fibrous and brecciated, and 1-100 μ wide veins through it are filled with a glass in which silicate fragments and a little troilite are embedded. It is surprising to note how the shock has been able to create such heavy local transformation; 10 mm away nothing unusual is observed. The local damage resembles in several respects the structural changes associated with spot welding. Examination under the electron microprobe suggests that the unknown silicate is almost pure SiO_2, possibly tridymite.

Bishop Canyon is chemically and structurally a typical phosphorus-poor, fine octahedrite of group IVA, resembling in particular Gibeon. It is, however, unusual in its silicate inclusions, the shock damage and low hardness.

Specimen in the U.S. National Museum in Washington:
226 g slice (no. 770, 9.5 x 4.5 x 0.9 cm)

Bitburg, Rhineland, Germany
49°58′N, 6°32′E

A mass said to have weighed 1.5 tons was smelted in a furnace before 1805. It was recognized as a meteorite (Chladni 1819: 353), but virtually nothing was saved of the undamaged material (Hey 1966: 57). The smelted material, e.g., no. 1881, 1534 of 546 g in
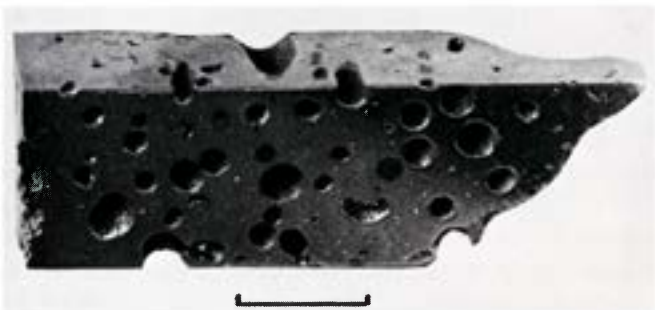

Figure 350. Bitburg (Copenhagen no. 1886, 493). A rectangular bar cut from melted material of the Bitburg meteorite. The numerous spherical gasholes are typical for most Bitburg samples presently in collections. Scale bar 10 mm.
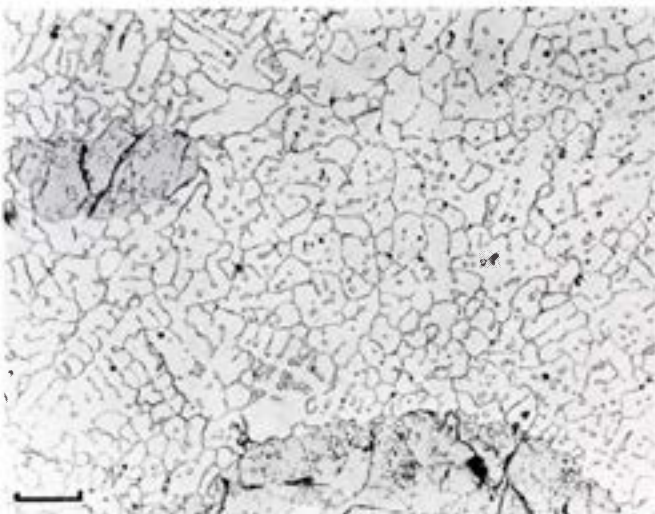

Figure 351. Bitburg. Detail of Figure 350. Two sulfide nodules. Metallic dendrites separated by sulfide-rich eutectics. Etched. Scale bar 200 μ.
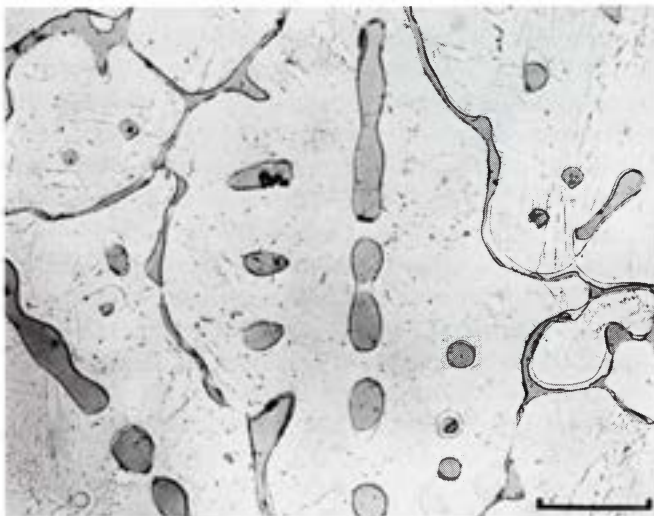

Figure 352. Bitburg. Detail of Figure 350. The dendritic metal was at high temperature austenite but transformed upon cooling to unequilibrated α_2. Etched. Scale bar 50 μ.

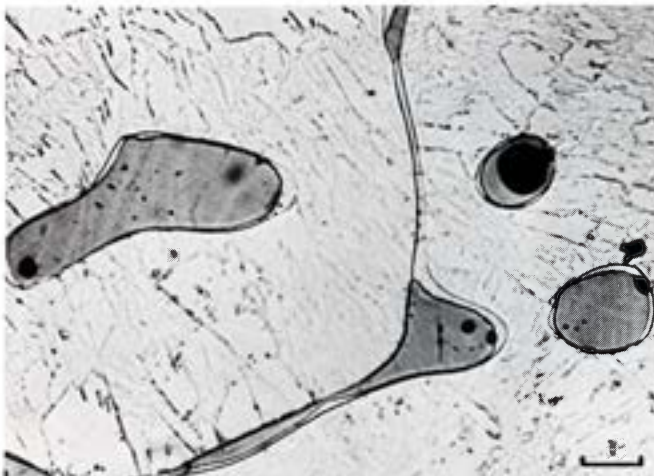**Figure 353.** Bitburg. Detail of Figure 350. Sulfide globules in the grain interior and lamellae in the grain boundaries. Black gasholes. α_2 metal. Etched. Scale bar 10 μ.
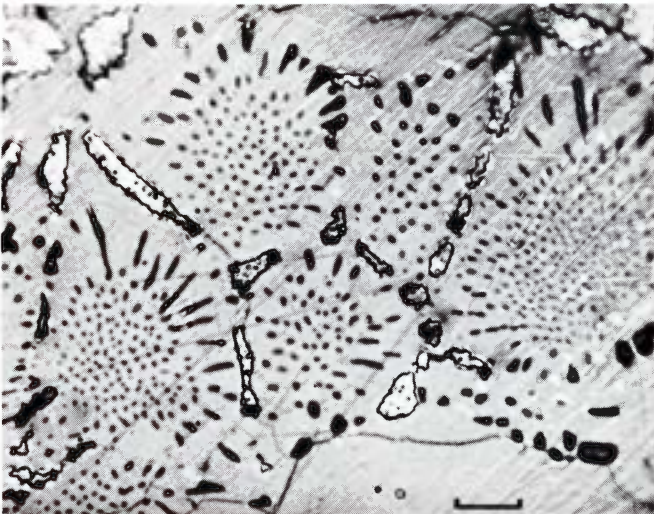

Figure 354. Bitburg. Detail of Figure 350. When the meteorite was melted, oxygen was absorbed from the air, causing complex ternary Fe-S-O eutectics to form locally. Etched. Scale bar 10 μ.

Copenhagen (Buchwald & Munck 1965: 24), is full of millimeter-sized spherical holes, giving the metal a Swiss-cheese-like appearance. The microstructure is that of a rapidly solidified iron-nickel alloy, with α_2 matrix penetrated by a web of iron sulfides and minor quantities of iron phosphides, confirming that the bulk of the meteorite has been artificially melted.

Unpublished results by Wasson (1972) indicate that the chemical composition is close to that of Pitts; if this is the case, Bitburg was probably originally an iron with silicate inclusions of the resolved chemical group I, rather than a pallasite as previously assumed. The only photomacrographs published (Brezina & Cohen, 1886-1906: plate 6) support this conclusion.

Black Mountain, North Carolina, U.S.A.

Approximately 35°37'N, 82°17'W; 700 m

Coarse octahedrite, Og. Bandwidth 2.6±0.6 mm. Neumann bands. HV 185±30.

Group I, similar to Duel Hill (1873), judging from the structure.

In high probability a transported fragment of Duel Hill (1873).

HISTORY

A fragment weighing about 600 g, more probably 800 g estimating from the cumulative weight of the preserved specimens, was found at the head of the Swannanoa River, near the base of Black Mountain, toward the eastern side of Buncombe County. It had several owners before being described by Shepard (1847) who stated that it was "evidently a portion of a mass that must have been much larger." The meteorite was found in 1835 and the largest part of Shepard's material came to Amherst College, Massachusetts (Shepard 1872a), where 351 g is now preserved (not 3.5 kg as listed by Hey 1966). Reichenbach (1862a: 622, 630, 631) mentioned 2-8 mm troilite nodules encased in graphite. Brezina (1885: 214) classified it as a coarse octahedrite together with Bendegó, Cosby's Creek and others.

COLLECTIONS

Amherst (351 g endpiece and some weathered fragments), London, Museum of Practical Geology (76 g), New York (54 g), London, British Museum (53 g), Vienna (45 g), Budapest (44 g, now lost according to Ravasz 1969), Berlin (33 g), Calcutta (22 g), Washington (18 g), Copenhagen (14 g), Chicago (7 g), Yale (6 g), Tempe (3 g).

CHEMICAL ANALYSIS

No modern analysis is available. From structural considerations, I would estimate the composition to be 6.7±0.2% Ni, 0.2% P and with trace elements corresponding to group I.

Figure 355. Black Mountain (Amherst). The weathered 351 g endpiece is the largest fragment preserved of this controversial meteorite which may be a transported sample of Duel Hill (1873). Scale bar in cm.

DESCRIPTION

The small fragment in the U.S. National Museum is severely corroded. Limonitic veins 0.2 mm wide separate irregular α-grains of different orientation. The grains are typically 14 x 4, 7 x 5 or 12 x 7 mm in size, and no Widmanstätten arrangement is visible. The endpiece in Amherst measures 6.5 x 3.5 x 3.5 cm. It displays a coarse Widmanstätten structure with a bandwidth of 2.6±0.6 mm and shows equiaxial grains about 10 mm across. The surface is rough from the detachment of individual α-grains along corroded grain boundaries. The ferrite grains have well-developed subboundaries with many 0.5-2 μ phosphide precipitates. Neumann bands are common; they are not attacked by the violent corrosion because they were not originally sensitized by decoration with phosphides. The hardness of the kamacite ranges from 155 to 225, apparently due to varying degrees of plastic deformation and because the α kamacite is inhomogeneous with respect to nickel and phosphorus, as evidenced by large variations in the size and frequency of the rhabdites. Taenite and plessite cover 1-2% by area, mostly as small wedges with acicular or martensitic interiors.

Schreibersite is common as 50-100 μ wide grain boundary precipitates. Rhabdites occur in all sizes up to 40 μ across. The phosphides are all brecciated and are often displaced by shear in successive steps, each 1-10 μ large. Troilite, cohenite and graphite were not observed, but troilite and graphite are known to be present from old

BITBURG – SELECTED CHEMICAL ANALYSES

| Reference | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1972, pers. comm.	12.40								34.8	140	0.46	

descriptions of other specimens (Reichenbach 1862a). See also last paragraph.

The structure indicates that Black Mountain is a coarse octahedrite of group I, similar to cohenite-poor parts of Duel Hill (1873) and Cosby's Creek. The structure, hardness and state of corrosion resemble Duel Hill (1873) so much that there is a possibility that Black Mountain is a fragment of this mass, which was discovered at an unknown date about 40 km farther northwest. It is known that two or three pounds had been chiseled off the Duel Hill mass before it reached scientific hands, so perhaps Black Mountain is the missing portion. The dates and circumstances of find for both masses are so uncertain that little weight can be attached to them. The general resemblance and the approximate coincidence in place and time of discovery seem to be decisive factors that indicate that the meteorites are identical. A modern trace-element examination would help to solve the question.
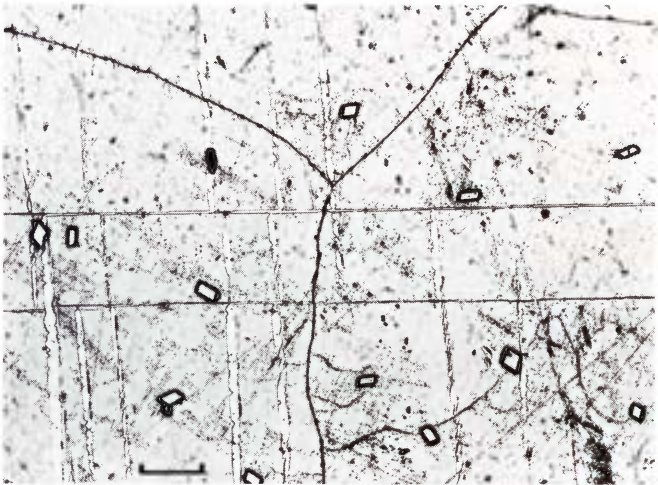

Figure 356. Black Mountain (Chicago no. 952). Subboundaries in the coarse kamacite lamellae, with rhabdite needles and Neumann bands. Etched. Scale bar 100 μ.
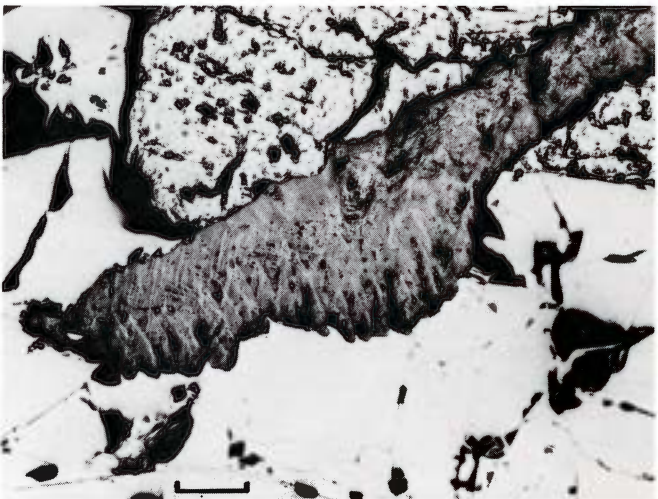

Figure 357. Black Mountain (Chicago no. 952). Schreibersite (white), cliftonitic development of graphite (dark gray), and troilite (gray, above) in a complex aggregate. Polished. Slightly crossed polars. Scale bar 100 μ.

Late in the present study, a 29 g sample (25 x 20 x 10 mm; Chicago no. 952) mislabeled Blue Tier but actually a part of Black Mountain, was examined. An old, almost obliterated inscription on the polished surface reads "Black Mt" and confirms the reidentification. This specimen contains 2 x 1 mm monocrystalline troilite crystals with a 1 mm wide schreibersite rim and numerous 0.1-0.2 mm cliftonite inclusions. Unidentified 50-200 μ silicate crystals are also present. There are several 100-200 μ cliftonitic graphite crystals in the kamacite and some of them display 50 μ wide rims of schreibersite, suggesting a rather early ($>600°$ C) precipitation of the graphite. There are also many carlsbergite platelets in the kamacite, generally smaller than 10 x 1 μ. All other details of the structure of no. 952 are as discussed in the preceding paragraphs.

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

18 g polished section and corroded fragments (no. 1540, 15 x 15 x 10 mm)

Bloody Basin. See Canyon Diablo (Bloody Basin)

Blue Tier, Tasmania
41°11'S, 148°2'E

According to Anderson (1913:56) a mass of 1.35 kg (3 lbs) was found by a party of miners some years prior to 1893. The locality was near Blue Tier, in County Dorset, on the northeast coast of Tasmania. The mass has been described as a medium octahedrite, and is in the Queen Victoria Museum in Launceston (Hey 1966: 59). An examination of specimen Me 952 in Chicago, allegedly from Blue Tier and acquired with the Ward collection, showed this to be something else, apparently a mislabeled Black Mountain sample. Material from the main mass was unfortunately not available for an examination.

Boaz. See Hope

Bodaibo, Irkutsk Oblast, Siberia, USSR
57°51'N, 114°12'E

Polycrystalline, fine octahedrite, Of. Bandwidth 0.30±0.05 mm. Duplex matrix. HV 186±8.

Group IVA. 8.00% Ni, 0.38% Co, 0.04% P, 1.96 ppm Ga, 0.11 ppm Ge, 1.7 ppm Ir.

HISTORY

A mass of 15.9 kg was found in 1907 in shaft No. 10 of the Vesennij mine on the river Bodaibo, a tributary to the river Vitim (Krinov 1947). It had, however, already been preliminarily described by Belaiew (1914a), and mentioned by Chirvinskij (1923). Zavaritskij & Kvasha (1952: 71) and Zavaritskij (1954) gave new descriptions with several photographs of the exterior and of etched sections.

COLLECTIONS

Moscow (11.0 kg main mass; 1.6 kg slices), Washington (261 g), Tempe (167 g).

DESCRIPTION

According to Zavaritskij & Kvasha (1952) Bodaibo is a rather flat ellipsoid with average dimensions of 25 x 9 x 8 cm. These dimensions are surprisingly small for a mass of 15.9 kg; the pictures seem to indicate dimensions of 25 x 15 x 9 cm. The surface is unusually uneven and pitted; locally large, shallow cavities occur, the largest being 30 mm in diameter and 10 mm deep.

The specimen in the U.S. National Museum is a section through the mass and has recently itself been divided in two sections. While a part of the surface is covered with 2-5 mm thick, blackish-brown, adhering corrosion products, other parts are deeply pitted and the nickel-rich taenite is exposed as bronze-colored leaflets. The heat-affected α_2 rim zone is corroded away, so the terrestrial age of Bodaibo must be considerable, in harmony with the conditions of find.

Etched sections prove Bodaibo to belong to the few iron meteorites which are composed of several parent austenite crystals. Parts of three crystals are clearly visible, each 2-10 cm across. The grain boundaries are 0.5-2 mm wide kamacite zones, in which small amounts of troilite-daubreelite have segregated. Due to late shock and reheating, the minerals form rather indistinct nests, 50-100 μ across, in which 3-15 μ daubreelite fragments are clearly visible, while the remainder forms fine-grained sulfide-metal eutectics with frayed edges.

Bodaibo is a fine octahedrite with straight, long ($\frac{L}{W} \sim 40$) kamacite lamellae with a bandwidth of 0.30±0.05 mm. At low magnification, the kamacite has apparently normal Neumann bands, but high magnification reveals that it is decomposed to a duplex structure with a hardness of 186±8. Tiny precipitates, 0.2-0.5 μ across, are extremely closely spaced upon the Neumann bands and dislocations; somewhat larger particles decorate the grain and subgrain boundaries. The precipitates may be carbides,

and, if so, Belaiew's old carbon analysis becomes meaningful. I am, however, more inclined to interpret the particles as fine taenite grains, precipitated from a kamacite, supersaturated with respect to nickel. Phosphides seem to be out of the question due to the low bulk phosphorus content. Similar duplex kamacite structures are present in Dalton and Jamestown. An electron-microscopic examination would probably disclose interesting details.

Taenite and plessite cover about 40% by area, mostly as comb and net plessite, but also as cellular and finger plessite and as poorly resolvable black taenite. A typical dense field will show an annealed taenite rim with a distinct grid (HV 195±10) followed by a martensitic transition zone (HV 275±20), a dark, unresolvable, duplex $\alpha + \gamma$ mixture (HV 250±15) and finally easily resolvable $\alpha + \gamma$ mixtures with γ-grains 1-2 μ in size and with hardnesses only slightly above that of the adjacent kamacite lamellae. Neither cohenite nor carbide particles could be identified.

A unique feature is the local plastic deformation along the primary austenite grain boundaries. In a 0.2-0.5 mm wide zone within the smaller grain, the plessite is violently torn and kneaded. Further away no deformations are visible. The deformation is clearly of post-Widmanstätten date, but it is difficult to visualize a process that selectively damaged the border zone of one grain without influencing the adjacent grain at all. Compare Kodaikanal.

Troilite occurs as nodules 0.1-8 mm in diameter with blurred, indistinct outlines. Careful polishing reveals the nodules to be shock-melted aggregates, rich in angular daubreelite fragments, and with microcrystalline sulfide fingers penetrating into the surrounding metal. The daubreelite fragments are 5-15 μ across and cover 10-20% by area; they are probably the shattered remnants of previously existing daubreelite lamellae.

While Bodaibo in many respects is a normal fine octahedrite similar to, e.g., Charlotte and Gibeon, it also shows some unusual structural developments. Duplex kamacite and gridded taenite point to annealing effects resembling those met in Jamestown, Anoka and Dalton. The micromelted troilite, probably due to shock, resembles

BODAIBO – SELECTED CHEMICAL ANALYSES

While most of the analytical results are in satisfactory agreement, considering the various times and methods, and average out neatly for a group IVA meteorite, the discrepancy in carbon is unusually large. In view of what will be said below about the microstructure, the present author would favor the modern carbon analysis.

| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Belaiew 1914a	7.50	0.50	0.05	1200	100							
Dyakonova & Charitonova 1963	8.49	0.32	+				200					
Moore & Lewis 1968	8.10	0.34	0.035	40	20		155					
Wasson 1968, pers. comm.	7.83								1.96	0.111	1.7	
Jarosewich 1968, pers. comm.	8.05	0.36'	0.04									

that of Gibeon and many others. Polycrystallinity is also present in Gibeon. The intense, but local, deformation along the grain boundary is very unusual. No other iron combines the features found in Bodaibo.

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

101 g slice (no. 2149, 12 x 6 x 0.3 cm)
140 g slice (no. 2149, 9 x 6 x 0.4 cm)
 20 g two small sections (no. 2149)

Bogou, Upper Volta
12°30′N, 0°42′E

Coarse octahedrite, Og. Bandwidth 1.90±0.30 mm. Neumann bands. HV 165±10.

Group I. 7.08% Ni, 0.47% Co, 0.17% P, 2% S, 77 ppm Ga, 301 ppm Ge, 1.6 ppm Ir.

HISTORY

A mass of 8.8 kg was seen to fall in the district of Gayéri, north of Fada-N'Gourma on August 14, 1962, about 10 a.m., or at noon according to another report. The meteorite fell near the village of Bogou, as reported in a temporary newspaper, but as Orloff has shown (unpublished report in Smithsonian Institution from Upper Volta Department of Geology and mines, July 1965) no such village exists. He visited the region, collected eyewitness reports and concluded that the place of fall was 350 m southwest of the small village Bohongou, with the coordinates given above. The farmer B. Lompo working in his field heard a passing airplane and shortly thereafter noticed a more unusual noise which increased in intensity until deafening. An object dug into the ground about 200 m from him, but as he supposed it to be a bomb or some radioactive instrument, he and fellow villagers did not excavate it, but advised the authorities. The local newspaper (*Carrefour Africain*, September 30, 1962) reported that "two instruments, which emitted sharp, terrifying whistles left the sky in the direction of the earth at a dizzy speed. One disappeared in the midst of the bush while the other fell in a field not far from Bogou." On August 30, gendarmes went to the field and excavated the meteorite from a hole, about 50 cm in diameter and 50 cm deep, made in clayey, slightly sandy, laterite. The other fragment was never found.

Through the generosity of the President of Upper Volta, M. Yameogo, and his Ambassador to France, M. Guisseau, the meteorite was sent to the U.S. Atomic

Figure 358. Bogou. Entire mass before it was cut. The domed side with a deep hemispherical depression below. Scale bar 30 mm. S.I. neg. M-657A.

Figure 359. Bogou. A view from the opposite, somewhat flattened surface. Scale bar 30 mm. S.I. neg. M-657C.

Energy Commission, represented by Dr. Pomeroy. A plaster cast was made and, with the idea of having the short-lived radioactive isotopes tested rapidly, the meteorite was cut October 23 in the Smithsonian Institution, whereupon slices were distributed to interested parties. Some of the resulting publications were Davis et al. (1963), Cobb et al. (1963), Tilles & Tamers (1963), Rowe et al. (1964), Nordemann & Tobailem (1964), Unik et al. (1964), and Yokoyama & Labeyrie (1964). Tobailem & Nordemann

BOGOU – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1966	7.15								77.4	301	1.4	
Cobb 1967	6.92	0.44					157		77		1.8	
Clarke & Jarosewich 1968, pers. comm.	7.16	0.49	0.17		<100	<5	158		78			

(1965) compared and discussed the results obtained in different laboratories. Fireman (1966), Goel (1966), Fisher (1967), Cobb (1967) and Voshage (1967) added further observations. The cosmic ray exposure age was found by different methods to be 440 million years (Cobb), 390 or 505 million years (Fisher), less than 900 million years (Tobailem & Nordemann) and 560±80 million years (Voshage). Marvin (1963) identified wüstite as a major mineral of the fusion crust.

About 3 kg is in Ouagadougou, the capital of Upper Volta. About 1.5 kg has been used up in the various investigations, and 3,100 g is in the U.S. National Museum.

DESCRIPTION

The recovered fragment, of which a cast is in the U.S. National Museum measured 19 x 11 x 10 cm; it was somewhat similar in shape and size to the body of a duck, with a sharp "breastbone" ridge on one side and an irregular cleavage fracture on the other. No doubt this is where the missing fragment broke off in the high atmosphere. Both the smooth, rounded surfaces and the fractured surface are covered with 0.1 mm thick, black oxide crusts, which show the usual striae and warts. Smooth zones and regions with thumbprint marks are mixed in a very irregular way. Two cavities, 20-30 mm in diameter and 10-15 mm deep, are caused by partial ablation melting of troilite nodules; it is interesting to note that in one case a well-like cavity with rounded, melted edges of iron has been developed, and in the flat bottom of this pit half the troilite is still preserved. In another case a troilite-graphite nodule ends flush with the surrounding surface because the nodule is highly refractory due to a substantial amount of graphite and olivine inclusions. Locally short, straight scars, about 10 x 1 mm, are seen in the crust; these are due to the partial burning of schreibersite lamellae.

The polished, etched slices show a coarse Widmanstätten structure of irregular lamellae ($\frac{L}{W} \sim 10$) with a bandwidth of 1.90±0.30 mm. Grain growth has locally created 5-15 mm nearly equiaxial ferrite grains in which almost resorbed plessite fields sometimes are located. It is quite surprising that a fall as fresh as this shows intercrystalline corrosion to many centimeters depth, normally in the form of 0.1 mm wide zigzag cracks from the surface to some troilite nodule. It is speculated that these cracks were produced in the high atmosphere when the meteorite fragmented; thus they were readily accessible for terrestrial corrosion in the two weeks before recovery. Near-surface parts of a few of the cracks appear, in fact, to be filled with ablated and dendritically solidified material that supports the idea of their early creation. The amount of corrosion products in and along fissures is so substantial, however, that it is by far the most corroded fresh fall the author has seen; the α-phase of 0.5 x 0.4 mm pearlitic plessite fields is partially converted to "limonite," and cohenite and schreibersite fissures are filled with 5-20 μ wide veinlets of oxide material, which is orange-fiery red under crossed Nicols, and may be Akaganeite. It is not impossible that part of the

observed corrosion is the result of wet sectioning on a bandsaw: the cutting of numerous slices took several days, during which newly exposed surfaces were thoroughly wet.

The kamacite has Neumann bands and many subgrain boundaries that often are decorated profusely with fine rhabdites. The kamacite ranges in hardness from interior values of 165±10, through a minimum of 150 in the recovered transition zone, to a value of 175±15 in the heat-affected α_2 zone (hardness curve type II). Rhabdites are common in the matrix as 2-10 μ thick, tetragonal prisms. Plessite fields are developed as open comb plessite, as sphero- and acicular-plessite, and particularly as pearlitic areas with single taenite lamellae about 0.2-1 μ wide. Some
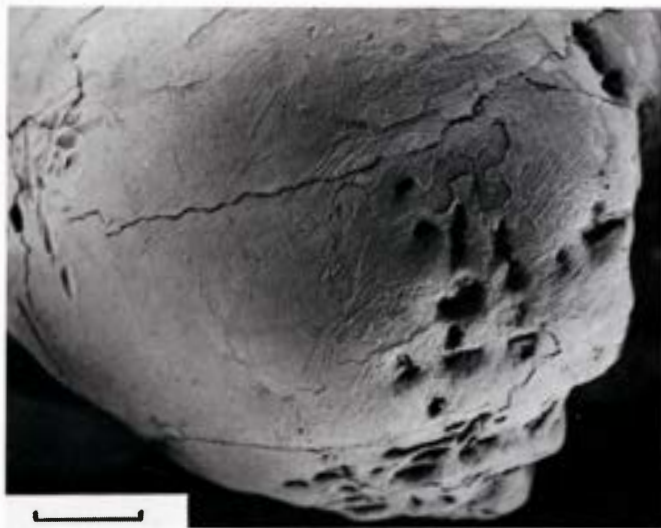

Figure 360. Bogou. Close-up of the domed surface, Figure 358. The oxidic fusion crust is partially spalled off, but the metallic fusion crust remains. The pits indicate where low-melting minerals (schreibersite, troilite) were preferentially ablated away. Smoked with NH_4Cl. Scale bar 10 mm. S.I. neg. M-656B.

Figure 361. Bogou (U.S.N.M. no. 2245). A full, deep-etched slice. The heat-affected α_2 rim zone is distinctly seen: wide under the knobs, but narrow at the bottom of regmaglypts. Large troilite-graphite-silicate aggregates with rims of schreibersite and cohenite. A few cohenite crystals are in the kamacite lamellae to the extreme right. Scale bar 20 mm. S.I. neg. M-1375A.

of the taenite is rich in dissolved carbon, as evidenced by the martensitic rim zone around it in the heated α_2 rim zone.

Troilite is abundant as 10-40 mm nodules. Some are monocrystalline with a few lenticular deformation twins but with local shear zones of 1-5 μ recrystallized grains. Others are more thoroughly recrystallized. The varying degree of recrystallization is one reason for the different reflectivity of the polished nodules. Another reason is the varying amounts of 0.1-5 mm graphite inclusions, and of 0.1-1 mm silicate grains, mostly olivine. In one place a 10 x 1 mm irregular daubreelite lens separates two troilite regions; the daubreelite has finely serrated boundaries against troilite, and less than 1 μ wide troilite lamellae are exsolved everywhere inside the daubreelite, parallel to its octahedric planes. This is certainly highly unusual, and indicates a rapid cooling of daubreelite supersaturated with
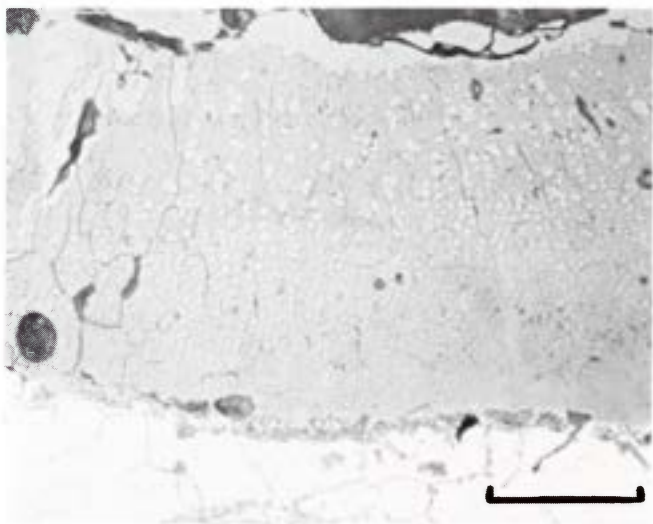
Figure 362. Bogou (U.S.N.M. no. 2245). The oxidic fusion crust. Magnetite (light gray) forms a continuous exterior layer (above) and is precipitated as fine skeleton crystals in the metastable wüstite (dark gray). Below the metallic fusion crust. Etched. Scale bar 50 μ.
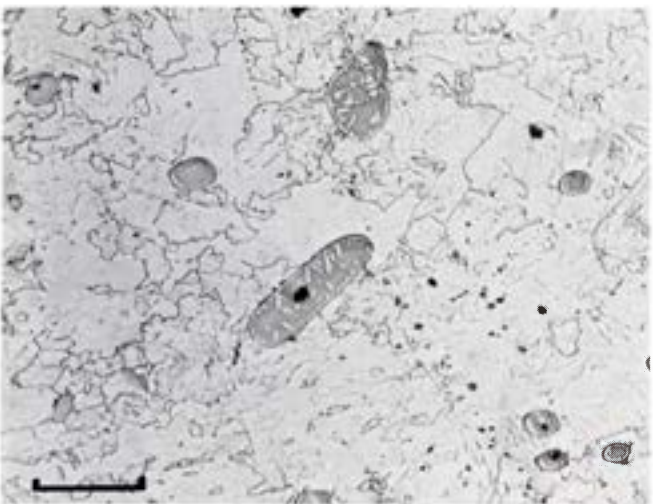
Figure 363. Bogou (U.S.N.M. no. 2245). Detail of the heat-affected α_2 zone A. Micromelted rhabdites are common. Etched. Scale bar 20 μ. S.I. neg. 658J.

troilite, plus a long-term annealing at rather low temperature. Point counting of several slices and photomicrographs showed an average content of 2% S in the mass.

The troilite is surrounded by 0.5-1.5 mm wide schreibersite rims upon which 0.1-0.5 mm cohenite has precipitated. Schreibersite lamellae 0.5-1 mm wide with 0.1-0.4 mm cohenite rims are common centrally in many α-lamellae, and rounded, cavernous 3 x 0.5 mm cohenite blebs are common in a few areas of the sections, but are mostly absent. Graphite as decomposition lamellae in the cohenite was not observed in this meteorite.

Because Bogou is a fresh fall, its crust commands some interest. It is composed of varying numbers of oxidic and metallic layers of rapidly solidified melts. Generally there is little mixing of the two types, with metallic layers occupying the inner part of the crust and the oxides the outer part, but occasionally an oxide layer is intercalated between metal layers, or 5-100 μ lenses and globules of metal are trapped in the oxides. A complete layer of oxide, typically 50 μ thick, consists of a continuous bluish-gray isotropic phase of wüstite and a lighter, more rose-purplish, isotropic phase of magnetite that is developed partly as cubic skeleton crystals suspended in wüstite and partly as an irregular outer semi-continuous layer. The skeleton crystals are serrated cubes that may be 0.5-1 μ across nearest the meteorite, but generally increase in size to about 5 μ outward. This is perhaps a quenching effect from the cold meteorite, similar to the effect seen in technological babbitt alloys cast for sleeve bearings that, when rapidly cooled, develop fine cubic SbSn-crystals near the cooled walls but coarser crystals farther away. The oxide crust may be deposited directly upon the metallic, unmelted meteorite, or it may rest upon one or more of the previously formed metallic melts.

The single metallic lamina is typically 25 μ thick and solidified in cellular, dendritic aggregates, where the dendrite arms are less than 1 μ thick. If several layers are present they usually interlock, resembling a jigsaw puzzle, because rapid surface reactions have taken place involving low-melting phosphorus-carbon eutectics. The innermost layer is frequently so rich in carbon that it has been able to carburize the outermost 10-100 μ of the unmelted substrate. This transformed upon cooling to martensitic structures, which attain a microhardness of no less than 275, as compared to a microhardness of the inner α_2 zone of 175±15. The innermost layer itself is often normalized, heat treated by the subsequent deposition of more layers. There are structural indications that the metallic layers are enriched in nickel frequently up to 60%; this could be confirmed by the microprobe. The magnetite and wüstite, on the other hand, are poor in nickel (0.1-1%) as shown by Marvin (1963) by X-ray analytical methods.

During the rapid penetration of the atmosphere the metal melted by frictional heating and was mainly lost in the trail. A small fraction was swept across the surface and redeposited in protected sites. In the oxygen-poor upper atmosphere, the melt was still sufficiently carbon-rich to

carburize the substrate, but later the metal was both decarburized and enriched in nickel. Iron was preferentially removed as fused oxides, which more or less perfectly separated from the metallic melts. In the late stages of the flight with cosmic velocity, near the point of retardation, no more fused metal was produced, but the exterior layers burned in situ to oxides. The highest oxide content is found in the outer 30-50 μ, which formed the mineral magnetite. A somewhat lower oxide content follows in the next 20-50 μ layer, which decomposed to magnetite and wüstite immediately. The wüstite did not decompose after the equilibrium diagram at 570° C, because time was insufficient; it may survive metastably for long periods of time, as noted on a number of terrestrially old iron meteorites. As is apparent, the fusion crust is quite complex and presents a number of intriguing questions.

Under the oxide and metal fusion crusts, the normal 0.5-2.5 mm wide zones of α_2 are encountered. They are also present under the surface that was created by fracturing in the high atmosphere. Melted rhabdites are common in the outer 50% of the zone.

Bogou is structurally a normal, coarse group I iron closely related to such well-known irons as Canyon Diablo and Odessa.

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

2,080 g slice (no. 2245, 12 x 8 x 3.8 cm)
  263 g endpiece (no. 2245, 7 x 6 x 1 cm)

Boguslavka, Primorski Region, Siberia, USSR
44°33′N, 131°38′E

Hexahedrite, H. Single crystal larger than 60 cm. Neumann bands and incipient recrystallization. HV 200±10.

Group IIA. 5.42% Ni, 0.46% Co, about 0.2% P, 0.1% S, 60 ppm Ga, 180 ppm Ge, 24 ppm Ir.

HISTORY

At 11:47 a.m. local time (Harbin) on October 18, 1916 (October 5, according to the old calendar), the population within an area of about 500 km in diameter observed the usual sound and light phenomena associated with a meteorite fall when two masses fell 5 km north of the small village Boguslavka, 160 km north of Vladivostok. They were both excavated three days later. The larger mass of 198.6 kg had made a funnel-shaped hole 130 cm deep and 270 cm wide in sand, while the smaller mass of 58.1 kg had made a similar 200 cm deep and 90 cm wide hole in clay, 1,000 m distant (Backlund 1916a, 1917; Chirvinsky 1923). While the two masses match almost perfectly along a cubic cleavage plane, it is evident that an endpiece is still missing; eyewitnesses claimed that a third fragment fell, but this was never found (Krinov 1946). The iron was described with illustrations by Zavaritskij & Kvasha (1952) and by Krinov (1955). It was briefly mentioned with a figure of the cleavage plane by Mason (1962a: figure 17). Boguslavka has been included in many recent papers on the age problems and isotope productions by, e.g., Fisher (1963), Sobotovich (1964), Berkey & Fisher (1967), Hintenberger et al. (1967). Cobb (1966) found by the $^{39}Ar/^{38}Ar$ method a cosmic ray exposure age of about 50 million years. An estimate of the trajectory of Boguslavka was presented by Astapovich (1958: 481).

COLLECTIONS

The larger mass is undivided in Moscow (196.6 kg). Odessa (43.2 kg), Moscow (7.8 kg slices), Leningrad (391 g), Minsk (366 g), Stalinabad (345 g), Copenhagen (258 g), Tempe (205 g), Sydney (147 g), Perth (58 g).

DESCRIPTION

Boguslavka is the second-largest iron seen to fall. The largest, Sikhote-Alin, fell in the same part of Siberia 31 years later. Boguslavka has deep regmaglypts 3-5 cm in diameter on the exterior surfaces and shallow ones of about the same aperture on the later cleavage faces. The breakup thus must have occurred at an altitude where the velocity still was high enough for atmospheric ablation to be active. In many depressions fine hair-lines are observed, but these are less abundant than on some smaller meteorites.

The 198 kg mass has dimensions of 60 x 19 x 30 cm; the 58 kg mass measures 36 x 19 x 17 cm. The matching, plane cleavage face is about 36 x 19 cm and indicates, as do the polished sections, that the whole mass was a very large single crystal of ferrite before it split along a $\{100\}$ cube face in the high atmosphere. See Figures 39 and 40.

The Neumann bands are straight but often discontinuous. In intersections, recrystallization of the matrix has

BOGUSLAVKA – SELECTED CHEMICAL ANALYSES

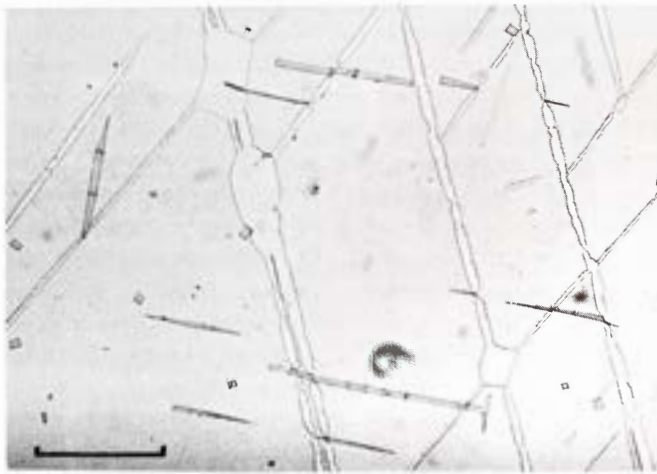| References | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson 1941a	5.48											
Trofimov 1950				480								
Dyakonova 1958a	5.46											
Buchwald 1966, unpubl.	5.54	0.50							48	166		
Cobb 1967	5.18	0.42					144		52.5		23.5	
Wasson 1969	5.45								60.5	180	24	
Rosman 1972								0.29				

Figure 364. Boguslavka (Copenhagen no. 1965, 116). Kamacite with sheared rhabdites. Recrystallization has started at twin intersections. Etched. Scale bar 100 μ.
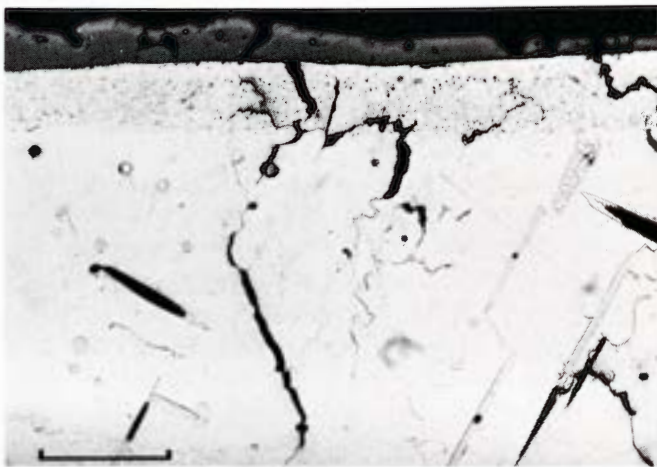

Figure 365. Boguslavka (Copenhagen no. 1965, 116). Above, oxidic fusion crust (dark gray) followed by a dendritic, metallic fusion crust (light gray). Then follows zone A with micromelted rhabdites and numerous hot cracks and gasholes in the phosphide melts. Etched. Scale bar 100 μ.

created new α-grains, 25-100 μ across, that show a tendency to grow along certain Neumann bands; compare Indian Valley. The recrystallized grains occur with a frequency of about 5 per mm^2. Recrystallization has also started along the troilite inclusions. The microhardness of the kamacite is 200±10, and the recrystallized grains are only slightly softer. Their orientation differs, however, from the parent kamacite, as evidenced by the various shapes of the Vickers hardness impressions.

Schreibersite is particularly frequent in the form of rhabdites that range from 3 x 1 mm to a more common size of 5-10 μ across. They are monocrystalline but frequently faulted and displaced many microns. The bulk phosphorus content is estimated to be above 0.20%.

Millimeter-sized nodules of troilite-daubreelite with rims of schreibersite and cohenite are common. The troilite is a fine aggregate of anisotropic, polyhedric 5 μ grains probably due to recrystallization. The cohenite is developed

as a 10-100 μ thick, discontinuous rim, either in direct contact with troilite or daubreelite or nucleated on another rim of 100 μ schreibersite. The cohenite is partially decomposed to 1-3 μ wide graphite lamellae that presumably have nucleated in fractures in the cohenite, judging from their morphology.

The heated rim zone of α_2 is 0.5-2 mm thick; melted rhabdites are present to half the depth of α_2. The microhardness of the α_2 zone is 190±15, decreasing to a minimum of 165±5 just inside the α_2 zone and increasing to an interior value of 200±10 (hardness curve type II). Locally a 20-100 μ thick, ablation-melted metallic crust is preserved, and a black, 50 μ thick magnetite crust covers most of the meteorite. At least locally, it is a two-phase oxide mixture of magnetite and wüstite.

Boguslavka is a normal hexahedrite that shows incipient recrystallization, and still contains cohenite in the process of decomposition to graphite. It is related to Smithonia.

Specimen in the U.S. National Museum in Washington:
185 g part slice (no. 1374, 5 x 4 x 1 cm)

Bohumilitz, Bohemia, Czechoslovakia
49°6'N, 13°49'E

Polycrystalline, coarse octahedrite, Og. Bandwidth 1.90±0.30 mm. Neumann bands. HV 175-275.

Group I. 7.27% Ni, 0.48% Co, 0.30% P, 73 ppm Ga, 268 ppm Ge, 2.0 ppm Ir.

HISTORY

A mass of 103 pounds, equal to 52 kg, since they are Bohemian pounds (Berzelius 1832), was plowed up in 1829 only 150 steps from the Bohumilice Castle, which lies in a small community 6 km north-northeast of Vimperk, Böhmerwald, in the České Budějovice region. A description was given by Sternberk et al. (1830), and about a third of the mass was cut and distributed. It was analyzed by Berzelius (1832) and later examined by Rose (1864a) who also presented accurate drawings of the microstructure. A compilation of old data with a short description will be found in Laspeyres (1895: 193). A second mass of 962 g was found in 1889 near Bohumilice (Brezina 1896: 341; Wülfing 1897: 38), and in 1925 a third individual of 5,850 g was plowed up 3.5 km west of Bohumilice and 0.75 km north-northwest of Vyškovice (Slavíková 1933). Bohumilitz is thus a small shower of at least three fragments, 52, 5.9 and 1 kg, with a maximum distance of about 4 km between the individuals.

It has been suggested (Želikzo 1936, Mineralogical Abstracts: volume 6: 392) that the shower fell in 1770, but this appears to be out of the question since weathering has removed all traces of the heat-affected rim zone, which normally is about 2 mm thick and would require many thousands of years to corrode away. In an early attempt to

determine terrestrial ages Vilcsek & Wänke (1963) found Bohumilitz to be at least 1,300 years old. Chang & Wänke (1969) found a cosmic ray exposure age of 220 million years.

COLLECTIONS

Prague (37.8 kg of the 1829 mass; the 1925 mass of 5.85 kg undivided; 500 g slices), Vienna (4,702 g), Chicago (1,885 g), Paris (1,482 g), Berlin (1,405 g), Budapest (634 g), Washington (323 g), Tempe (275 g), Tübingen (267 g), New York (249 g), Rome (241 g), Bonn (138 g), Strasbourg (122 g). Further 10-50 g specimens in Amherst, Calcutta, Dresden, Göttingen, Hamburg, Harvard, Vatican and Yale. All structural and analytical data so far are apparently based on material cut from the 1829 mass.

DESCRIPTION

All three masses are corroded and pitted. The original sculpture is partly obscured by flaking off of weathered portions, and all traces of fusion crust and heat-affected α_2 zones seem to have disappeared. Tuček (1958: plates 10 and 11) presented some photographs of the two larger masses and reported their present dimensions: 37.8 kg measuring 34 x 24 x 19 cm, and 5.85 kg measuring 24 x 11 x 10 cm. Sections show that at least the largest mass at high temperature was composed of several austenite units. No. 899 in Chicago and no. 11 in Prague thus display a 10 x 5 cm austenite grain partly surrounded by another, larger grain of a different orientation. The grain boundaries are filled with centimeter-wide aggregates of troilite, graphite and schreibersite. The Widmanstätten structure is well developed with a bandwidth of 1.90 mm (not 0.85 mm as given in Hey 1966: 62, 612). Grain growth of the kamacite has partly destroyed the straight lamellae and created almost equiaxial 3-5 mm grains locally. Neumann bands are common, but many are partly resorbed, and incipient recrystallization to new, equiaxial, 50 μ α-grains may be observed in many places (compare Seeläsgen: figures 1571-72). The Neumann bands are frequently decorated along both sides with 0.5-1 μ phosphide precipitates. The subboundaries of the kamacite are also decorated.

Taenite occurs sparingly as slender lamellae and as wedges the interiors of which are often martensitic. The few plessite fields are developed as comb plessite or have pearlitic and spheroidized interiors, which is a common characteristic of the group I irons. Cosmic deformation has bent the linear elements and faulted and sheared the plessite fields locally. The microhardness of the kamacite varies correspondingly within wide limits, from 175±15 in the undeformed regions to 275±25 in heavily coldworked areas. It is noteworthy that this wide range may be observed within the same square centimeter polished section; it ties nicely in with the degree of cold-working, observable from the bending of Neumann bands, and so on.

Schreibersite is present as 2-16 mm long monocrystalline skeleton crystals and as 25-100 μ wide grain boundary precipitates. Rhabdites, 5-10 μ across, are also common. All phosphides are brecciated and sheared. Although cohenite is not abundant it is sometimes observed as monocrystalline 0.1-0.5 mm wide rims around schreibersite and troilite. The cohenite is partly decomposed to graphite lamellae and granulated ferrite to a degree as seen in, e.g., Wichita County. Graphite nests, 25 x 5 mm or smaller, occur with troilite, schreibersite and an unidentified opaque mineral. The graphite is spherulitic or composed of aggregates of sheaves with undulatory "horsetail" extinction.

Troilite occurs as 1-10 mm nodules which include varying amounts of graphite. The troilite is shock melted and solidified to 1 μ aggregates, in which similar-sized grains of daubreelite and somewhat larger schreibersite fragments are dispersed. The troilite-graphite-schreibersite aggregates and the schreibersite skeleton crystals are enveloped in 2-3 mm wide rims of swathing kamacite. Silicates are apparently present in minor quantities in the troilite-graphite aggregates but were not available for identification.

Bohumilitz is a typical, inclusion-rich coarse octahedrite closely related to, e.g., Odessa.

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

103 g part slice (no. 446, 7 x 5.5 x 0.4 cm)
127 g part slice (no. 2678, 6 x 4 x 0.9 cm)
 40 g part slice (no. 2679, 5.5 x 3 x 0.4 cm)
 53 g part slice (no. 2680, 7 x 2 x 1 cm)

Bolivia, South America

Coarse octahedrite, Og. Bandwidth 2.7±0.5 mm. Partly recrystallized. HV 145-250.

Group I. 6.6% Ni, about 0.2% P, 88 ppm Ga, 377 ppm Ge, 1.5 ppm Ir.

Reheated, probably both cosmically and artificially. Probably paired with Pooposo.

BOHUMILITZ — SELECTED CHEMICAL ANALYSES

| References | percentage | | | C | S | ppm | | | | | | |
	Ni	Co	P			Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moss in Hey 1966	7.2	0.48				12	112		67	278		
Smales et al. 1967						11.2	114	15.1	70	273		
Moore & Lewis 1968	7.23	0.47	0.30	460	40							
Wasson 1970a	7.37								75.3	264	1.8	
Crocket 1972											2.3	7.0

Until 1966 the newest analysis was from 1891 and gave 7.72% Ni and 1.22% Co!

HISTORY

A mass of 21.25 kg was in the mineral collection of F.A. Canfield, Dover, New Jersey, when it was bequeathed in 1926 to the U.S. National Museum. The meteorite was described by Merrill (1927b) with an unsatisfactory analysis by Shannon. The only information regarding the origin was a fragment of an old letter from Canfield of which the first page and date were missing: "A friend has given me a mass of meteoric iron which weighs 47 pounds and has never been cut. It was found 30 years ago in Bolivia and purchased by a priest, who thinking it was silver paid 600 $ in gold for it."

COLLECTIONS

Washington (20.6 kg), London (105 g), Tempe (96 g).

DESCRIPTION

The mass is roughly a triangular, flat pyramid with average dimensions of 23 x 22 x 11 cm. Terrestrial corrosion has created shallow pits resembling thumbprints on the sides while the base, except for a finger-sized cavity, is smooth. One side has been cut to produce a few slices. Corrosion penetrates to a depth of at least 5 cm, particularly along grain boundaries and around inclusions.

Etched sections show an indistinct Widmanstätten structure with short, finger-like lamellae ($\frac{L}{W} \sim 6$) and a bandwidth of 2.7±0.5 mm. There is no oriented sheen. Locally, larger patches of ferrite, due to grain growth, are

Figure 366. Bolivia (U.S.N.M. no. 793). Main mass in the Smithsonian Institution. Scale bar 40 mm. S.I. neg. 5464.

seen. The ferrite shows an extremely unusual microstructure. Neumann bands are partially recrystallized to 20-100 μ grains; these grains often are elongated along certain Neumann band directions. Precipitates 1 μ wide, in the form of oriented needles and subangular bodies, are very common in the ferrite and resemble the isothermal taenite described by Brentnall & Axon (1962). The hardness ranges widely, from 150±5 in pure, recrystallized ferrite grains, to 225±25 in the isothermal taenite.

Taenite and comb plessite are present in minor amounts, 1-3%. Some are plastically deformed and sheared. Most taenite has thorns protruding into the surrounding kamacite.

Schreibersite occurs occasionally as 10 x 1 mm irregular lamellae but more commonly as 20-50 μ grain boundary precipitates. It is also common as 1-5 μ precipitates on the subboundaries of the ferrite. The bulk phosphorus content is estimated to be 0.20±0.04%. Rhabdites are not present. The schreibersite is monocrystalline, but heavily brecciated and sheared, and it is completely enveloped in a 1-5 μ wide, creamcolored reaction zone, which apparently is austenite. A similar reaction zone has been described by Buchwald (1967a) in Seeläsgen.

Cohenite occurs in patches, typically as 3 x 1 mm short, rounded inclusions centrally in the α-lamellae. It is monocrystalline (HV 1000±30), but heavily brecciated, and is decomposed to ferrite plus graphite along the fissures in 10-20 μ wide zones. The decomposition has reached a stage between that observed in Wichita County and that in Dungannon. The cohenite has many reentrant edges and irregular shapes as a result of the partial decomposition. Small schreibersite blebs are, as usual, embedded in or precipitated upon the cohenite.

Corrosion has removed what was probably a 12 x 8 mm troilite nodule; the typical rim of schreibersite plus cohenite is still preserved around the hole.

No trace of the heated rim zone from the atmospheric penetration is preserved. On the contrary, limonitic deposits up to 2 mm in thickness are found adhering to it.

The structure is that of a group I iron, like Campo del Cielo or Yardymly, except that a pronounced reheating to 550° or 600° C has taken place. When this occurred, the ferrite recrystallized and the taenite phase around the schreibersite grains was formed. It is also likely that the ferrite phase at this temperature had to correct its dissolved nickel from, say, 6.5% to about 5%. This could have been accomplished by rejecting fine γ-particles with 15-20% Ni. The particle density would be high where the kamacite was rich in nickel, such as around the cohenite inclusions, but low where the kamacite was depleted in nickel, such as

BOLIVIA – SELECTED CHEMICAL ANALYSES

| Reference | percentage | | | ppm | | | | | | | | |
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970, pers. comm.	6.6±0.2								88.0	377	1.5	

around the schreibersite and taenite. This distribution is actually seen. The partial decomposition of cohenite to ferrite plus graphite may have taken place simultaneously.

It is most likely that the reheating occurred at a cosmic event. There are, however, locally high temperature reaction zones between the corrosion products and the meteoritic minerals indicating that some early owner *also* heated the meteorite. The finely exsolved γ-particles observed everywhere in the α-phase indicate a rather rapid temperature increase since a slower temperature increase, as would be expected in cosmos, would provide time for diffusion and correction of the nickel concentration according to the equilibrium diagram, e.g., as seen in Cambria.

It is, therefore, an unsolved problem whether the highly unusual microstructure was created in cosmos or originated artificially or, probably, is a combination of both. A comparison with Pooposo, a little known iron from Bolivia, is recommended.

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

19.95 kg main mass (no. 793, 23 x 22 x 11 cm)
682 g slice (no. 793, 12 x 8 x 1 cm)

Boogaldi, County Baradine, New South Wales
31°4′S, 149°8′E

Fine octahedrite, Of. Bandwidth 0.42±0.06 mm. Decorated Neumann bands. HV 190±15.

Group IVA. 9.1% Ni, about 0.15% P, 2.25 ppm Ga, 0.15 ppm Ge, 0.6 ppm Ir.

HISTORY

A mass of 2.05 kg was found in 1900 by W. Gould on the surface of a hard ridge. The location was two miles from Bugaldie post office and 15 miles northwest of Coonabarabran, corresponding to the coordinates given above. It was described with two photographs of the crust by Baker (1900), and again by Liversidge (1902) who gave excellent photographs of the exterior and of an etched section. Both authors mentioned that the iron had been found at the end of a furrow in the hard ridge and concluded that the iron had fallen less than a year before and had hit the ground at a very acute angle. This is probably a misinterpretation since we now know that irons of this small size are decelerated completely in the upper atmosphere and fall almost vertically through the last

kilometers. Brezina & Cohen (Atlas 1886-1906: plate 34) gave a photomacrograph, and Cohen (1905: 390) presented a description. Hodge-Smith (1939: plate 5) reproduced two of Liversidge's photographs of the exterior. Owen & Burns (1939) and Owen (1940) X-rayed the kamacite and found a well-defined alpha parameter of 2.8628Å. Axon (1961) reexamined the structure and noted the various plessite forms and the deformed kamacite lamellae, which together indicated a cosmic heat treatment.

COLLECTIONS

Sydney (1.18 kg main mass), London (230 g), Washington (79 g), Greifswald (20 g).

DESCRIPTION

The pear- or drop-shaped mass has the overall dimensions of 13 x 8 x 5 cm and weighs 2.05 kg. The mass may be compared to an eagle's head with a rounded, massive end and a hooked bill. In the fusion crust of the massive end are six to eight concentric ridges, each of which is no more than a tenth of a millimeter high but easily seen. These ridges were well figured by Liversidge (1902: plate 5). Perpendicular to the ridges, and radiating from this common area, are numerous low ridges and grooves in the fusion crust. The bill end is smoother but also covered with a thin fusion crust. The very smooth general shape resembles those of Bingera No. 1 and other small, uncorroded irons, such as Föllinge, Avče, Bushman Land and Charlotte, and is probably due to a stabilized flight and a high ablation loss.

Sections perpendicular to the surface show an exterior oxide crust of a thickness varying up to about 0.5 mm, composed of dendritic iron oxide melts. Locally these penetrate 0.5 mm into the mass along 25-50 μ wide cracks which were previously filled with schreibersite. The metallic fusion crust, located below the oxide crust, is composed of successive 25-50 μ thick layers of columnar dendrites which have grown perpendicular to the substrate. In the bill end the heat-affected α_2 zone is 6-6.5 mm thick with melted phosphides present in the exterior 50% of the zone. The thickness of the heat-affected zone in the head end could not be learned from the material available. The hardness of the α_2 zone is 190±15.

Etched sections display a fine octahedrite structure of straight, long ($\frac{L}{W} \sim 30$) kamacite lamellae with a width of 0.42±0.06 mm. The kamacite is filled with Neumann bands

BOOGALDI – SELECTED CHEMICAL ANALYSES

| References | percentage | | | C | S | Cr | Cu | ppm | Ga | Ge | Ir | Pt |
	Ni	Co	P					Zn				
Lovering et al. 1957	8.99	0.48				44	95		<2	<1		
Wasson 1966	9.2								2.20	0.135	0.60	
Smales et al. 1967						49	100	<1	2.29	0.17		
Crocket 1972											0.52	4.5

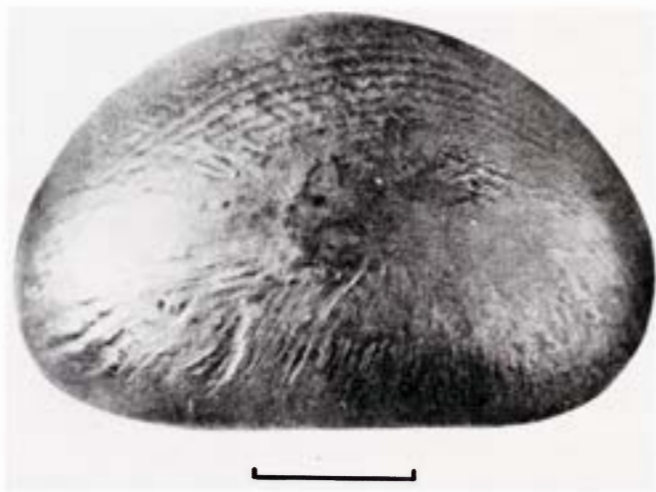Reed (1969) examined the kamacite phase with the microprobe and found 7.5% Ni and 0.11 P.

Figure 367. Boogaldi (main mass in Sydney). End view showing the concentric ridges in the fusion crust. Scale bar 20 mm. (From Hodge-Smith 1939: Plate 5.) See also Figure 36.

which are frequently distorted due to plastic deformation. A close inspection of the bands shows that both sides are decorated by 0.5 μ phosphide precipitates. Because of this, their original location may still be seen in the heat-affected rim zone, albeit the metal has been through an $\alpha \rightarrow \gamma \rightarrow \alpha_2$ transformation. In the inner half of the zone this transformation took place so rapidly that the phosphides did not have time to dissolve. The microhardness of the α-phase is 190±15 (hardness curve type II).

Taenite and plessite cover about 50% by area. The plessite shows all the varieties found in group IVA irons, as in, e.g., Chinautla. Comb plessite and net plessite dominate, but cellular plessite is very common. The fields richer in nickel have martensitic zones between the taenite rims and the duplex interior which is decomposed to $\alpha + \gamma$ of varying fineness, sometimes unresolvable with a 40x oil objective.

Schreibersite is ubiquitous in the grain boundaries as 10-25 μ wide precipitates. Occasionally a 100 μ wide inclusion occurs, nucleated upon a 50 μ daubreelite grain. Schreibersite is further common as 2-20 μ vermicular bodies in the plessite fields where it substitutes for taenite of the same size. Most of the schreibersite crystals are fractured, and frequently displaced by shear, along successive cleavage planes. Individual steps of displacement may be 2-10 μ. The bulk phosphorus content of Boogaldi is estimated to be about 0.15%.

Troilite occurs as scattered, lenticular bodies, 1-2 mm across. On the exterior is a pit, 4 mm in diameter and 1-2 mm deep; this is probably the site of a small troilite nodule that melted out during entry. Daubreelite occurs as scattered, subangular blebs 20-60 μ in diameter.

Boogaldi is a fine octahedrite which has preserved very well the delicate morphology in the fusion crust and is possibly only a few hundred years old. Structurally, it is related to Hill City, Mart, Chinautla and Duchesne, and chemically, it is a typical group IVA of the more phosphide-rich variety.

Botetourt County, Virginia, U.S.A.

Approximately 37°30'N, 79°45'W

According to Shepard (1866) "a large mass not easily transported on horseback" was found in 1850. Only inconspicuous fragments have ever reached scientific circles. Cohen (1905: 114) described and analyzed some material and found about 17% Ni. A small polished section which was shown to me by Dr. E.P. Henderson, Washington, had an ataxitic structure somewhat similar to Babb's Mill; however, it had been significantly reheated artificially so that the present structure resembled the figures of Babb's Mill, Troost's Iron (Buchwald 1967a: figures 11-16). The possibility that the Botetourt County material represents transported fragments of Troost's Iron should be borne in mind and examined when the occasion arises.

Boxhole, Plenty River, Northern Territory, Australia

22°37'S, 135°12'E; 470 m

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm. ϵ-structure, and reheated to a range of structures. HV 120-310.

Group IIIA. 7.67% Ni, 0.49% Co, 0.11% P, 0.05% S, 18 ppm Ga, 37 ppm Ge, 8.2 ppm Ir.

HISTORY

A circular depression near Huckitta about 170 m in diameter, was recognized as a meteor crater during geological surveying of the area northeast of Alice Springs, Central Australia (Madigan 1937). The crater has a level bottom, filled with clay and debris to an unknown depth, and, being situated on sloping ground, has a depth that varies from 9 to 15 m. The rim is, on the average, only 3 m higher than the surrounding landscape which is a peneplain in Precambrian schists and gneisses. Bedrock is partly exposed on the interior sides of the crater. There is evidence of considerable erosion since the impact took place, but "there appear to be no standards by which the age of this crater can be placed between 500 and 50,000 years" (Madigan 1937). One fragment of meteorite iron, about 100 g in weight, and two iron-shale balls, about 8 cm in diameter, were found on the first visit, and more material was later recovered by cooperation with the nearby cattle station owner. No silica-glass was found. The iron fragments were described and analyzed by Madigan (1940), and were found to be very similar to the fragments found a few years earlier in connection with the Henbury craters.

Hodge & Wright (1967) sampled the soil in the area around the crater for a distance of 1.5 km and concluded that, within this zone, there was a spotty distribution of weathered meteoritic particles similar to those found around the Henbury craters. There was much contamination of terrestrial iron-bearing particles. Kohman & Goel

(1963) measured the relative proportion of the cosmogenic nuclides ^{14}C and ^{10}Be and dated the impact to 5400 ± 1500 years ago. Reed (1969), using the microprobe, found 7.1% Ni and 0.10% P in solid solution in the α-phase. It is not known exactly how much material has been found in connection with the crater because several private parties have been active at different times; an estimate, based on various reports and collections, would be that at least 500 kg iron meteorites and perhaps 50 kg shale balls have been recovered.

COLLECTIONS

Adelaide (179 kg, maximum 167 kg), London (83.5 kg, maximum 82 kg), New York (8.7 kg, maximum 7.6 kg), Washington (6.5 kg), Sydney (3.3 kg), Tempe (2.7 kg), Canberra (1.5 kg), Perth (1 kg), Tübingen (1 kg), Copenhagen (31 g).

DESCRIPTION

While many specimens in collections apparently are fragments from a large body that exploded on impact with the ground, others have had individual trajectories through the atmosphere. The 3.7 kg specimen in the U.S. National Museum is an example. When it landed, it was probably rather evenly covered with regmaglypts, 1-2 cm in diameter, but subsequent corrosion significantly altered the surface. The part exposed to the air is pock-marked with small pits, 1-10 mm in size, which are smooth and covered with an adhering, glassy, dark red-brown crust. The buried part has lost much more material and displays large, sharp-edged grooves, 2-5 cm in diameter, which are covered with a loose, rough ocher-colored skin.

The small iron fragments, 50-200 g in size, may be smooth wedge-shaped or elongated pieces, or they may be contorted and twisted slugs. All have edges often knife-sharp which were produced by the fragmentation and augmented by subsequent corrosion. A shale ball is almost always found by digging in the surface soil. The typical shale ball is a 100-200 g nodule of iron oxides with all iron corroded away. During this process the scale first formed while still adhering to the nucleus, fractured because the interior expanded during the rust formation. The end result is an irregular, rounded, cavernous mass which often has quartz and feldspar from the base rock adhering and giving the outer layers the appearance of a bread crust or a dried up mud bed. When the shale ball eventually disintegrates by erosion and mechanical action, all that is left are flaky

segments of iron oxides. The shale is magnetic, crushes to a brown powder, and gives off water in a closed tube; compare Canyon Diablo.

The polished and etched sections of large specimens show a well developed Widmanstätten pattern of long, straight bundled lamellae ($\frac{L}{W}\sim 30$) with a bandwidth of 1.00 ± 0.15 mm. The oriented sheen is somewhat subdued and mottled because the ferrite shows ϵ-transformation structures in varying degrees, corresponding to shock pressures above 130 k bar. The hardness is 305 ± 15. The plessite is in the form of degenerated, almost resorbed comb plessite areas with 2-10 μ wide taenite lamellae. The swollen taenite ribbons may have martensitic or acicular interiors. Ferritic grain growth before the ϵ-forming event has wiped out several α-lamellae boundaries and has been active in many plessite areas to create a characteristic polycrystalline interior.

Schreibersite is a minor constituent, only present as 10-20 μ wide grain boundary precipitates and an occasional 50 μ nodule. The ferritic matrix is, however, rather loaded with 1-2 μ rhabdites. There are significantly more phosphides in Boxhole than in Henbury.

Troilite occurs as scattered 0.5-2 mm rhombic nodules and as elongated bodies, typically 9×0.4 mm. They are monocrystalline units with occasional lenticular twin sparks from deformation, and there are no schreibersite borders. Daubreelite is present on the 20% level as lamellae parallel to (0001) of the troilite. The troilite itself is often fractured along this basal plane and divided in 10-25 μ thick plates. Plate-shaped, oriented chromium nitrides occur frequently in α as $25 \times 1 \mu$ straight or gently bent, hard particles. On one specimen (no. 3227) the rim, heated from atmospheric penetration, is still preserved on one side as a 2 mm wide α_2 zone; the other sides of the specimen were either late fracture planes, or have been severely corroded, since all traces of α_2 are gone. The α_2 zone has a hardness of 200 ± 10 (hardness curve type I).

While the larger specimens conform to this description and probably fell as independent bodies, dislodged at high altitude from the main body, the small slugs may be violently deformed. On the exterior they are twisted and contorted, and etched slices through such specimens confirm the first impression. The Widmanstätten lamellae are bent and torn out in long stringers. The ferrite is recrystallized or converted to α_2 in the form of serrated, patchy grains 25-50 μ in size. A clear indication of the presence of carbon dissolved in taenite is seen around many

BOXHOLE – SELECTED CHEMICAL ANALYSES

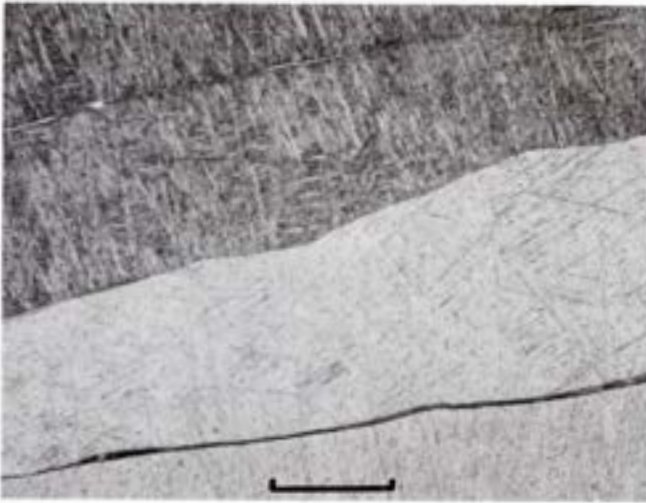| References	percentage			C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Lovering et al. 1957	7.72	0.50				62	133		13	31		
Wasson & Kimberlin 1967	7.64								18.1	37.2	8.2	
Moore 1969, pers. comm.	7.66	0.48	0.11	130								

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.