Figure 368. Boxhole (U.S.N.M. no. 1305). Typical kamacite lamellae with shock-hatched structures of varying appearance but similar hardness. Narrow, cloudy taenite lamellae. Etched. Scale bar 300 μ.

plessite and taenite areas, where a 50 μ rim zone is completely transformed to martensitic-bainitic structures. The heat-altered matrix ranges in hardness irregularly from 120 to 180; the structure and the hardness indicate that the slugs were reheated as a whole; there are no regular gradients against the present surfaces. Schreibersite is melted but has not had time to dissolve the surrounding walls and create a smooth, round cavity. The rhabdites are melted and partly resorbed in the matrix. The troilite is melted and injected into centimeter-long narrow cracks, more or less parallel to (111) planes. Upon solidification, fine-grained eutectics and mixtures with iron were created. The structures described here correspond closely to structures described from highly shocked Canyon Diablo specimens and from Henbury specimens, and they were probably caused by the compression and heating when the explosion shock shattered the impacting mass. The residual temperature must for a few seconds have been above 1000° C to create the observed associations of α_2, melted schreibersite and melted troilite.

Summing up, we can thus conclude that about 5,000 years ago a large iron body penetrated the atmosphere with no appreciable loss of speed. At high altitude a minor part of the surface, probably protuberances and other irregularities, were torn off and proceeded as independently falling bodies. The main mass exploded on impact, created the crater and hurled numerous fragments up to a few kilometers away. The major part of the main mass probably vaporized or was disseminated as minute melted globules. It appears that the event was rather similar, on a minor scale, to what occurred at Henbury, Wabar and Canyon Diablo.

The least damaged Boxhole specimens, those that fell as rather normal independent irons, indicate that the preatmospheric structure was a shock-hardened medium octahedrite with ϵ-structure. The detailed chemical composition, the ϵ-structure and the somewhat higher phosphide content seem to establish Boxhole as a meteorite different

from Henbury. It is, however, related to Henbury, as well as to the smaller meteorites, Red River, San Angelo and Canyon City.

The reheated and distorted slugs are structurally similar to explosion fragments from Canyon Diablo, Henbury and Wabar.

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

2,109 g full slice (no. 1305, 18 x 13 x 1.5 cm)
3,700 g individual (no. 1305, 17 x 17 x 6 cm)
  208 g fragments (no. 1305)
   53 g individual (no. 1638)
  431 g 37 individuals (no. 3227)
  373 g 4 shale balls (no. 1306)
  472 g 6 shale balls (no. 3228-29) no. 3227-29 collected by E.P.
    Henderson and Brian Mason 1963 (personal communication).

Braunau, Bohemia, Czechoslovakia
50°36'N, 16°20'E

Hexahedrite, H. Single crystal larger than 25 cm. Neumann bands. HV 155±10.

Group IIA. 5.39% Ni, 0.44% Co, 0.24% P, 0.08% S, 59 ppm Ga, 183 ppm Ge, 12 ppm Ir.

HISTORY

At 3:45 on the morning of July 14, 1847, people were awakened by the sound of loud detonations which roused them out of their houses in several villages in the Sudeten Mountains near the Braunau Benedictine Abbey. The detonations were also heard in Münsterberg 50 km east, and in Breslau, 75 km northeast of Braunau, and probably even farther away. Two fiery masses were observed to fall near the town of Braunau, while a blackish meteoric train slowly dissipated on the northwestern sky. One mass of 23.6 kg was recovered from a vertical hole 0.9 m deep in a meadow, and another of 17.2 kg penetrated the roof of a small cabin where three children were sleeping, about 2,200 m farther south. A detailed account with map and sketches was given by Beinert (1847; 1848). The

Figure 369. Braunau. The endpiece in Tübingen shows the distinct regmaglypts. Scale bar in cm.

Braunau meteorite was only the third iron observed to fall, and because the larger mass was cut and rapidly distributed to leading authorities, it meant a decisive step forward in understanding iron meteorites.

Neumann (1848; 1850) described etched surfaces and measured the traces appearing on the cut faces. He found the traces, which were later named after him, to be twin lamellae in the cubic ferrite. Today we know that the Neumann bands are deformation twins in the α-phase produced by shocks below 130 k bar, and that the twin plane is $\{211\}_\alpha$, corresponding to the icositetrahedron (= trapezohedron). Haidinger (1847) observed that the whole mass was one ductile crystal which would easily split along the cubic cleavage planes with a blow from a hammer. Tschermak (1872a; 1874) proposed the term hexahedrites for such irons. Rose (1864a: 48, 138) described and illustrated, with a beautiful technique, the fine tetragonal needles of iron-nickel phosphide and proposed the name rhabdite for them. Reichenbach (1858) observed and described the heated rim zone and compared it to that of the other then-known falls, Charlotte and Hraschina. Cohen (1905) reviewed the literature and appended an analysis.

Böggild (1927) measured the rhabdites on the goniometer, and Perry (1944) and Vogel (1952) gave photomicrographs. Marvin (1963) identified wüstite coexisting with magnetite in the fusion crust. This was surprising, as wüstite was believed to decompose rapidly in a terrestrial environment. El Goresy (1965) observed chromium sulfide in Braunau, and saw in the microcrystalline troilite an indication of cosmic reheating. Reed (1965a, b) determined the composition of the kamacite and phosphide phases with a microprobe. Age determinations have been carried out by Cobb (1966) and Chang & Wänke (1969), who found low cosmic ray exposure ages of the order of 7×10^6 years.

COLLECTIONS

The smaller mass of 17.2 kg, previously in the abbey of Braunau, is now in the National Museum, Prague, which also has 1,085 g samples of the larger mass (Tuček 1966: 21 and plate 3), Vienna (2.45 kg), Berlin (1.48 kg), Tübingen (915 g), Munich (590 g), London (551 g), Chicago (465 g), Paris (430 g), Washington (237 g), Moscow (236 g), Dresden (235 g), New York (222 g), Budapest (200 g, lost in 1956 ?), Göttingen (160 g), Calcutta (156 g), Copenhagen (117 g), Canberra (116 g), Leningrad (110 g), Breslau (96 g), Harvard (92 g), Bonn (91 g) Hamburg (47 g), Amherst (40 g), Tempe (26 g). Small pieces are also to be found in other collections.

DESCRIPTION

The weights in modern units of the two recovered masses are 23.8 kg and 17.2 kg, with the dimensions of 25 x 25 x 13 cm and 23 x 21 x 14 cm. Beinert (1848) described the masses as spherical segments; from his unsuccesful attempts to reconstruct the parent mass he concluded that two more fragments of similar sizes had also fallen but had not been found. It is, however, also possible that the two individuals were formed at sufficient altitude to become deeply ablated and grooved, whereby the original parting surface, presumably a $\{100\}$ cleavage plane, became unrecognizable.

The surfaces are heavily sculptured and subdivided in grooves, each about 2-4 cm in diameter and 5-15 mm deep. The fused crust has striae and streamers and spill-overs on edges. The sections show that a 100-200 μ thick magnetite-wüstite crust, often composed of five to eight successive layers, may be deposited either directly on the metallic meteorite or, more commonly, may be formed over one to six layers of dendritic, fused metal, totalling 50-200 μ. The microhardness is 300-350.

The heat-affected α_2 zone extends 2-3 mm below the crust, and the included rhabdites are melted within half this distance. As usual, the solidification of the small inclusions started from the cold interior which acted as a heat sink. This may be concluded from the observation that the primary dendrites line the rhabdite cavities, particularly on the inward side. The microhardness of the α_2 zone is
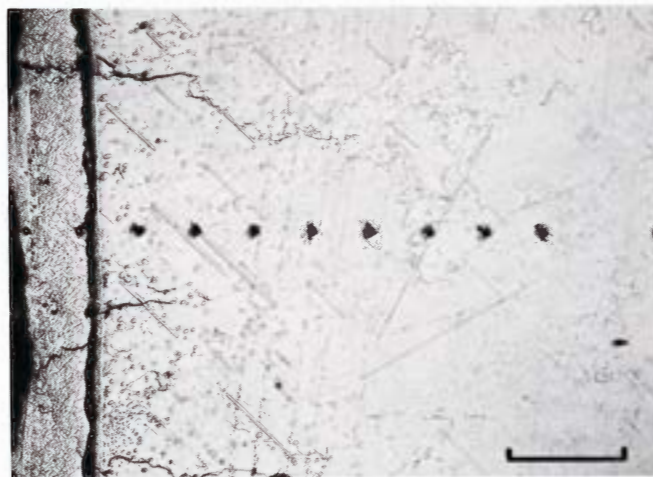

Figure 370. Braunau (U.S.N.M. no. 976). The metallic fusion crust, to the left, is spalling off along the interface with the heat-affected α_2 zone. A row of microhardness indentations is visible. The precipitates in several, almost vertical lines, indicate the site of previous Neumann bands. Etched. Scale bar 300 μ.

BRAUNAU – SELECTED CHEMICAL ANALYSES

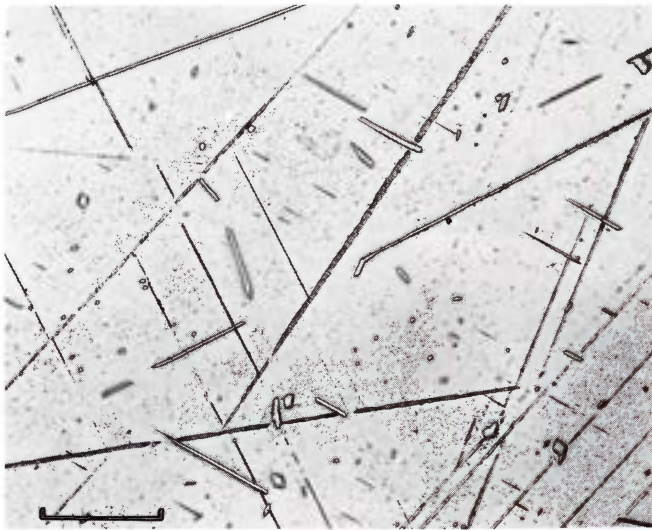| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Duflos & Fischer 1848	5.52	0.53										
Knauer in Cohen 1905	5.21	0.92	0.24	900	800	500	700					
Cobb 1967	5.32	0.44					131		56.5		11	
Wasson 1969	5.49								61.5	183	12	

Figure 371. Braunau (U.S.N.M. no. 976). Decorated Neumann bands and plate-shaped and prismatic rhabdites. Etched. Scale bar 200 μ.

unusually low, 165±10. Neumann bands are still visible in the α_2 zone because the many rhabdites which earlier had precipitated here still mark their directions.

At an early stage in the analysis it was shown that Braunau is one large cubic ferrite crystal. The microhardness is 155±10, indicating a rather well-annealed ferrite. Neumann bands extend from rim to rim, but each band is often discontinuous and decorated along both sides with a number of 2-5 μ thick rhabdites. On several specimens of this meteorite it is evident that plate-shaped rhabdites, up to 2 mm long, are arranged in parallel planes with a mutual distance of about 1 cm, as in Hex River. Furthermore, in the matrix there is a profusion of rhabdites smaller than 1 μ across.

Troilite is present as 1-10 mm irregular nodules. They are fine-grained and complex in that they are apparently rapidly solidified melts produced by shock. Larger 10-20 μ partly dissolved fragments of daubreelite and schreibersite are trapped in the 1-2 μ polycrystalline sulfide-metal eutectic. The sulfide eutectic also penetrates the grain boundaries of the surrounding metal, creating a 25-50 μ network. Similar development of the troilite nodules is observed in a great many other meteorites, e.g., see Bingera, Bodaibo, and Wabar.

Braunau is a normal, monocrystalline hexahedrite, structurally resembling Coahuila, and with indications of a cosmic, mild reheating.

Breece. See Grant

Brenham, Kiowa County, Kansas, U.S.A.

Although Brenham is a very important meteorite, it is not treated in this monograph because it is a pallasite. Brief mention and a few references will, however, be found under Hopewell Mounds which represents transported Brenham material.

Bridgewater, North Carolina, U.S.A.
35°43'N, 81°52'W; 300 m

Medium octahedrite, Om. Bandwidth 0.65±0.15 mm. ϵ-structure. HV 270±25.

Group IID. 9.9% Ni, 0.35% P, 81 ppm Ga, 82 ppm Ge, 10 ppm Ir.

HISTORY

A mass of 29 pounds (13.2 kg) was found in 1890 during plowing; the locality was 3 km from Bridgewater Station in the western part of Burke County, near the Mc Dowell County line. Since the direction from Bridgewater is not stated, the coordinates above are for Bridgewater. The mass was easily broken into two pieces by the finders who assumed it was silver. It was acquired by Kunz (1890a) who described it, and soon thereafter it came to Vienna with part of Kunz's collections (Brezina 1896: 234, 271). It was again described by Cohen (1905: 381), and photographs were presented by Vogel (1928; 1932).

COLLECTIONS

The smaller of the two broken pieces, 4.5 kg, and half of the larger piece, 4 kg, are in Vienna. The rest has been cut and distributed. Budapest (537 g) Prague (168 g), Helsinki (150 g), New York (156 g), Berlin (141 g), Chicago (102 g), Rome (92 g) Stockholm (67 g), Washington (54 g), London (51 g), Ottawa (42 g), Delft (about 30 g), Yale (19 g), Vatican (17 g).

BRIDGEWATER – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Venable in Kunz 1890a	9.94	0.76	0.35									
Wasson 1970, pers. comm.	9.8								81.0	82.0	10	

DESCRIPTION

The average dimensions were 22.5 x 15 x 10 cm, and the mass was pitted and covered with limonitic weathering products. It was easily split along octahedral, phosphide-rich planes, probably aided by the presence of terrestrial corrosion products here.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a bandwidth of 0.65±0.15 mm. The kamacite shows an indistinct ϵ-structure and has a hardness of 270±25. The hardness ranges widely, partly because the ϵ-structure is superimposed by cold working to various degrees. Locally a violent shear has displaced adjacent structural components as much as 2 mm; the shear zone itself may be as narrow as 10 μ.

Taenite and plessite cover 30-40% by area, mostly as dense and martensitic fields. A typical plessite field will have a yellow tarnished taenite rim (HV 335) followed by an indistinct martensitic transition zone (HV 365±15). Then follows a marked martensite developed parallel to the bulk Widmanstätten structure (HV 425±25), and finally a duplex $\alpha + \gamma$ structure (HV 300±15).

Schreibersite occurs as 0.2-0.5 mm wide, angular, monocrystalline blocks located along the midrib of many kamacite lamellae and also as 10-50 μ wide grain boundary precipitates. Irregular 5-20 μ schreibersite grains are rather frequent in the comb plessite where they are easily mistaken for small taenite blebs. A modest quantity of 0.5-1 μ thick rhabdites are also present. Troilite is only present as minor inclusions, e.g., 2 x 1 or 4 x 0.2 mm, often partly surrounded by schreibersite crystals 1 mm wide. The troilite is monocrystalline with lenticular twin sparks. Locally 1-100 μ wide daubreelite lamellae are present, and a 0.3 mm chromite crystal (HV 1080±50) was also observed.

Bridgewater resembles somewhat N'Kandhla and Puquios and is a member of group IID.

Specimens in the U.S. National Museum in Washington:
24 g part slice (no. 554, 5 x 2 x 0.4 cm)
30 g part slice (no. 2695, 5 x 4 x 0.15 cm)

Briggsdale, Colorado, U.S.A.
40°40′N, 104°19′W; 400 m

Medium octahedrite, Om. Bandwidth 1.25±0.15 mm. Neumann bands. HV 190±10.

Group IIIA. 8.21% Ni, 0.51% Co, 0.18% P, 20.1 ppm Ga, 40.7 ppm Ge, 0.72 ppm Ir.

HISTORY

An oriented mass of 2.23 kg from Briggsdale, Weld County, was recognized as a meteorite in 1949 (Nininger & Nininger 1950). A photomicrograph of an etched section was published here (plate 16) and later reprinted in Nininger's book (1952a: plate 8).

COLLECTIONS

One half is in Tempe (1,172 g), the other in London (902 g), a small slice is in Washington (60 g).

Figure 372. Bridgewater (Helsinki no. A 2318). Cut almost parallel to (111)γ. Strong oriented sheen in the Widmanstätten structure. Millimeter-sized schreibersite crystals with rims of swathing kamacite. Terrestrial corrosion (black). Deep etched. Scale bar 20 mm.

Figure 373. Briggsdale (Tempe no. 535.1x). A view of the entire mass before cutting. Scale bar 20 mm.

BRIGGSDALE – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore & Lewis 1968	8.25	0.51	0.18	80	30							
Scott et al. 1973	8.17								20.1	40.7	0.72	

DESCRIPTION

The mass is roughly a half sphere with maximum dimensions of 11 x 10 x 6 cm. The smooth, convex front surface terminates along an undulating edge against the rather plane back side. Spillover of ablation-melted metal from the front side has been deposited here as layered, warty ridges and narrow carpets. A section near the edge shows the deposits to be locally 3 mm thick and to wedge out in an irregular way. The mass was evidently highly oriented, as Nininger mentioned, during entry, and while only minor amounts of fused metal could solidify on the frontal surface, relatively thick deposits could build up on the protected rear side (HV 325±25). Similar orientation effects have been described from Costilla Peak (Maringer 1960) and are present on a great many other oriented or semi-oriented irons. The heated rim zone of α_2 is 2-5 mm wide, and has a hardness of 200±10. Immediately below the α_2 zone is a recovered transition zone with a minimum hardness of 160 (hardness curve type II).

The Widmanstätten pattern consists of long ($\frac{L}{W} \sim 25$) bundles of α-lamellae with an average width of 1.25±0.15 mm. Neumann bands are well developed in the kamacite, and they are decorated by 1-2 μ wide phosphide particles. The kamacite matrix is also rich in almost submicroscopic precipitates, probably consisting of both taenite and phosphides. The hardness of the duplex kamacite is 190±10.

Plessite occupies about 25% by area, mostly as open-meshed comb plessite patterns. In the swollen parts of the taenite ribbons annealed martensite is present, and occasionally pearlitic structures with 0.4 μ wide taenite lamellae may be observed. An indistinct grid of fine, crossing lines in the taenite may be the traces of sliplines, decorated by ultrafine precipitates. A similar grid is present in Anoka, Dungannon, and other irons.

Schreibersite is common as 40-80 μ wide grain boundary precipitates with a local, larger, angular block. All schreibersite is monocrystalline. Rhabdites were not seen but may, as mentioned above, be present on a submicroscopic scale. Beautifully developed phosphide eutectics have formed within the outer half of the heated α_2 rim zone.
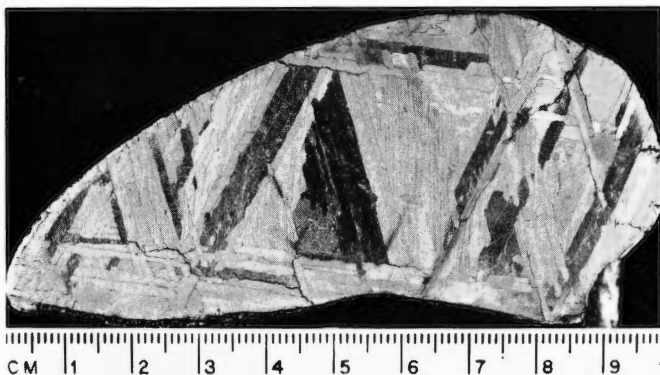

Figure 374. Briggsdale (Tempe no. 535.1x). This full slice shows the heat-affected continuous α_2 rim, and an interior medium octahedrite structure. Etched. Scale in cm. (Courtesy C.B. Moore.)

Only one troilite nodule, 1 mm in diameter, was located in the available sections. It was shock melted and solidified to 1-5 μ iron-sulfide eutectics. Tiny veinlets of fused sulfides had penetrated 25-100 μ into the adjacent metal along grain boundaries.

Briggsdale is a shocked and annealed medium octahedrite of group IIIA. It is related to Roebourne but is not as fully annealed and recrystallized as this one.

Specimen in the U.S. National Museum in Washington:
60 g slice (no. 1704, 8 x 2 x 0.6 cm)

Bristol, Tennessee, U.S.A.
36°32'N, 82°6'W; 450 m

Fine octahedrite, Of. Bandwidth 0.30±0.05 mm. Neumann bands HV 185±25.

Group IVA. 8.07% Ni, 0.42% Co, 0.055% P, 2.13 ppm Ga, 0.12 ppm Ge, 1.6 ppm Ir.

HISTORY

A mass of 20 kg was found about 1925 near Holston River, approximately 19 km southeast of Bristol, Sullivan County, in the Appalachian Mountains. It was reported by C.J. Stone to the American Meteorite Laboratory, where Nininger recognized it as a meteorite (A.D. Nininger 1939; Goldberg et al. 1951). Since Holston River is only about 9 km southeast of Bristol, the information on the locality of find is inconsistent; the approximate coordinates are given above. Nininger & Nininger (1950: plate 1) produced a photomacrograph, and Massalski et al. (1966) accompanied their microprobe analysis of the plessite fields with several photomicrographs. Bristol was also included in microprobe studies by Wood (1964) and Short & Andersen (1965) and in the thermomagnetic study by Lovering & Parry (1962). Isotope and age determinations were conducted by Vilcsek & Wänke (1963), Voshage & Hintenberger (1963), Bauer (1963) and Hintenberger & Wänke (1964). The cosmic radiation age was given by Voshage (1967) as 470±60 million years and by Chang & Wänke (1969) as 330±40 million years. The terrestrial age, by the $^{36}Cl/^{10}Be$ method, was determined to be 200,000±50,000 years by Chang & Wänke (1969).

COLLECTIONS

London (4,450 g), Tempe (2,149 g), Harvard (1,103 g), Chicago (443 g), New York (193 g), Washington (126 g). The balance of more than 10 kg appears to be mainly in private collections.

DESCRIPTION

The weathered, lenticular mass had the approximate dimensions of 28 x 20 x 9 cm. Corrosion penetrates along grain boundaries to 5 or 10 mm depth which is rather unusual for a fine, homogeneous octahedrite, and the heated rim zone of α_2 has disappeared. In many places the

surface is disintegrating into small fragments separated by octahedral planes. It is thus plausible that the high terrestrial age of 200,000 years determined by Chang & Wänke (1969) is correct.

The polished sections show few, if any, inclusions. The troilite foil mentioned by Nininger & Nininger (1950) appears to be the only one recorded. However, it may only represent an unusually concentrated corrosion attack along a certain set of octahedral planes. The black ribbon, 1 mm wide, probably consists mainly of terrestrial oxides.

The Widmanstätten structure is well developed as straight, long ($\frac{L}{W} \sim 35$) lamellae with a bandwidth of 0.30±0.05 mm. Neumann bands are common, even in the finest cells of the comb plessite. The microhardness is 175±15, except in near-surface zones where it occasionally increases to 210. The Neumann bands and the taenite

Figure 376. Bristol (U.S.N.M. no. 1324). Typical structure. Above, an open-meshed net plessite, then kamacite with Neumann bands, and below, a duplex, almost unresolvable finger plessite. Etched. Scale bar 200 μ. (Perry 1950:volume 1.)

lamellae are then bent and distorted, indicative of significant cold work. It appears that the damage could be due to necking and disruption in the atmosphere, but the evidence is not conclusive because it was only detected on the single available section and may not be representative for the main mass.

Taenite and plessite cover 40-50% by area and are of the usual IVA variety: (i) comb and net plessite; (ii) cellular plessite, i.e., open-meshed plessite subdivided in differently oriented cells of variable size (100-400 μ) and each containing oriented taenite rods and blebs; (iii) dense duplex $\alpha + \gamma$, where precipitation has occurred on a micro-Widmanstätten scale; and (iv) yellow taenite with indistinct brown and dark martensitic transition zones towards the interior duplex zones. The morphology and hardness suggest that slight cosmic annealing has occurred subsequent to the Neumann band producing event.

Schreibersite and rhabdite were not detected, in accordance with the low bulk phosphorus content of 0.055%. Neither were troilite nor other meteoritic minerals observed on the small U.S. National Museum specimen. Troilite is undoubtedly present in other sections.

Bristol is a normal group IVA meteorite, closely related to Gibeon and Charlotte and slightly cosmically annealed.

Figure 375. Bristol (Tempe no. 216.14). A general view of the fine octahedrite which is closely related to Gibeon. Etched. Scale bar in cm. (Courtesy C.B. Moore.)
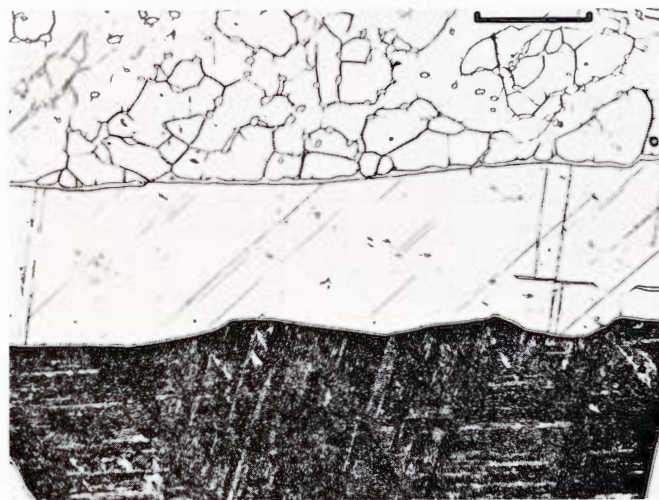
BRISTOL – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Goldberg et al. 1951	8.20	0.49							2.41			
Lovering et al. 1957		0.44				111	333		<2	<1		
Nichiporuk & Brown 1965											1.7	5.0
Smales et al. 1967						104	134		2.19	0.15		
Moore et al. 1969	8.11	0.40	0.055	75	20		130					
Schaudy et al. 1972	7.90								2.13	0.12	1.6	

Reed (1969) gave the composition of the kamacite as 7.3% Ni, 0.058% P.

For a possible connection with Harriman (Of), the reader is referred to page 630.

Specimen in the U.S. National Museum in Washington
126 g part slice (no. 1324, 4.5 x 3x 1 cm)

Britstown, Cape Province, South Africa
30°36′S, 23°30′E

Plessitic octahedrite with silicates, Opl. Bandwidth 20±10 μ. HV 385±15.

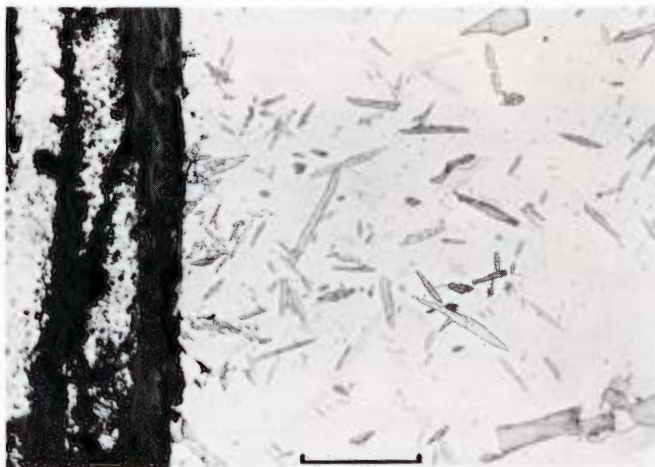Anomalous. No analysis available, but estimated to contain 18±2% Ni.

HISTORY

A complete individual, weighing 544 g, was brought from South Africa to Germany by an engineer, Mr. Brandau, before 1910. He had obtained it from a Mr. Wipplinger of Britstown, the locality of which is given above, according to Times Atlas 1956, plate 95. Through Ward's Establishment the mass came to Harvard University, where it was described with a photomacrograph by Palache (1926a). The main mass (470 g) was in Harvard, but is apparently now lost; other specimens are in London (17 g), Washington (19 g) and Yale (19 g).

CHEMICAL ANALYSIS

None is available. The structure indicates, however, that Britstown is rather rich in nickel, possibly with 18±2%.

DESCRIPTION

The irregular, knobby mass has the overall dimensions of 9 x 6 x 5 cm and is somewhat corroded, having 0.5-1 mm thick limonitic crusts adhering locally. The weathering has selectively attacked the α-phase beneath the crust but has not penetrated very far. The ablation-melted crust is preserved in many places as laminated, dendritic,

metallic material up to 1 mm thick. In the heated rim zone, melted schreibersite is present to a depth of 1 mm, and α_2 to a depth of 2-3 mm. The conclusion must inevitably be that Britstown is a well-preserved fall, contrary to the statement of Palache (1926a) and Hey (1966).

The polished and etched section shows a metallic matrix in which irregular troilite-silicate-graphite nodules of a few millimeters size are scattered. The metal is decomposed to fine spindles of α, typically 200 x 20 μ in size, in a Widmanstätten pattern. The ferrite phase shows no Neumann bands but has tangles of subgrain boundaries and a hardness of 205±8. Evidently the transformation upon cooling from γ to α only just got started when relatively rapid cooling prevented further large scale diffusion from taking place. The interstices between the
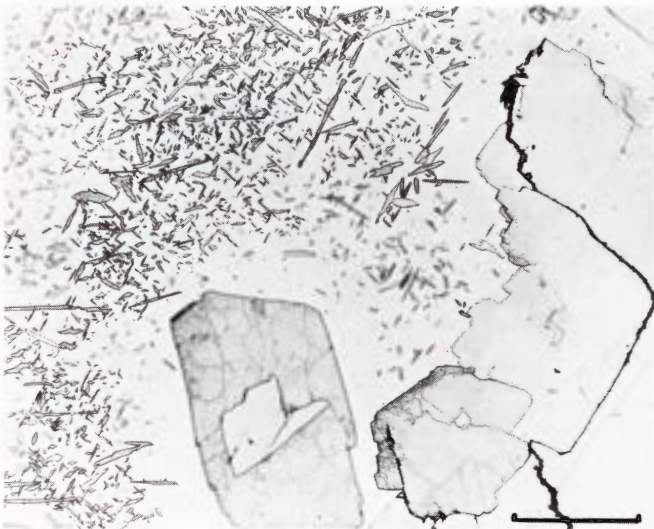
Figure 378. Britstown (U.S.N.M. no. 766). The size of the pointed α-platelets varies from place to place on the section, compare Figure 377. Gray areas with subboundaries are swathing kamacite around schreibersite (S) and silicate-troilite (outside the picture). Etched. Scale bar 200 μ.
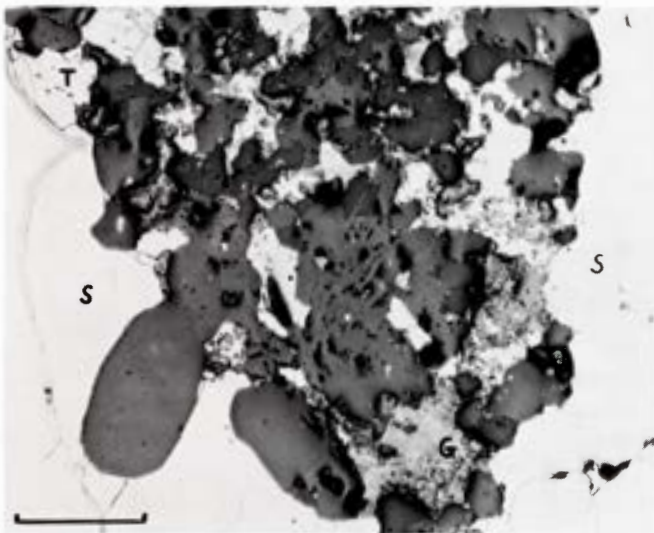

Figure 377. Britstown (U.S.N.M. no. 766). A metallic fusion crust of laminated dendritic material is partially preserved on the left. The interior shows pointed α-platelets (gray) in retained taenite. Etched. Scale bar 200 μ.

Figure 379. Britstown (U.S.N.M. no. 766). Complex nodule of silicates (dark gray), troilite (T), graphite (G) and schreibersite (S). Polished. Scale bar 200 μ.

kamacite spindles are occupied by taenite which is decomposed to martensite or bainite and has a high hardness of 385±15. In the heat-affected surface zones, the martensite is tempered to lower hardnesses of 290 - 325.

Schreibersite is present as large monocrystalline skeleton crystals, e.g., 4 x 2 mm, but also as minute, subangular bodies, 10-50 μ in diameter. Swathing kamacite with an extremely ragged rim is developed in proportion to the size of the schreibersite crystals, from 200 μ widths down to 20 μ. Although schreibersite is not seen in all of the kamacite spindles, its presence in many of them is sufficient to make it highly probable that it is also present in the rest of the spindles, either above or below the section plane. It appears, therefore, that the schreibersite was the first to precipitate from the austenite phase and that kamacite later nucleated and grew preferentially around these inclusions. The bulk content of the meteorite, based upon point counting, is about 0.25% P.

Complex nodules of troilite-olivine-graphite-schreibersite occur in several places. The troilite individuals are 0.5-2 mm in diameter and show undulatory extinction; they are fractured and divided in lenticular units and, in the 1-2 μ thick fracture zones, anisotropic graphite is present. Olivine is common as rounded, euhedral crystals with kaleidoscopic colors in reflected light. The interstices between the olivine crystals are filled with troilite and graphite, grouped in sheaves. Occasionally aggregates, up to 1 mm, of sheaves or spherulites of graphite with fine extinction may be seen. Perfect cliftonite individuals 50 μ in diameter occur locally. Schreibersite occurs as millimeter-sized rim zones; they are monocrystalline but brecciated and easily break free during polishing. In one schreibersite crystal two thin, 3 μ, but long, 1 mm, plates of an unidentified, silvery white, anisotropic mineral, associated with graphite was seen.

Britstown appears to be an anomalous iron, which may be related to Wedderburn and Freda. Its troilite-silicate-graphite-schreibersite association also indicates relationships to Dayton.

Specimen in the U.S. National Museum in Washington:
19 g slice (no. 766. 6 x 2 x 0.2 cm).

Brownfield (iron), Texas, U.S.A.
33°13'N, 102°11'W

Medium octahedrite, Om. Bandwidth 0.75±0.20 mm.

Group IID. 10.32% Ni, 78 ppm Ga, 85 ppm Ge, 10 ppm Ir.

HISTORY

A mass of 1,626 g was plowed up in 1966, in a field near Brownfield, Terry County, and was recognized as a meteorite, according to a note by Mr. Glenn I Huss, Denver (Meteoritical Bulletin, No. 40, 1967).

COLLECTIONS

Glenn Huss, Denver (main mass), Copenhagen (114 g), Harvard (56 g).

DESCRIPTION

The Brownfield iron is, unfortunately, entirely undescribed. The specimen in Harvard is a full slice, measuring 5 x 3.5 x 0.4 cm. It has a crust of terrestrial oxides 0.5-1 mm thick, and corrosion penetrates to the center along some fissured Brezina lamellae. The heat-affected α_2 zone has apparently been lost to corrosion.

The etched section displays a medium Widmanstätten structure of straight, long kamacite lamellae with a width of 0.75±0.20 mm. Schreibersite is common as lamellae up to 12 x 2 mm in size or as cuneiform crystals, always wrapped in asymmetrical envelopes of swathing kamacite 0.5-1.5 mm in size. Troilite occurs as 1/2-3 mm nodules, associated with the larger schreibersite crystals. Long and sometimes conspicuous shear zones of preatmospheric origin cross the entire section.

No details could be seen by a cursory examination of deep-etched samples, but the major features correspond well to those of already known irons of group IID, such as Elbogen, Needles and Carbo.

Bruno, Saskatchewan, Canada
52°16'N, 105°29'W; about 350 m

Hexahedrite, H. Single crystal larger than 5 cm. Neumann bands. HV 155±10.

Group IIA. 5.41% Ni, 0.20% P, 0.18% S, 61 ppm Ga, 185 ppm Ge, 37 ppm Ir.

HISTORY

A mass of 12.7 kg was found in 1931 by A.D. Ebner of Bruno while he was hauling rocks from his field. When a sample was forwarded to the Nininger Laboratory, which had published advice to the farmers on the importance of meteorites and how to recognize them, its meteoritic nature was confirmed. The whole mass was purchased by Nininger and later fully described with emphasis on the beautiful flight-markings (1936). Nininger gave the above coordinates

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BROWNFIELD – SELECTED CHEMICAL ANALYSES

| Reference | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970, pers. comm.	10.32								77.8	85.2	10.0	

for the find, which put it about two geographical minutes east-southeast of the town Bruno. The coordinate set in Hey (1966) is apparently a misprint. It is interesting that Nininger, when describing his etching experience with the rhabdite and schreibersite inclusions, suggested that they were surrounded by a nickel-depleted matrix, a conclusion which, much later, was shown to be generally applicable to phosphide inclusions (see, e.g., Reed 1965a). Photographs of the exterior have been published by Nininger (1936; 1952a: plate 11 and 32), Nininger & Nininger (1950: plate 17) and Rinehart (1958).

Figure 380. Bruno (Tempe no. 132.1). The main mass with its eminent regmaglypts and fusion crusts. Scale bar 50 mm. See also Figure 38.
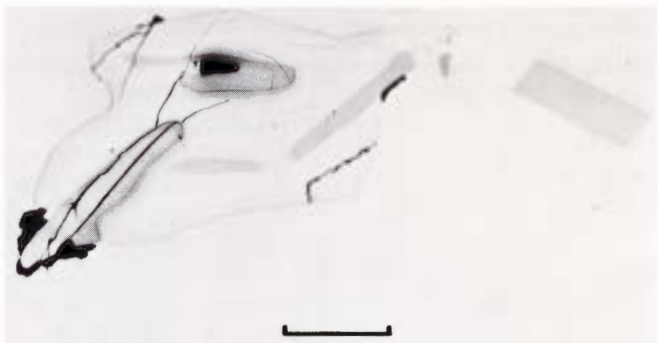
Figure 381. Bruno (U.S.N.M. no. 922). To the left a cohenite crystal with four schreibersite inclusions (gray) and a small kamacite island. To the right a rhabdite crystal in kamacite. Black is terrestrial limonite. Polished. Scale bar 50 μ.

COLLECTIONS

Tempe (12.6 kg), London (58 g), Washington (17 g).

DESCRIPTION

The meteorite is an angular block with five major faces and a sixth smaller one, all of which have been richly sculptured by frictional ablation and by the cascading of molten metal over one face. The maximum dimensions are 18 x 17 x 16 cm. The regmaglypts are 1-3 cm across and a few millimeters deep. Many of them are elongated and radiate away from what was apparently the leading face when the meteorite entered the atmosphere. Fine, metallic hair-lines, or striae, cover the depressions and radiate away from the same general face. Corrosion has only attacked the mass slightly. It has probably been exposed for a shorter period of weathering than have the majority of irons that have been found.

The etched section shows few large inclusions. The metallic matrix is monocrystalline, ferritic with Neumann bands extending from one rim zone to the other. The heated rim zone of α_2 is 2-5 mm thick; the more curved the surface is, the thicker it is. Angular veinlets of melted phosphides, 1-2 μ wide, connect the melted rhabdites, but it is unusual to see unambiguous indications of the presence of cohenite particles. Around these, which are no more than 25-50 μ in diameter, bainitic and ledeburitic structures have developed. Their microhardness is correspondingly high, about 450, in sharp contrast to the 170±10 of the α_2 zone, in which they are located.

The interior is characterized by several generations of rhabdites, approximately 50, 6, and less than 2 μ in diameter. One set of Neumann bands is discontinuous and small rhabdites have apparently nucleated here in much the same way as in Scottsville; compare figures 1560-1563. The microhardness of the kamacite is 150±10, but I doubt if this is a true interior value. All of the small specimens examined have been cut from near-surface knobs, the metal of which recovered to low hardness values during the atmospheric flight.

Cohenite occurs as up to 200 μ irregular particles which are ductile and hard and stand in high relief. They have frequently grown around schreibersite or rhabdite crystals, see Figure 381.

Bruno is a slightly annealed, monocrystalline hexahedrite, which is structurally and chemically closely related to Scottsville.

Specimen in the U.S. National Museum in Washington:
17 g slice (no. 922, 3 x 2 x 0.5 cm; Figure 6 in Nininger, 1936)

BRUNO – SELECTED CHEMICAL ANALYSES

| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hawley in Nininger 1936	5.79	0.29	0.20		1800	400						
Wasson 1969	5.41									61.3	185	37	

Burgavli, Yakutsk, Siberia, RSFSR
66°24′N, 137°28′E

Coarse octahedrite, Og. Bandwidth 2.6±0.5 mm. Neumann bands. HV 175±15.

Group I. 6.68% Ni, 0.12% P, 96 ppm Ga, 519 ppm Ge, 1.1 ppm Ir.

HISTORY

A mass of 27.8 kg was found in 1941 about 400 km northeast of Yakutsk in Siberia. It was recovered from alluvial deposits in the stream bed of the rivulet Burgavli, which was being dredged for gold. It was, as often has been the case with meteoric irons, first mistaken for silver, and it was heavily treated with a sledge hammer in order to split it, with little success. A detailed account of the circumstances of the finding was given by Guselnikov (1948). For a while the meteorite was in Kolymsk Geological Museum, Magadan (Krinov 1945a), but it was later transferred to Academy of Sciences, Moscow (Krinov 1960a: 471). It was analyzed by Dyakonova & Charitonova (1963), and it was included in a study by Vdovykin (1964) on the graphite-rich chondrules in the iron meteorites Yardymly and Burgavli. Isotope and age studies have been published by Starik et al. (1961; 1963), Fisher (1963), Sobotovitch (1964) and Marshall & Feitknecht (1964). The main mass is in Moscow, but small slices have been distributed.

DESCRIPTION

The mass is a flattened, lenticular body of the approximate dimensions of 30 x 25 x 8 cm. It had rather smooth, weathered surfaces with limonitic crusts 1 mm thick. After removal of the major part of the corrosion products the mass weighed 24.9 kg. The corrosion penetrates the whole mass along grain boundaries and along schreibersite and troilite inclusions, and the heat-affected rim zone has been lost.

The Widmanstätten structure is coarse and best seen on larger slices. The average bandwidth is 2.6±0.5 mm, but due to grain growth of the ferrite, the linear morphology is widely eliminated. Instead, the kamacite bulges here or pinches there, and many areas are occupied by almost equiaxial ferrite grains 5-20 mm in diameter. Neumann bands are common, and both these and the subgrain boundaries of the ferrite appear to be decorated by submicroscopic precipitates. The hardness is 175±15.

Taenite and plessite are scarce, occupying less than 1% by area. The larger taenite ribbons may have acicular interiors. Comb plessite, 1 x 0.5 mm in size, is observed locally, often completely surrounded by ferrite of one orientation due to the ferritic grain growth. The taenite ribbons display a hardness of 350±30 and locally show incipient decomposition to fine pearlitic structures.

Schreibersite occurs as H-, L- and Y-shaped crystals, 10 x 1 mm, and as grain boundary precipitates 50-200 μ wide. They are monocrystalline, but brecciated and sometimes displaced 2-5 μ. Rhabdites, 5-20 μ in diameter, are ubiquitous; the longer ones are broken and displaced a few microns. Troilite-graphite nodules, 10-20 mm in diameter, with a 0.5 mm schreibersite rim and rims of swathing kamacite up to 10 mm thick are rather common. The graphite is, as is usual in group I, present in different amounts, shapes and distributions within the troilite nodules. Vdovykin (1964) X-rayed a composite of about 1/3 graphite and 2/3 troilite which was separated by a crescent-shaped sharp boundary.

Cohenite was not observed but is expected to be present in minor amounts, either alone or as narrow rim zones around schreibersite.

Burgavli is structurally a typical group I iron, although not all characteristic minerals and structures were observed on the small specimen in the U.S. National Museum. Burgavli appears to be closely related to Seeläsgen, Osseo, Magura and Sarepta.

Specimen in the U.S. National Museum in Washington:
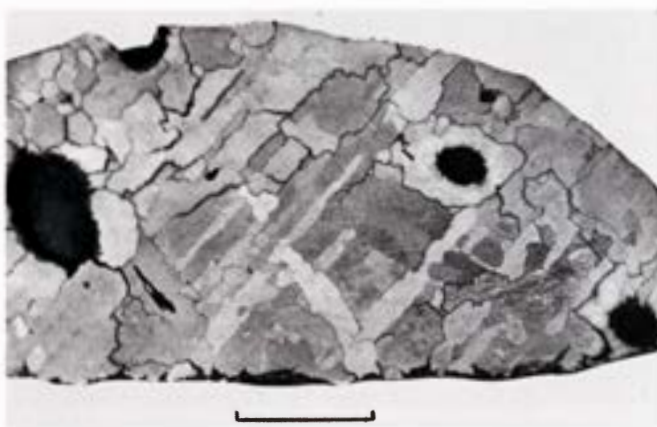130 g wedge-shaped slice (no. 1879, 6 x 3.5 x 1 cm)

Figure 382. Burgavli (Moscow). Coarse octahedrite, displaying kamacite grain growth. Three large troilite-graphite nodules with schreibersite and kamacite rims. Deep-etched. Scale bar 30 mm.

BURGAVLI – SELECTED CHEMICAL ANALYSES

| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Dyakonova & Charitonova 1963	6.65	0.65	0.12				300					
Wasson 1970a	6.71								95.8	5.19	1.1	

The analytical value for cobalt appears to be about 20% too high.

Burkett, Texas, U.S.A.
31°56'N, 99°14'W

Coarse octahedrite, Og. Bandwidth 2.00±0.40 mm. Neumann bands. HV 190±15.

Group I. 6.87% Ni, 0.17% P, 0.17% S, 0.16% C, 87 ppm Ga, 368 ppm Ge, 2.1 ppm Ir.

HISTORY

According to Reeds (1917) an iron meteorite was found in 1913 on the premises of Mr. D.W. Howe in Coleman County about 5.5 km south of Burkett. The coordinates were only given approximately but will, on a modern map, correspond to those given above. The mass was partially buried in sandy, gravelly loam on level ground. It was sold to the Foote Mineral Company, Philadelphia, and was later acquired by the American Museum of Natural History. There the weight was registered at 8.4 kg.

Several casts were made, and the meteorite was subsequently cut into six pieces weighing respectively 3,082, 2,771, 833, 826, 324, and 192 g (MacNaughton 1926). Some of these specimens were later exchanged with other institutions. The Smithsonian received the 826 g sample (no. 586) while Ward's Natural Science Establishment (Ward's Price List no. 342, 1931) acquired the 324 g
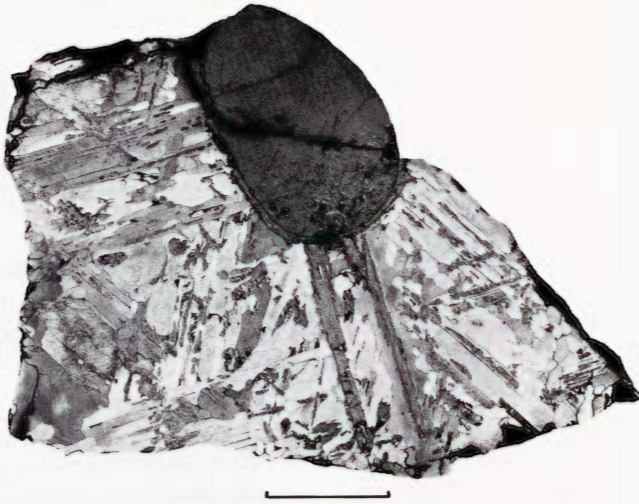
Figure 383. Burkett (U.S.N.M. no. 586). A large troilite nodule with schreibersite and cohenite rims. Cohenite is common as elongated platelets in the kamacite lamellae. Deep-etched. Scale bar 20 mm. S.I. neg. 329.

and 192 g samples. These were purchased by the Paris Museum and Nininger, respectively. In 1959 the Nininger sample was sawed in two; one piece of 75 g went to the British Museum, and the other of 100 g, to Tempe, Arizona.

An additional sample, of 349 g (U.S.N.M. no. 1382) was, surprisingly enough, found in the Smithsonian Collection during the present work. It turned out to be genuine Burkett, although never mentioned before.

According to letters and notes in the Smithsonian Institution, which were kindly put at my disposal by Mr. Roy S. Clarke, the 349 g sample had been separated from the main mass prior to its being sold to the Foote Mineral Company. This sample had been the property of the J.M. Babington family, in Coleman, until it was finally purchased by the Smithsonian in 1941 (no. 1382). Evidently the total weight of the meteorite was originally about 8.8 kg.

COLLECTIONS

New York (3,071 g, 2,773 g and 818 g), Washington (1,173 g), Paris (324 g, artificially reheated and partially forged), Tempe (100 g), London (75 g).

DESCRIPTION

The mass is weathered and exhibits adhering iron oxides up to 1 mm thick. A large troilite nodule, 4 x 2 x 2 cm, is located on the surface, protruding as a hump and not yet weathered to any significant extent. The reason probably is that it is monocrystalline and presents few points of attack.

The polished and etched section reveals a well developed Widmanstätten pattern of short, irregular ($\frac{L}{W} \sim 10$) α-lamellae with a bandwidth of 2.00±0.40 mm. Neumann bands are frequent, and subboundaries in the ferrite are visible because they are decorated by small precipitates, $<1\,\mu$ in diameter. Some grain growth in the α-phase has taken place, thereby eliminating the straight boundaries of the kamacite lamellae. The hardness is 190±15.

The cohenite crystals are dominating. They occur as slender bands or fingers, typically 10 x 1 x 1 mm in size. They are arranged in the Widmanstätten kamacite and are particularly abundant near the troilite. The cohenite is anisotropic and monocrystalline and has locally small inclusions of schreibersite. Taenite and plessite are not abundant in Burkett, about 2% by area. As usual in group I

BURKETT – SELECTED CHEMICAL ANALYSES

The first analysis was performed on weathered material, and 2.23% iron oxide was reported; therefore, the newest nickel determination is preferable.

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Booth, Garrett & Blair, in Reeds 1917	6.67	0.56	0.17	1630	1700		140					
Wasson 1970a	6.87								87.2	368	2.1	
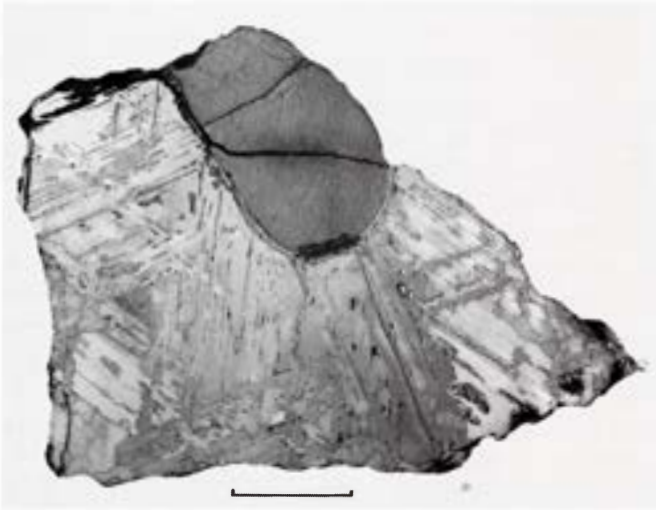
Figure 384. Burkett. Same as Figure 383, but refinished to a smoother surface. Graphite is seen in the right part of the troilite nodule. Slight changes have occurred in outlines of kamacite, schreibersite and cohenite due to removal of about 1 mm. Deep-etched. Scale bar 20 mm. S.I. neg. 1509.
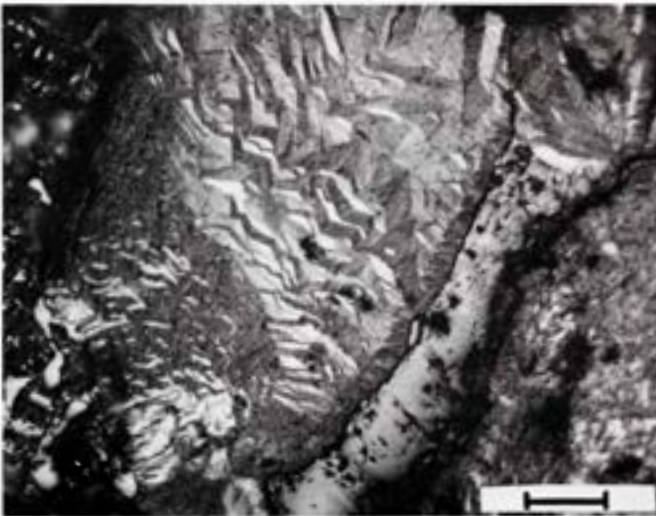
Figure 385. Burkett (U.S.N.M. no. 1382). Graphite in troilite. The graphite shows "kink-bands." Crossed polars. Scale bar 100 μ.

irons, the taenite is mostly associated with cohenite, for example, as 10-30 μ wide ribbons separating the cohenite-bearing α-lamellae. The taenite interior is often transformed to nickel-carbon martensite. Degenerated comb plessite fields are also present.

Troilite, although not expected to be present at all by Reeds (1917), occurs as scattered, large nodules, with swathing rims of schreibersite and cohenite. One nodule of 4 x 2 x 2 cm is an anisotropic monocrystal, with local deformation zones and fractures along which 1-10 μ

recrystallized grains or lenticular twin plates may be observed. A coarse-grained, anisotropic graphite aggregate occurs as a band 10 x 1 mm at the troilite-schreibersite border. The graphite shows kink bands with about 50 μ steps, probably due to compression.

Schreibersite is common as monocrystalline lamellae, 20 x 0.8 mm in size, centrally located in α and sheathed in cohenite 0.3 mm in width; then as 25-100 μ wide grain boundary precipitates and eventually as swathing rims, 0.8 mm thick, around the troilite.

Burkett is in its structure a typical group I iron, corresponding to such meteorites as Cranbourne and Seymour.

Specimens in the U.S. National Museum in Washington:
824 g endpiece (no. 586, 10 x 7 x 2.5 cm)
349 g fragment (no. 1382, 8 x 3 x 3 cm)

Burlington, New York, U.S.A.
42°43'N, 75°8'W; 500 m

Medium to coarse octahedrite, Om/Og. Bandwidth 1.3±0.2 mm. α_2 matrix. HV 200±12.

Group IIIE. 8.34% Ni, 0.49% Co, 0.23% P, 16.9 ppm Ga, 34.9 ppm Ge, 0.45 ppm Ir.

The whole mass has been intensely heated by a blacksmith.

HISTORY

A mass of between 50 and 100 kg was found before 1819 by a farmer while he was plowing his fields near the north line of the town of Burlington, Otsego County. The blacksmith heated the whole mass in his forge in order to enable him to cut off portions for the manufacture of such articles as the farmers most needed. The smith was content to find that he never worked stronger, tougher, or purer iron, and that it made excellent horseshoe nails. Only a few pieces, weighing altogether about 5 kg, were saved and came eventually into collections (Silliman 1844). However, these have altered structures due to the blacksmith's operations (Buchwald 1965). At least a conical lump of 4 kg passed through the hands of Shepard (1847), before it was distributed; apparently the two 1 kg-specimens in Amherst and Washington came from this mass. A short description with photomicrographs was given by Perry (1944: plate 73), who, however, failed to recognize that it was the blacksmith who was responsible for the peculiar structures.

BURLINGTON – SELECTED CHEMICAL ANALYSES

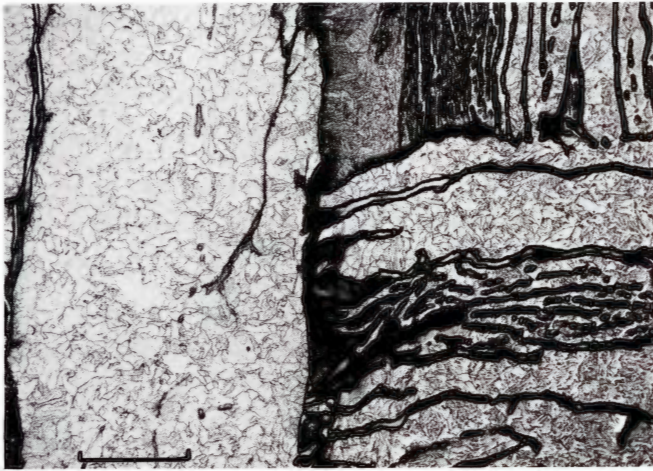| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	8.52	0.49	0.23									
Scott et al. 1973	8.15									16.9	34.9	0.45	

Figure 386. Burlington (U.S.N.M. no. 978). Artificially reheated. The kamacite is transformed to unequilibrated α_2. The comb plessite is partially resorbed. Etched. Scale bar 500 μ. (Perry 1950: volume 1.)

COLLECTIONS

Washington (1,325 g), Amherst (1,059 g), Tübingen (789 g), Yale (723 g), London (290 g), Chicago (121 g), New York (69 g), Göttingen (62 g), Stockholm (57 g), Tempe (46 g), Copenhagen (30 g).

DESCRIPTION

The specimen in the U.S. National Museum is a ragged fragment with the average dimensions of 10 x 8 x 4 cm. It shows heavy indentations from hammer and chisel blows and is slightly opened along one system of octahedral planes. A similar exterior damage is typical of the other large, surviving fragments, as for example, that in Tübingen. The 700 g fragment in Yale is remarkable, as it shows the large impressions of a heavy forging tool, probably a drop hammer, which has squeezed the mass thoroughly and distorted the Widmanstätten lamellae. A blistered, porous crust on many specimens bears a superficial resemblance to the genuine fusion crust, but it is really composed of low-melting, sulfide-phosphide-oxide eutectics created during the forging operations.

Etched sections show a mottled, medium Widmanstätten structure with a bandwidth of 1.3±0.2 mm. The mottling is due to the prolonged artificial reheating whereby the kamacite lamellae transformed to a polycrystalline mosaic of austenite units which, upon cooling, formed serrated α_2 grains about 50 μ across. The hardness is 200±12. The taenite and plessite areas are blurred, with indistinct borders, indicating extensive diffusion.

Figure 387. Burlington (U.S.N.M. no. 978). Detail of a kamacite lamella (T) between two kamacite lamellae (K). All transformed to α_2, however, of different morphology because of high nickel content in the taenite and low in the kamacite. Etched. Scale bar 40 μ. See also Figure 27A.
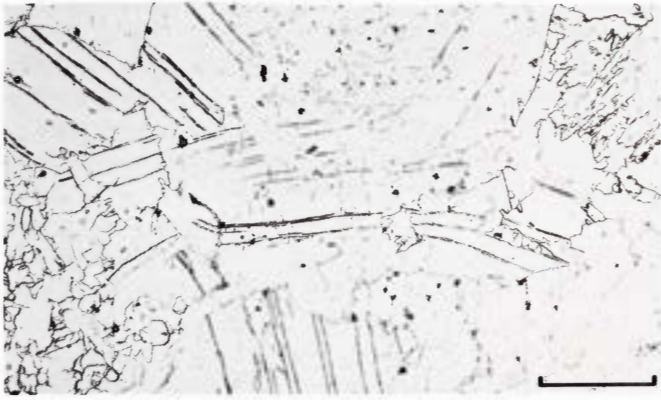
Figure 388. Burlington (U.S.N.M. no. 978). In some of the unequilibrated α_2 grains there are mechanical deformation twins, resembling Neumann bands. They are probably due to cold hammering. Etched. Scale bar 200 μ.

The original schreibersite crystals are melted and almost dissolved in the metallic matrix. The troilite inclusions left gaping holes when they melted, oxidized and sweated out. One hole is conical, 20 mm long and 6-13 mm wide. The melted sulfide migrated in the high-temperature γ-boundaries and may now be found everywhere as 1-10 μ droplets and grain boundary veinlets. Furthermore, high temperature reactions between oxides which were formed from corrosion, sulfides, and phosphides have created peculiar mineral assemblages. From the various observations above, it is safe to assume that the temperature was above 1000° C one hour or more, either at one time or repeatedly (compare Shepard 1847). Under these circumstances, it is interesting to note that the helium content as determined by Chackett et al. (1953) apparently was not influenced and is in harmony with noble-gas determinations on non-damaged meteorites (see, e.g., Wänke 1960b; Hintenberger et al. 1967).

The Burlington specimens have a certain value today, because they may serve as reference specimens for the structure alterations created when a nineteenth century blacksmith got hold of a meteorite.

From structural and chemical examinations it is estimated that Burlington belongs to the small group IIIE, which comprises Coopertown, Rhine Villa, Kokstad, Willow Creek and Staunton.
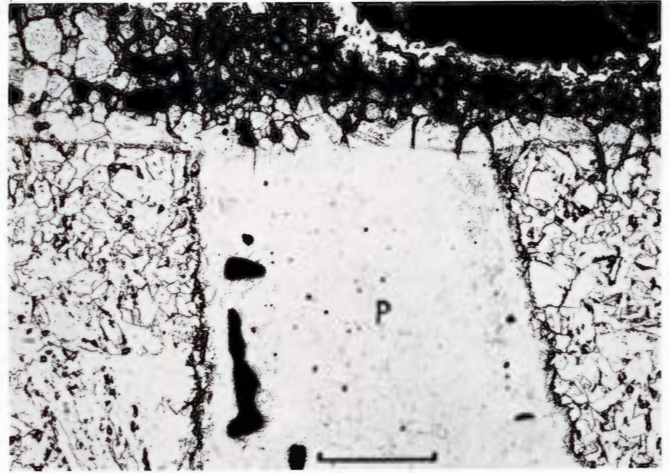
Specimens in the U.S. National Museum in Washington:

1290 g endpiece, hammered (no. 978, 10 x 8 x 4 cm; Shepard Collection no. 19)
25 + 10 g fragments (no. 978)

# Bushman Land, Cape Province, South Africa

Approximately 30°S, 20°E

Fine octahedrite, Of. Bandwidth 0.33±0.05 mm. Neumann bands, HV 180±8.

Group IVA. 8.90% Ni, about 0.10% P, 2.08 ppm Ga, 0.134 ppm Ge, 0.98 ppm Ir.

Figure 389. Burlington (U.S.N.M. no. 978). What here resembles a genuine fusion crust (above) is a low melting iron-sulfur-phosphorus eutectic that formed during the forging operations. High temperature grain boundary oxidation is also visible. The central part (P) was originally a dense plessite field. Etched. Scale bar 200 μ.
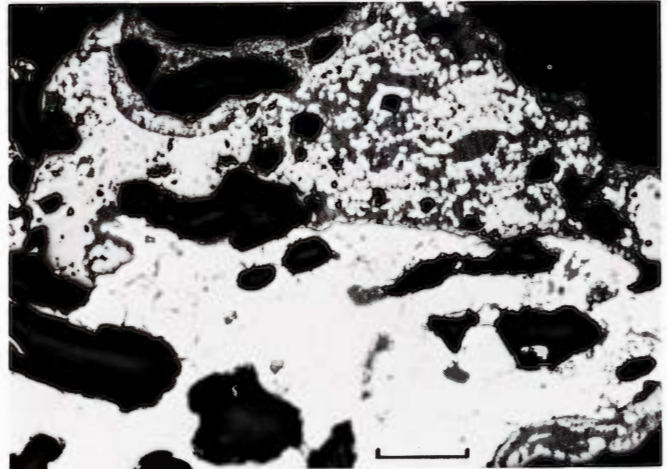
Figure 390. Burlington (U.S.N.M. no. 978). Artificial high temperature oxidation products, rich in sulfur, phosphorus and oxygen, on the surface. Polished. Scale bar 100 μ.
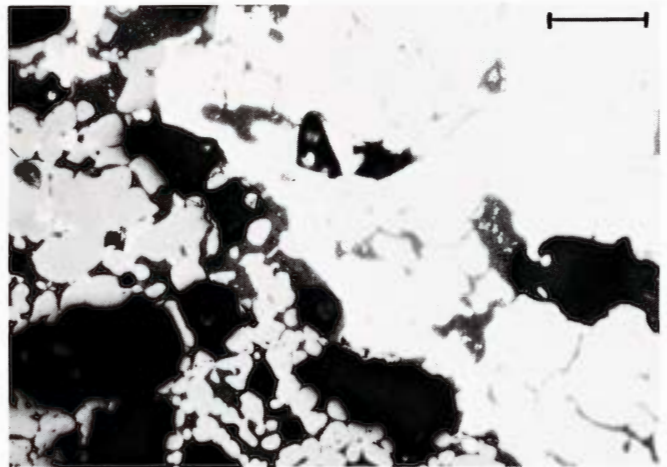
Figure 391. Burlington (U.S.N.M. no. 978). Another view of the Fe-S-O eutectics (left), and the matrix with sulfide melts in the grain boundaries. Polished. Scale bar 40 μ.

HISTORY

A mass of 3 kg was discovered about 1932 in Bushman Land, Carnarvon District, by a Boer farmer. In the 1960s the meteorite was acquired by the geologist, Dr. Brian A. Edmond, Ottawa, who attempted in vain to obtain more details of the circumstances of finding. The original owner believed that is was "a falling star, picked up in 1932 or 1934," but this supposition could never be substantiated.
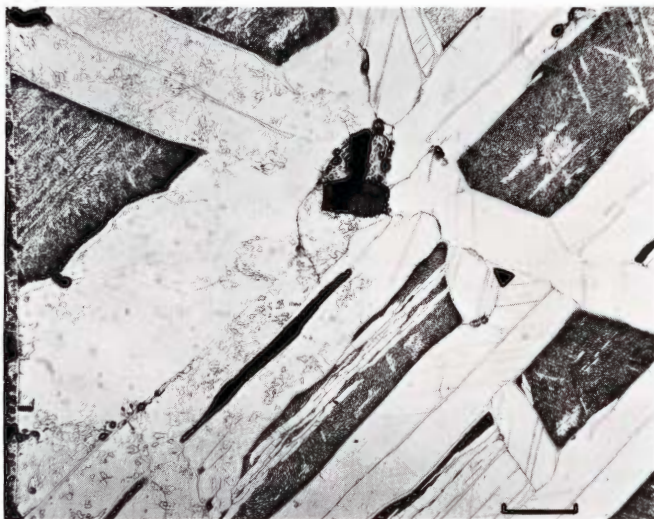

Figure 392. Bushman Land (U.S.N.M. no. 2515), The heat-affected α_2 zone extends from the fusion crust (extreme left) to the chromite-troilite crystals (center). Neumann bands in the unaffected interior (right). Etched. Scale bar 500 μ. See also Figure 37.

In 1965, the meteorite was purchased by the Smithsonian Institution and accessioned as a Gibeon specimen, which it resembles (Smithsonian Archives, Accession Number 265,573). When examining numerous Gibeon masses, I discovered that this mass could not belong with the others, so I described it as an independent fall, Bushman Land (Buchwald 1969a). Renewed attempts to contact previous owners were unsuccessful, so the locality of the find and the origin remain obscure. Its name has been chosen liberally to indicate that we only know the general area, Bushman Land, 100-200 km southeast of the accepted Gibeon strewnfield.

COLLECTIONS

Washington (2,865 g main mass), see Figure 37.

DESCRIPTION

The well-preserved mass weighs 3.00 kg and is an entire monolith with the average dimensions of 12 x 9 x 7 cm. It is irregularly angular but smoothly rounded. One side is slightly concave and covered with regmaglypts, 8-15 mm in size. The other faces are rather smooth with little sculpturing. The over all size allows it to fit comfortably into a hand as a "hammerstone," and, from abrasion marks on one of the flat sides, it appears that it has for a while been used as such or, alternatively, as a door stop (Figure 37).

The black or brown-stained fusion crusts and the structure were examined on several parallel sections taken

Figure 393. Bushman Land (U.S.N.M. no. 2515). Metallic fusion crust (above) with gasholes and oxide inclusions. A heat-affected plessite field to the left. Etched. Oil immersion. Scale bar 20 μ.
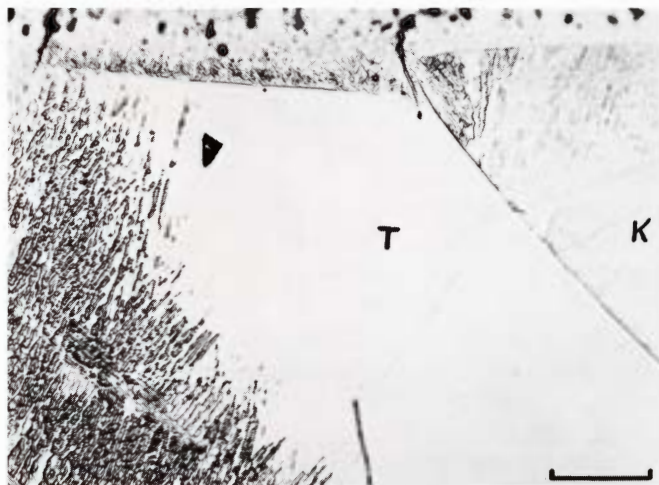

Figure 394. Bushman Land (U.S.N.M. no. 2515). Metallic fusion crust (above) with gasholes and oxide inclusions. The nickel-rich low-melting taenite (T) ablates away before kamacite (K). Etched. Oil immersion. Scale bar 20 μ.

BUSHMANLAND – SELECTED CHEMICAL ANALYSES

| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
J. Nelen 1966, pers. comm.	8.97											
Schaudy et al. 1972	8.83								2.08	0.134	0.98	

from a corner of the mass. The exterior part of the fusion crust is 25-100 μ thick and is composed of intergrowths of magnetite and wüstite, somewhat corroded and partly spalled off. The interior part of the fusion crust is composed of metallic dendrites, frequently developed as columnar crystals, 3-6 μ wide, perpendicular to the cold substrate. Up to 20 successive metallic layers, each 30-50 μ thick, could be counted in places. The layers form thin sheets that are discordantly and irregularly superimposed upon each other, suggesting successions of metallic melts streaming in from shifting directions, and rapidly solidifying in protected positions. Even in the innermost layers, which must have formed in the upper part of the atmosphere, small oxide globules, 1 μ in size, may be detected in the metal. Farther out the oxides become larger and more abundant. The hardness of the dendritic metal is 330±30.

Under the two fusion crusts is a 2 mm wide heat-affected α_2 zone. In the other 50% of it the phosphides are micromelted, and it may be seen how they
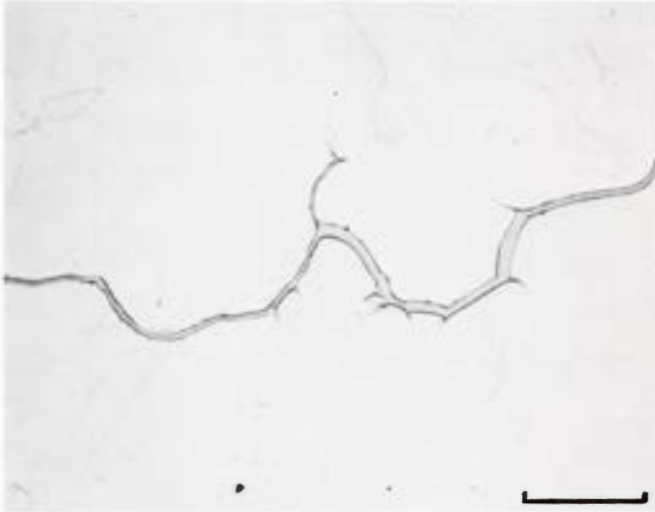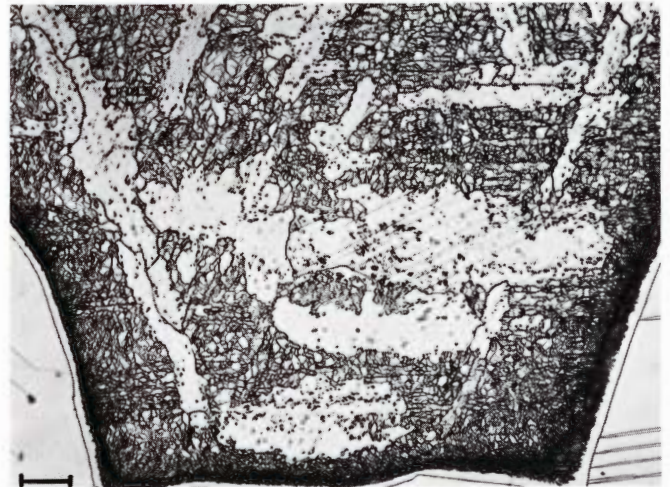

Figure 395. Bushman Land (U.S.N.M. no. 2515). Phosphide melt that penetrates along high temperature austenite grain boundaries. Etched. Oil immersion. Scale bar 20 μ.
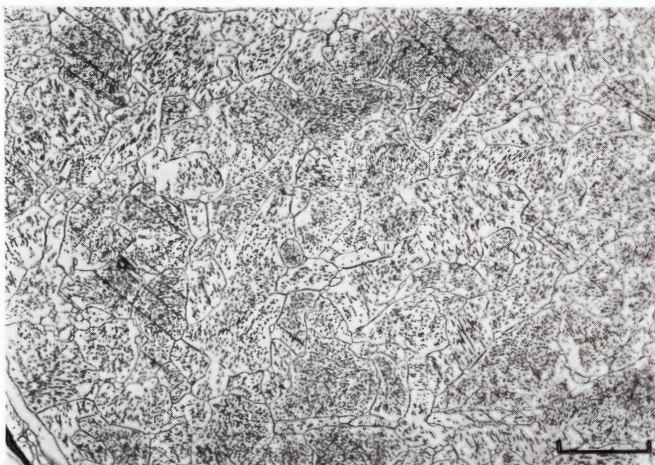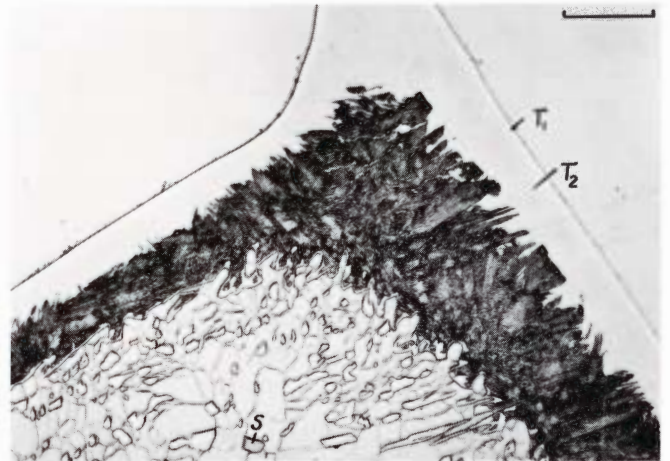

Figure 396. Bushman Land (U.S.N.M. no. 2515). Cellular plessite of the type so common in group IVA. Etched. Scale bar 200 μ.
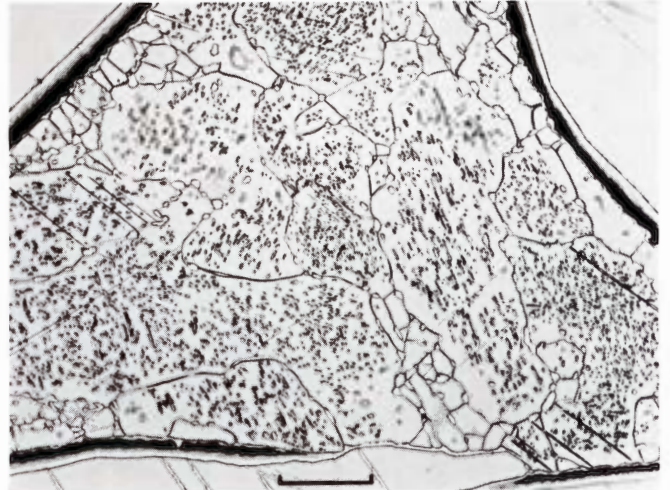
Figure 397. Bushman Land (U.S.N.M. no. 2515). Another variety of cellular plessite in a smaller field. Each cell displays a different crystallographic orientation. Etched. Scale bar 100 μ.

Figure 398. Bushman Land (U.S.N.M. no. 2515). Finger plessite of the type so common to meteorites of group IVA. Etched. Scale bar 50 μ. See also Figure 126.


Figure 399. Bushman Land (U.S.N.M. no. 2515). A typical plessite development: 1-2 μ wide yellow taenite rim (T_1) is followed by a somewhat thicker cloudy taenite zone (T_2). Next come transitional zones of tempered martensite-bainite (black), and finally an open-meshed duplex plessite. In this, a small schreibersite crystal (S) may be noted. Etched. Oil Immersion. Scale bar 20 μ.

solidified rapidly by heat conduction from the cool interior of the meteorite. The serrated α_2 grains are 25-100 μ across and display hardnesses of 205±15. The hardness drops to 155±15 in the recovered transition zone from α_2 to the unaffected interior (hardness curve type II).

Several microcracks are present. They progress through both fusion crusts and through the exterior part of the α_2 zone. A close examination reveals that no cracks are found below the region where the phosphides were micromelted. The cracks are evidently hot cracks, developed as intercrystalline cracks through grain boundaries rich in micromelted phosphides. They formed during flight and were potential sources for later splitting and corrosion attacks. Similar microcracks are no doubt present in the exterior 1 mm skin of most meteorites, but they are rarely detectable because corrosion rapidly destroys the evidence.
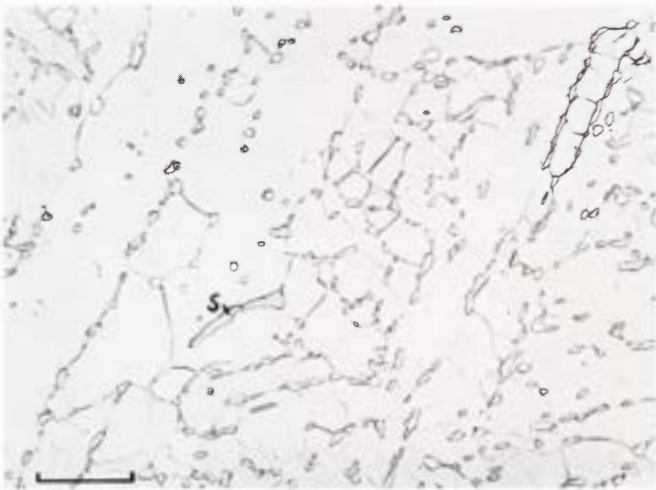
Figure 400. Bushman Land (U.S.N.M. no. 2515). Open-meshed duplex plessite. Numerous somewhat spheroidized taenite particles and subboundaries in the kamacite. Schreibersite (S). Etched. Oil immersion. Scale bar 20 μ.
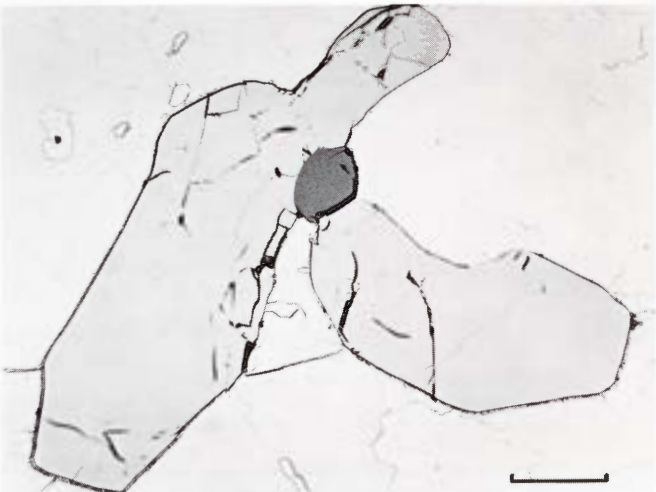
Figure 401. Bushman Land (U.S.N.M. no. 2515). Two schreibersite crystals in the inner part of the heat-affected α_2 zone. They were apparently originally nucleated by the black troilite crystal. Etched. Oil immersion. Scale bar 20 μ.

Etched sections display a fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 40$) kamacite lamellae with a width of 0.33±0.05 mm. The subboundaries are only indistinctly visible because there are few precipitates on them. Neumann bands are common, and the hardness is 180±8.

Taenite and plessite cover 40-50% by area, mostly as comb and net plessite fields. Finger plessite and cellular plessite (HV 195±10) are well developed, and duplex fields of unresolvable, or easily resolvable, $\alpha + \gamma$ also occur. A very small amount of martensite-bainite (HV 285±15), which developed parallel to the bulk Widmanstätten structure, may also be detected, often as transition zones between taenite rims and duplex interiors.

Schreibersite only occurs as 10-20 μ wide veinlets in the grain boundaries, and as 5-25 μ irregular particles in the plessite fields. Rhabdites are not present. The bulk phosphorus content is estimated to be 0.10±0.02%.

Troilite is present as nodules ranging from 20 μ to 1.6 x 1 mm in size. The larger ones are angular single crystals displaying multiple twinning due to deformation. The smaller ones are regular troilite-daubreelite intergrowths, often forming parallel stacks of alternating 1 μ wide lamellae. The multiple twinning in the troilite has developed whenever the troilite lamellae have been above 3-5 μ in thickness.

The meteorite is only slightly corroded. Locally, a limonitic veinlet, 10-30 μ thick, penetrates several millimeters into the interior along schreibersite-loaded boundaries by way of the exterior cracks, but otherwise little damage has occurred. From the state of corrosion, it cannot be completely ruled out that the meteorite was really observed to fall about 1930. Therefore, it is unfortunate that we have no reliable information regarding the place and year of discovery. Hopefully, precise methods will be developed in the future which will help to solve the problem of the terrestrial age of meteorites.

Bushman Land is a fine octahedrite which is closely related to Mantos Blancos, Hill City, Muonionalusta and other phosphorus-rich irons of the resolved chemical group IVA. It is distinguished from the Gibeon specimens by its higher nickel and phosphorus content (Gibeon has no schreibersite), its lower iridium content, and its fine preservation which suggests that it is a much younger fall than Gibeon. While Gibeon has shock-melted troilite, the troilite of Bushman Land only shows multiple twinning.

Specimens in the U.S. National Museum in Washington:
2,865 g main mass (no. 2515, 12 x 9 x 7 cm)
Polished sections

Butler, Missouri, U.S.A.
38°11'N, 94°26'W; 250 m

Plessitic octahedrite, Opl. Spindle width 0.15±0.03 mm. HV 180±12.

Anomalous. 15.72% Ni, 1.03% Co, 0.05% P, 87.1 ppm Ga, 2000 ppm Ge, 1 ppm Ir.

A part of the meteorite has been severely hammered, reheated and even forged.