.51				1.2	154		15	25		
Wasson & Kimberlin 1967	9.99								18.8	32.8	0.06	
Moore & Lewis 1968	9.65	0.57	0.63	430	300		130					

Schreibersite is extremely common as Brezina lamellae, typically 20 x 1 mm, surrounded by 1-2 mm swathing kamacite. Smaller H, L and Y shaped inclusions, and 0.1-1 mm broad rims around the troilite nodules, are also common. The "island arc" type is already mentioned. Finally, 5-10 μ thick rhabdites occur in variable amounts in the ε-phase. Point counting of the phosphides leads to an estimate of 0.7% P as a bulk value.

Troilite occurs as 0.1-6 cm nodules; a point counting of 600 cm^2 shows a total of 54 cm^2 troilite, corresponding to about 2.0% S. The nodules are composed of homogeneous monocrystalline troilite crystals, in which are numerous blackish, shiny, angular inclusions, 1-10 mm in diameter. These appear to occur with one or two per troilite nodule, and are probably phosphates (sarcopside, graftonite). Some troilite crystals show minor amounts of pressure twinning in the form of lenticular, oriented platelets.

Cohenite and graphite have been reported from this meteorite, but these minerals appear to be completely absent. Chromite is present locally as 200 x 10 μ prisms, often associated with small troilite and schreibersite precipitates. The fusion crust and the heat-affected rim zones are completely removed by corrosion.

Bear Creek, in structure and mineral association (phosphates), is similar to many other group IIIB irons, particularly Apoala, Augustinovka, Bella Roca, Chupaderos, Cuernavaca, Grant, Narraburra, Sam's Valley, Smith's Mountain and Verkhne Dnieprovsk.

Specimens in the U.S. National Museum in Washington:

115 g part slice (no. 968, 6 x 3 x 2 cm, Shepard Collection)
119 g weathered fragments (no. 968, Shepard Collection)
41 g polished slices (no. 3285, 4 x 2.5 x 0.2 cm and 2 x 2 x 0.2 cm)

Bear Creek (Jefferson), Colorado, U.S.A.

Coordinates as Bear Creek.

Medium octahedrite, Om. Bandwidth 0.60±0.10 mm. ε-structure.

Group IIIB, with about 10% Ni and 0.5% P, judging from the structure.

Should no longer be listed separately, since it is a fragment of Bear Creek.

HISTORY

A fragment of 41 g was mentioned by Tassin (1902a: 686) as being in the Shepard Collection of the U.S. National Museum. It was supposed to be a fall, having occurred June 1867, 30 miles from Denver. It was again listed, without further comment, by Merrill (1916a: 186). Previously Preston (1902b: 77), however, pointed out that the fragment could be a piece detached from the Bear Creek meteorite, which was found in 1866, 25 or 30 miles west of Denver, in Jefferson County. Hey (1966) listed Jefferson County as a doubtful meteorite.

The structure of Jefferson has apparently never been compared with that of Bear Creek, since the only material extant is the uncut specimen in the National Museum. A check of Shepard's handwritten catalog of his collection as

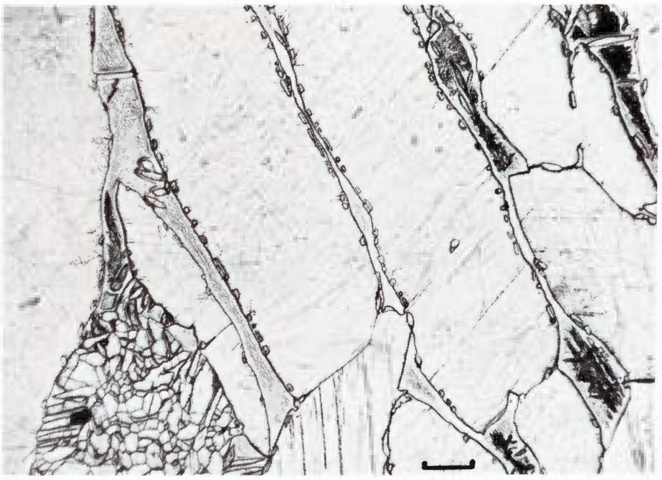

Figure 321. Bear Creek (Tempe no. 352.1). Low magnification reveals a shock-hatched kamacite and a significant number of schreibersite particles arranged in island-arcs adjacent to taenite. Etched. Scale bar 200 μ.

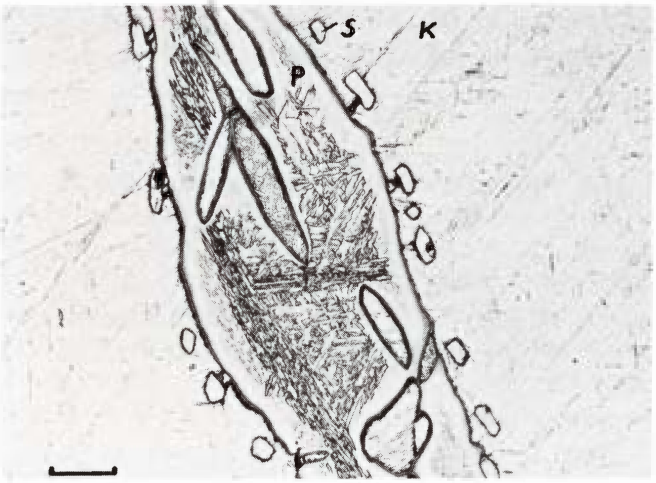

Figure 322. Bear Creek (Tempe no. 352.1). Shock-hatched kamacite (K), martensitic-bainitic plessite (P) and islands of schreibersite (S). Etched. Scale bar 50 μ.

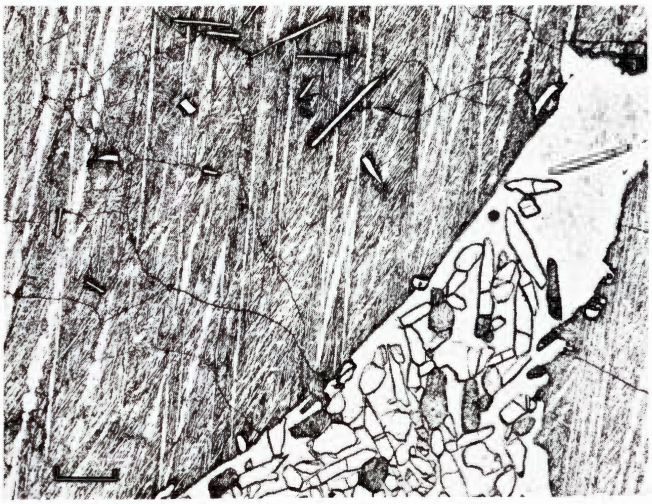

Figure 323. Bear Creek (U.S.N.M. no. 3285). Plessite with acicular kamacite, and large rhabdites in a shock-hatched kamacite. Etched. Scale bar 100 μ. (Perry 1950:volume 1.)

of November 1884, two years before his death, disclosed that no such fall as Jefferson was listed, and this was confirmed by checking the handwritten catalog of the collection as deposited by his son in the U.S. National Museum in July 1886. Apparently, then, the mislabeling occurred between 1886 and 1902.

COLLECTION

Only the 41 g fragment in Washington is known.

CHEMICAL ANALYSIS

No analysis has been performed.

DESCRIPTION

The fragment measures 4 x 3 x 1 cm and has been separated by chiseling along weathered octahedral planes from a larger mass. It weighed 41 g until it was split in halves recently in order to test the theory that it was a part of Bear Creek. The occluded chlorides, mentioned by Tassin, should be taken as nothing more than a statement that the iron is corroded and probably of high terrestrial age. That it is a fall, observed in June 1867, may be safely ruled out. No fusion crust and no heat-affected α_2 zone are present.

The etched section through the fragment discloses a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 0.60±0.10 mm. The kamacite has subgrain boundaries and a contrast-rich ϵ-structure, of the type which usually appears to be associated with shocks above 130 k bar. Plessite covers about 50% by area, mostly as net plessite with pointed α-platelets. The thicker taenite wedges are decomposed to martensitic platelets, which are parallel to the overall Widmanstätten structure.

Schreibersite is common, partly as 20 x 5 x 2 mm platy crystals, and partly as 10-20 μ thick, rounded grains that are located their own thickness outside the taenite-plessite regions. Some schreibersite is further present as 2-15 μ concave bodies inside the plessite fields, where these substitute for taenite. Rhabdites occur as 5-20 μ thick prisms in several of the kamacite lamellae. Troilite was not observed in the available sections.

From the brief description above it is seen that Jefferson in every structural detail is identical to Bear Creek. Since, moreover, its state of corrosion, date of find and approximate locality are the same as Bear Creek, and since it comes from Shepard, who possessed the main mass of Bear Creek, but did not know of any "Jefferson-fall in 1867," it is safe to conclude that Jefferson is nothing more than a mislabeled Bear Creek specimen, as Preston concluded in 1902.

Specimen in the U.S. National Museum in Washington:

39 g fragment (no. 1047, 4 x 2.5 x 1 cm, Shepard Collection no. 81).

Bear Lodge, Wyoming, U.S.A.

44°33'N, 104°13'W; 1200 m

Medium octahedrite, Om. Bandwidth 1.15±0.15 mm. Annealed ϵ. HV 210±10.

Probably group IIIA, judging from the structure. 7.88% Ni, 0.51% Co, 0.14% P.

HISTORY

An angular, weathered mass of 48.7 kg was found in 1931 by a workman who was repairing the highway at the eastern base of Bear Lodge Mountains, 19 km northeast of Sundance, Crook County. It was briefly described by O'Harra (1932); Nininger & Nininger (1950: plate 5) presented a photomacrograph.

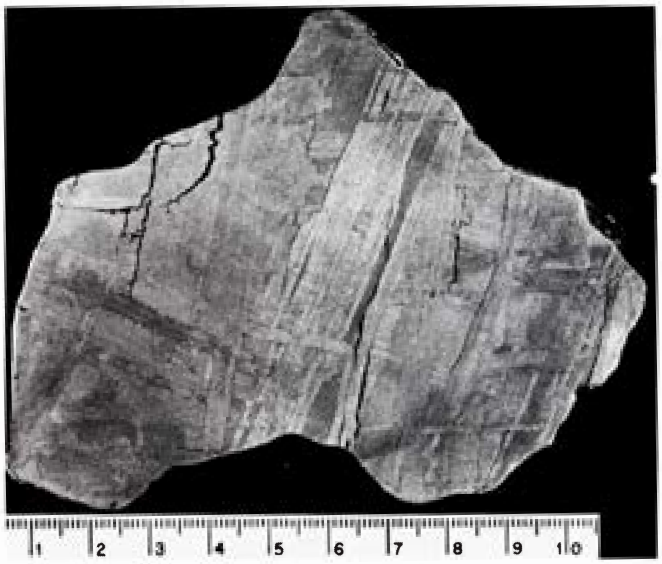

Figure 324. Bear Lodge (Tempe no. 286.ax). A general view of a deep-etched section. The matte appearance is mainly due to an annealed shock-hatched kamacite. Scale bar in cm. (Courtesy C.B. Moore.)

Figure 325. Bear Lodge (U.S.N.M. no. 867). The shock-hatched kamacite has precipitated numerous γ-particles during annealing in space. The taenite and plessite fields display tempered features. Etched. Scale bar 50 μ.

COLLECTIONS

South Dakota School of Mines, Rapid City (main mass), Washington (3.26 kg), London (537 g), Tempe (330 g).

DESCRIPTION

The mass, with overall dimensions of 35 x 25 x 16 cm, is covered with 0.1-0.4 mm thick adhering oxide-shales from terrestrial weathering. It is roughly sculptured with thumbprints, 2-5 cm in diameter, and with edges and ridges. There is no doubt that the pits and the general morphology were created in the atmosphere, since the heated rim zone of α_2 is preserved as a 1-2 mm wide zone along the edges of several sections. Corrosion has at the most removed 1 mm, but also penetrates to the center of the sections along grain boundaries.

Etched sections display a somewhat distorted Widmanstätten structure of slightly undulating, long ($\frac{L}{W} \sim 30$) bundled lamellae with a width of 1.15±0.15 mm. About 30% by area is covered by taenite and plessite. The latter is mostly an open-meshed comb plessite, partly resorbed in the matrix, but may also display martensitic and fine-grained, duplex structures. The matrix must have been shocked above 130 k bar, since the ferrite is of the hatched-acicular variety. At high magnification it appears that the matrix is two phased; all linear elements of the hatched structure are, in fact, produced by rows of less than 0.5 μ thick taenite particles. The structure may be interpreted as a result of shock and gentle reheating that decomposed the supersaturated, deformed ferrite. In harmony with this interpretation is the low microhardness of 210±10, as shock-hardened, unannealed ϵ is normally 300±25.

Figure 326. Bear Lodge (U.S.N.M. no. 867). The fine γ-precipitates delineate the previous hatched ϵ-structure. Also four rhabdite crystals. Etched. Scale bar 10 μ.

Schreibersite is only present in minor amounts as 25 μ thick veinlets in the grain boundaries. Rhabdites occur as 1-5 μ thick prisms that often are sheared several microns. Troilite was seen as one scalloped inclusion 3 mm in diameter on a total of 300 cm^2; its microstructure could not be examined as it was in the middle of a large, deep-etched section. Daubreelite is present as 20-50 μ rounded blebs in the matrix.

Bear Lodge is structurally somewhat similar to such irons as Boxhole, Casas Grandes and Merceditas. It is, judging from the structure, a normal group IIIA iron that has been subjected to mild plastic deformation plus, at some later time, an intensive shock plus a mild reheating that may have been associated with the shock.

Specimen in the U.S. National Museum in Washington:
3,265 g endpiece (no. 867, 17 x 16 x 3 cm)

Bechuanaland, South Africa

A meteorite entered under this name in catalogs by Brezina (1896: 306), Wülfing (1897: 23) and Berwerth (1903: 51) is probably a mislabeled Gibeon sample. It never reappeared as a Bechuanaland sample, probably because the owners realized their mistake and corrected it.

Bella Roca, Durango, Mexico
24°55′N, 105°25′W

Medium octahedrite, Om. Bandwidth 0.70±0.10 mm. ϵ-structure. HV 260±10.

Group IIIB. 9.91% Ni, 0.55% Co, 0.85% P, 2% S, 16.7 ppm Ga, 31.1 ppm Ge, 0.014 ppm Ir.

HISTORY

A mass of 33 kg was found before 1888 on a peak of the Sierra de San Francisco, called La Bella Roca, near Santiago Papasquiaro. Acquired by H.A. Ward during one of his collecting trips to Mexico, the meteorite was described by Whitfield (1889), who presented two woodcuts of the exterior appearance. After being cut in slices and widely distributed by Ward, it was described again by Brezina (1896: 271) and by Cohen (1905: 374) with photomicrographs in the Atlas (Brezina & Cohen 1886-1906: plate 37). Etched sections later appeared in many publications, e.g., Ward (1904a), Mauroy (1913), Nininger & Nininger (1950) and Mason (1962a: figure 26).

BEAR LODGE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
O'Harra 1932	8.12											
Moore & Lewis 1968	7.88	0.51	0.14	50	20							