

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 \pm 15. The hardness drops to 155 \pm 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.

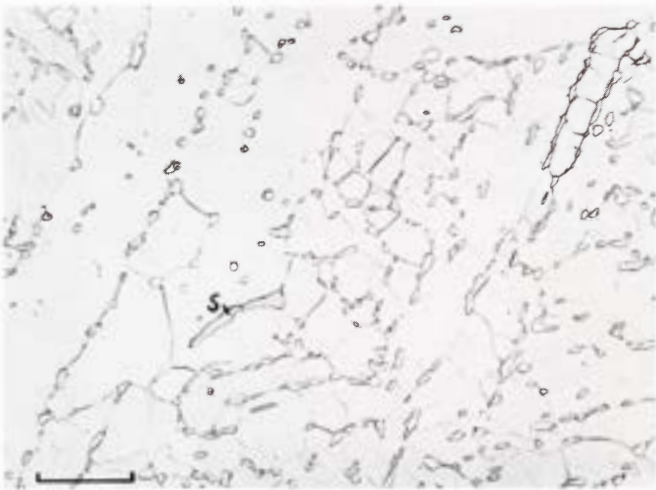


Figure 400. Bushman Land (U.S.N.M. no. 2515). Open-meshed duplex plessite. Numerous somewhat spheroidized taenite particles and subboundaries in the kamacite. Schreibersite (S). Etched. Oil immersion. Scale bar 20 μ .

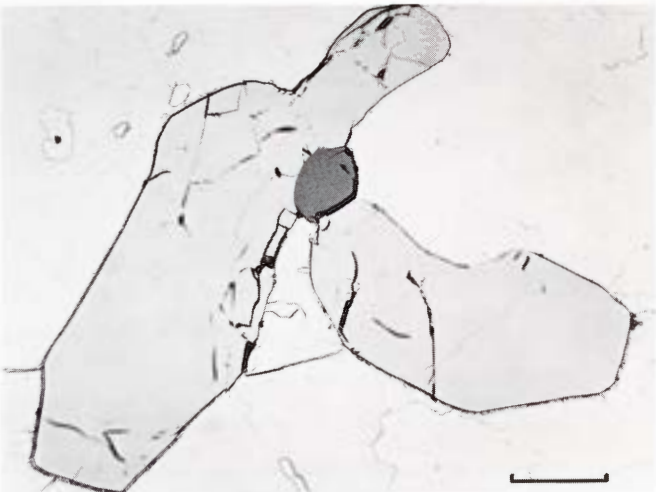


Figure 401. Bushman Land (U.S.N.M. no. 2515). Two schreibersite crystals in the inner part of the heat-affected α_2 zone. They were apparently originally nucleated by the black troilite crystal. Etched. Oil immersion. Scale bar 20 μ .

Etched sections display a fine Widmanstätten structure of straight, long ($l/w \sim 40$) kamacite lamellae with a width of 0.33 \pm 0.05 μ . The subboundaries are only indistinctly visible because there are few precipitates on them. Neumann bands are common, and the hardness is 180 \pm 8.

Taenite and plessite cover 40-50% by area, mostly as comb and net plessite fields. Finger plessite and cellular plessite (HV 195 \pm 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 \pm 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 \pm 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 \pm 0.03 mm. HV 180 \pm 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.

HISTORY

A mass of about 40 kg was plowed up by a farmer named Abram Crabbe, living eight miles southwest of Butler, Bates County. Crabbe took the mass to the blacksmith who spent nearly two hours in cutting off a piece after first heating it (Broadhead 1875). Smith (1877) gave the weight as about 36 kg and presented an analysis which showed only 10% Ni and was the only one known until 1958. Descriptions were given by many authors in the following years: Brezina (1880a; 1881), Huntington (1886; 1888: 92), Cohen (1905) and Brezina & Cohen (Atlas 1886-1906: plates 7-9). Brezina (1882) gave four large lithographs of etched sections and prepared tables of the Widmanstätten angles based upon an examination of Butler. Farrington (1915) reviewed the literature.

Perry (1944) presented four micrographs, and Vogel (1932) experimented with transformation upon reheating of small samples. Lovering & Parry (1962) included Butler in their thermomagnetic analysis, and Reed (1965a; 1965b;

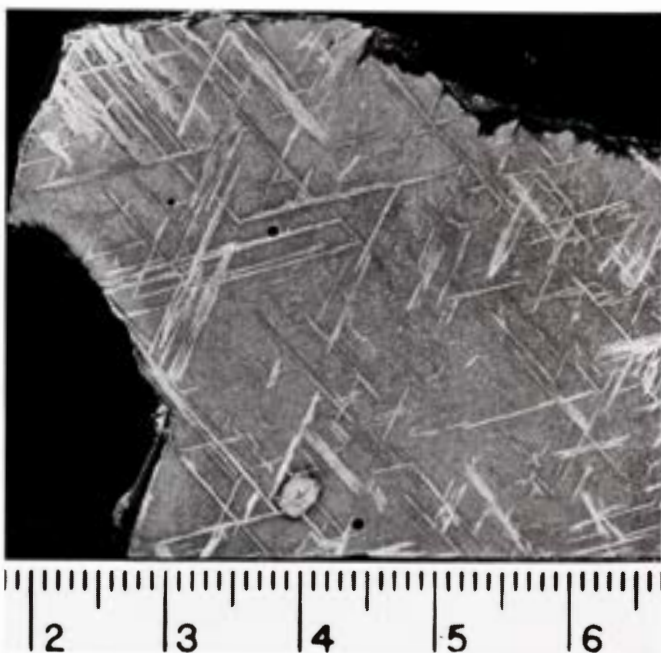


Figure 402. Butler (Tempe no. 137ax). Plessitic octahedrite with an anomalously high germanium content. Large troilite nodule (gray) and three graphite nodules (black). Deep-etched. Scale bar in cm. (Courtesy C.B. Moore.)

1969) determined, in a series of papers, the composition of the α , γ and phosphide phases. Goldstein (1966) and Wasson (1966) showed that Butler structurally and chemically was an anomalous meteorite, particularly because it has the extremely high concentrations of 2000 ppm Ge or 0.2% Ge, which is about five times higher

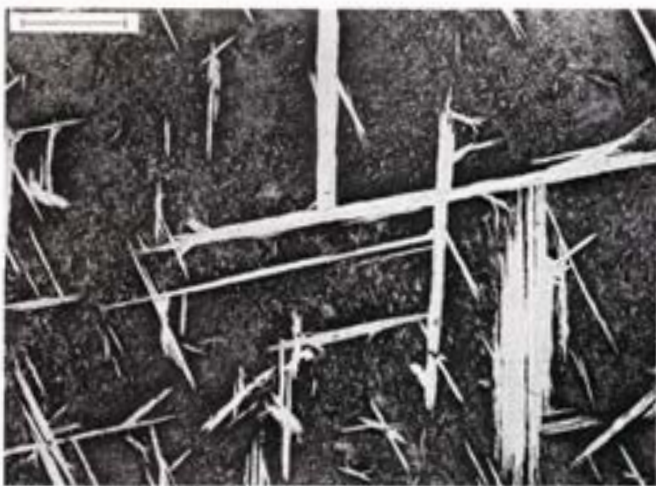


Figure 403. Butler (Copenhagen no. 1876, 2247). Deep-etched sections immediately suggest that Butler is an anomalous meteorite. Scale bar 3 mm. See also Figure 72.



Figure 404. Butler (Harvard no. 354). An area rich in relatively coarse kamacite spindles. Schreibersite (S). Compare Figure 405 with the same magnification. Etched. Scale bar 500 μ . (Perry 1950: volume 1.)

BUTLER – SELECTED CHEMICAL ANALYSES

Goldstein (1966) showed by the microprobe technique that germanium follows nickel. Germanium reaches a maximum of 0.4% in some taenite areas, while the typical kamacite bands contain 0.17%. Cobalt, on the other hand, was enriched in the nickel-poor areas. He found 1.7% Co in

kamacite and 0.6% Co in taenite. His calculated average value for the whole meteorite, 1.4% Co, is, however, not as reliable as the value of 1.03% obtained by wet chemical analysis.

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Dyakonova 1958a	15.31											
Wasson 1966	16.04								87.1	2000	1	
Moore et al. 1969	15.80	1.03	0.05				150					

than the highest concentrations observed in other iron meteorites.

Schultz & Hintenberger (1967) examined a sample for the content of noble gas isotopes like ^3He , ^4He , ^{21}Ne , ^{36}Ar and ^{38}Ar . From these data, Voshage (1967) estimated a cosmic ray exposure age of 420-850 million years.

COLLECTIONS

Harvard (8,028 g endpiece and 5,283 g slices), Paris (3,627 g), Vienna (3,050 g), Yale (970 g), London (608 g), Chicago (504 g), Budapest (494 g), Fort Worth (394 g), Tempe (339 g), New York (335 g), Stockholm (278 g), Copenhagen (278 g), Amherst (223 g), Leningrad (176 g), Prague (142 g), Bonn (110 g), Los Angeles (105 g), Vatican (81 g), Rome (66 g), Hamburg (65 g), Strasbourg (60 g), Dorpat (44 g), Berlin (39 g), Moscow (12 g), Denver (x g).

DESCRIPTION

The largest preserved specimen is no. 354 of 8.0 kg in the Harvard Collection. It is an irregular shoe-shaped block of 30 x 6 x 5 cm. It shows how one end was violently hammered by the blacksmith with overfolding and smoothing as a result. The other end has a heavy chisel mark. Specimen no. 980 of 391 g in the U.S. National Museum is an endpiece which is similarly hammered and has high temperature oxide-scales. It is somewhat opened along the $\{111\}$ planes and shows overfolding. Other specimens in collections show various degrees of hammering and heating. Thus there is no doubt about the correctness of the original source's statement regarding the blacksmith's treatment of the specimen. Fortunately, however, it appears that there was a steep temperature gradient from the maltreated end of the specimen to the opposite end which seems to be structurally unaltered.

Undamaged Specimens, e.g., no. 1876, 2247 in Copenhagen, have a peculiar Widmanstätten structure of long bundled kamacite lamellae with pointed ends. The lamellae have a width of 0.15 ± 0.03 mm and an average length of 15 mm. Deviations are, however, very common

and give the etched surface a beautiful and intriguing life, Figure 72. Instead of having the normal blunt, rounded ends, the α -sparks taper out to sharp points or wedges. They are frequently grouped together so that they resemble a bundle of flames. Neumann bands were not observed, but subboundaries divide the kamacite lamellae in 20-100 μ cells. The hardness of the kamacite is variable, 180 ± 12 ; this may be due to a real variation in the quantity of nickel, cobalt and phosphorus in solid solution.

Taenite and plessite cover about 80% by area. A typical field will exhibit a narrow yellowish taenite rim (HV 375 ± 20) followed by martensitic-bainitic transition zones (HV 280 ± 20). Then come poorly resolvable, duplex $\alpha + \gamma$ structures (HV 240 ± 20), and, finally, there frequently occurs a micro-Widmanstätten structure. This takes the form of a dense basket weave of 5-10 μ wide α -sparks in a duplex $\alpha + \gamma$ matrix.

Troilite is common as large nodules 1-2 cm in diameter, but it also occurs as small globules down to 30 μ across. They have served as nucleation centers for rims of swathing kamacite 0.2-0.5 mm wide. The troilite appears to be polycrystalline aggregates of 5-15 μ units. Point counting of the troilite showed 2 cm-sized and 9 mm-sized inclusions on 124 cm^2 sections, adding up to a total of 0.35% S in the meteorite.

Schreibersite occurs only as minute angular bodies 10-50 μ across, particularly at the intersections of the α -lamellae. Reed (1965a; 1969) found 44-49% nickel in these bodies and only 5.8% Ni and 0.026% P in the surrounding kamacite. Rhabdites are not present.

Graphite is present in the plessite areas as spherical clusters. These occur with a frequency of about one per 8 cm^2 and are about 0.5 mm in diameter. They are composed of numerous randomly oriented graphite crystallites, each about 1 μ across. It appears that the graphite is a very late precipitate from the latest part of the

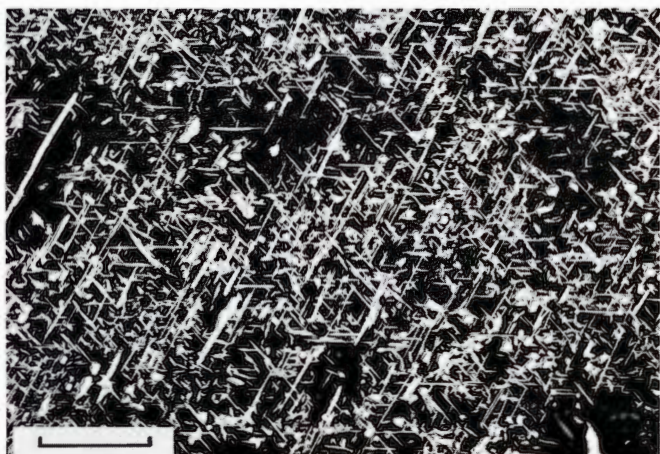


Figure 405. Butler (Harvard no. 354). An area of fine-grained, unresolvable $\alpha + \gamma$, in which there are numerous fine Widmanstätten spindles of kamacite. Etched. Scale bar 500 μ . (Perry 1950: volume 1.)



Figure 406. Butler (Copenhagen no. 1876, 2247). The black matrix is at high resolution seen to be composed of minute $\alpha + \gamma$ particles. Widmanstätten α -spindles are associated with three schreibersite particles. Etched. Scale bar 50 μ .

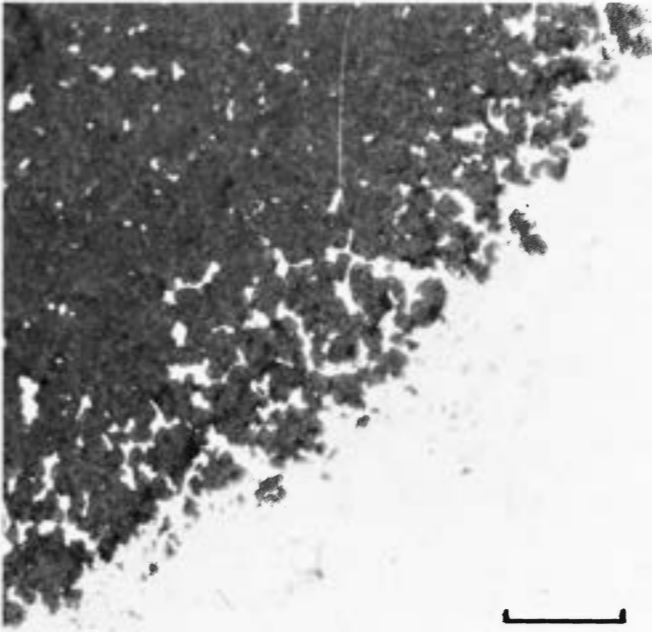


Figure 407, Butler (Copenhagen no. 1876, no. 2247). The edge of a graphite nodule, composed of micron-sized crystallites. Numerous metal particles are present along the edge. Polished. Scale bar 40 μ .

cooling period or from some gentle reheating, since it fills in the interstices of plessite fields.

There is no unequivocal structural or morphological pattern that may be attributed to the high concentration of germanium.

The iron is corroded and has an adhering, thick oxide crust. No trace of fusion crust or α_2 zone was found.

Damaged Specimens, e.g., Harvard no. 354, U.S.N.M. no. 980, show deformed Widmanstätten patterns and an α -phase which is transformed to α_2 . In the 100 μ thick surface zone there is high temperature intercrystalline oxidation, and the small schreibersite bodies are melted to a depth of many centimeters. The troilite is melted and has penetrated the high temperature austenite grain boundaries in a lace-like network, 1-2 μ thick. The taenite has diffuse boundaries and sends "thorns" out into the former α -phase.

The plessite is blurred and partially homogenized. The alterations indicate a peak temperature of about 1000° C when artificially reheated. The hardness of the various phases is different from the original values, but not radically. The α_2 phase was found to be relatively soft, 162 \pm 8, corresponding to a rather low nickel content (~6%). The plessite ranges from 220 to 260 according to the actual composition and degree of homogenization inflicted by the artificial reheating.

Butler is structurally and chemically an anomalous meteorite which has no close relatives at all.

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

130 g (no. 96)
391 g endpiece (no. 980, 5 x 4.5 x 3 cm), heated, hammered
12 g small fragments (no. 2699)
104 g part slice (no. 3292, 6 x 4 x 0.4 cm)

Cabin Creek, Arkansas, U.S.A.

35°27'N, 93°19'W

Medium octahedrite, Om. Bandwidth 1.1 \pm 0.2 mm, Neumann bands. Uncertain position due to the lack of material. About 8% Ni and 0.3% P.

HISTORY

This meteorite, of which little is known except for the exterior shape, fell at 3:17 p.m. on March 27, 1886. It was accompanied by all the usual effects of a falling meteorite and was heard and seen by numerous people in the counties of Crawford, Franklin, Johnson, Pope, Logan and Yell on both sides of the Arkansas River, an area of at least 125 x 125 km. People in the town of Dardanelle, about 25 km southeast of the landing site, were startled by an unusually loud report, accompanied by a peculiar whizzing sound as if hot metal had come in contact with water. They saw the smoke trail in a partly cloudy sky and heard another terrific explosion before everything was quiet again. Unfortunately, the reports printed by Kunz (1887a) gave little information of the direction of the moving meteorite and few other details of the fall itself.

The mass of 107 pounds (48.2 kg) fell almost vertically through the last part of its trajectory, due to air resistance. It broke some branches off a tall pine tree and buried itself 90 cm in the ground, only about 10 km east of Cabin Creek (now Lamar), and 7 km north of the mouth of Piney Creek, on the east side. The corresponding coordinates are given above. Three hours after the fall, Mr. and Mrs. Shandy were able to find the hole and excavate the mass, reportedly still uncomfortably warm. It was sold to Mayor Caraway, who in turn sold it to Colonel J.C. Betten. A small fragment was sent to Professor Clarke at the Smithsonian Institution (U.S.N.M. no. 76, 34 g), but the main mass was, after having been exhibited at Eureka Springs for some time, sold to the New York lapidary and collector, G.F. Kunz, who described it and reproduced photographs of the exterior (1887a). About 1890, Kunz's valuable collection, comprising 91 different meteorites, was sold to the Naturhistorisches Hofmuseum in Vienna, reportedly aided by a grant of 159,000 Austrian florins (about \$65,000) from Albert Mayer von Gunthof (Brezina 1896: 234).

Brezina described the iron with excellent macrophotographs of the exterior (1892) and gave a brief description of the interior structure (1896: 283). Heide (1957: figure 70), Rinehart (1958), Mason (1962a: figure 21) and others have also reproduced photographs of the exterior shape.

COLLECTIONS

Main mass undivided in Vienna (47.4 kg), Washington (34 g), Bally (22 g), London (5 g), Chicago (1 g).



Figure 408. Cabin Creek. The main mass in Vienna. Domed front side with marked regmaglypts. The height of the specimen is 44 cm. (Courtesy Dr. Gero Kurat, Vienna.)



Figure 409. Cabin Creek. The rear side of the main mass in Vienna. Shallow, large regmaglypts and depressions from ablated troilite nodules. The height of the specimen is 44 cm. (Courtesy Dr. Gero Kurat, Vienna.)

ANALYSIS

Only an old analysis by Whitfield (Kunz 1887a) is available. It is obviously unsatisfactory by reporting only 6.60% Ni, a trace of cobalt and 0.41% P.

DESCRIPTION

The mass is somewhat turtleshaped with the average dimensions of 44 x 39 x 7.5 cm. It has a convex front with deep, angular pits 1-4 cm across and with marked ridges between the individual pits, Figure 408. The surface is vividly striated from the center of the convex side towards the edges, and many ridges stand in prominent relief, higher than their width. The front and back sides meet along a 2 cm thick edge over which the ablation-molten metal has spilled and formed irregular crossbedded crusts.

The back (Figure 409) is very different from the front, being almost a plane and displaying shallow regmaglypts, 3-7 cm across, with no sharp ridges between them. This surface is covered with 0.5-4 mm thick, wrinkled, warty deposits of metal and magnetite. In one place a polished section shows a crust, 1.4 mm thick, composed of 18 individual laminae. The innermost 8-10 laminae are oxide-free, dendritic metal (2-5 μ thick dendrites) solidified in a cellular-columnar structure. The following layers become increasingly richer in oxides; these are located in the grain boundaries as veins, 1-3 μ thick, but are also present in the grain interiors as 2-20 μ irregular spherules, occupying about 10% by area. In many places, loosely sintered 0.1-1 mm metallic droplets with intercalated oxides may be seen. They apparently increase to 5-10 mm beads locally, according to Kunz (1887a). The hardness of the metallic fusion crust is 280 \pm 60, the variation being due to microcavities and oxide inclusions.

Troilite inclusions, ranging from 13 mm in diameter to irregular nodules of 55 x 25 mm, are present on both front and back sides. They have been partly melted out and left characteristic cavities particularly on the back. Kunz (1887a) and Brezina (1892) counted a total of 22 troilite cavities on all surfaces. The morphology of the surfaces strongly indicates that Cabin Creek was a stabilized, oriented fall.

Unfortunately, only two small, near-surface fragments could be examined as the main mass has never been cut. The fragments had been removed by chiseling and were badly deformed in the process. Since they are from exposed knobs, they represent the heat-affected zone, probably along the edge where front and back sides meet. The Washington specimen (no. 76) has a crust no less than 3-4 mm thick, of dendritic, metallic laminae; the interior is heat-affected α_2 matrix with micromelted phosphides. The Vienna specimen (no. P 6344, 3.6 g), kindly loaned to me by Dr. G. Kurat, has a central portion which was not transformed by the atmospheric flight.

The etched sections display a medium octahedrite structure of straight ($\frac{W}{L} \sim 10$) kamacite lamellae with a width of 1.10 \pm 0.20 mm. The kamacite has subboundaries decorated by 1-3 μ rhabdites, and undecorated Neumann

bands are common. Taenite and plessite cover about 30% by area, both as comb and net plessite, as duplex unresolvable $\alpha + \gamma$ fields and as fields with martensitic interiors. The taenite lamellae and rims are cloudy, evidently due to a submicroscopic decomposition to α plus γ .

Schreibersite occurs as 20-100 μ wide, monocrystalline grain boundary precipitates. They are, due to chiseling, deformed and chipped more than is usually the case. Schreibersite is also common as 2-15 μ vermicular particles inside plessite, substituting for taenite bodies of similar sizes. Rhabdites are only present in limited amounts as 0.5-1 μ prisms. The bulk phosphorus content is estimated to be 0.3 \pm 0.1%. Troilite is apparently common, judging from the numerous surface nodules, but it was not present in the sections.

The α_2 zone, which occupies most of the sections, is of the usual type, displaying unequilibrated, serrated α_2 units, 25-100 μ in size. The microhardness is 190 \pm 10. The phosphides are micromelted in the exterior half, where the temperature temporarily exceeded 1000 $^\circ$ C. Fine zigzagging veinlets of micromelted phosphides connect adjacent molten pools. The taenite is yellowish-white and has lost its cloudiness, perhaps because it has become homogenized. It is now surrounded by 20-50 μ wide dark-etching martensitic-bainitic zones, rich in carbon. The carbon must have come from the taenite lamellae, having diffused a short distance out by the brief atmospheric reheating.

The small, heat-affected and mechanically-damaged sections were insufficient for classification. It is recommended that the main mass be cut and larger sections, truly representing the undamaged interior, made available for metallographic examinations and a complete chemical analysis, the more so since Cabin Creek is one of the few authentic iron meteorite falls.

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

34 g polished near-surface fragment (no. 76, 3 x 2 x 1 cm)

Cacaria, Durango, Mexico

24 $^\circ$ 23'N, 104 $^\circ$ 45'W

Medium octahedrite, Om. Bandwidth 1.20 \pm 0.20 mm. α_2 matrix. HV 180 \pm 10.

Group IIIA. 7.66% Ni, 0.46% Co, 0.11% P, 19 ppm Ga, 36 ppm Ge, 9 ppm Ir.

The whole mass has been subject to forging, and the structure is altered.

HISTORY

A rounded mass of 41.42 kg was mentioned by Barcena (1876) and Castillo (1889) as being in the National Museum in Mexico City. It had been found on the Hacienda de Cacaria, about 50 km north of Durango and had later been transported to Durango where it was used as an anvil for several years. Fletcher (1890a) discussed the history and

erroneously concluded that Cacaria and the 46.4 kg Rancho de la Pila mass belonged to the same fall.

H.A. Ward (Farrington 1895: 61) prepared a plaster cast of Cacaria and cut material for exchange (Cohen 1900b: 362). Judging from the present shape and size of the meteorite, Ward apparently cut about 2.5 kg, of which about 2 kg (no. 922 of 1,586 g and no. 923 of 383 g) went to Chicago and 178 g (no. 1480, formerly Chicago no. 521) to the U.S. National Museum. Influenced by Fletcher's conclusion as to the identity of Cacaria and Rancho de la Pila, Ward sometimes used the two names synonymously (see, e.g., Cohen 1900b: 362) which, up to our time, has caused considerable confusion.

Cohen (1905) analyzed material in Vienna and also a 53 g specimen obtained from Ward. He concluded that one and the same meteorite might vary in composition from 7.7% to 12.1% Ni, a conclusion which we now know was wrong. The higher of the reported values was evidently in error, either in analytical technique or in calculation. Or perhaps some mislabeled specimen was involved. Berwerth (1914: 1081) referred Cacaria to the man-damaged meteorites, a conclusion which was correct, but forgotten or disbelieved. Nininger cut 76 g from the mass and gave a short description (1931a). Haro (1931) quoted Fletcher's work from 1890 uncritically, but he added a map from

which the coordinates given here are taken. Sierra de la Cacaria is a mountain range (2000-2500 m) situated 25-60 km northwest of the town of Durango.

COLLECTION

Mexico City, Museum de Chopo (main mass of about 38 kg), Chicago (1,975 g), London (296 g), Washington (165 g), Tempe (76 g), Mexico Institute of Geology (44 g), Vienna (19 g).

DESCRIPTION

The main mass, which I relocated with difficulty in the old, now closed, section of the Mexican National Museum – the so-called Museum de Chopo – has the shape of a flattened ball with the maximum dimensions of 25 x 20 x 15 cm. All edges are rounded and somewhat overfolded due to heavy hammering. The exterior smooth and flat surfaces are due to significant forging. At one place one can, in fact,



Figure 410. Cacaria. Main mass in Museum de Chopo, Mexico City. Its exterior shape has been significantly altered by forging in which some kind of a drop hammer was used. Scale bar 5 cm.



Figure 411. Cacaria. Main mass, seen from a different angle. Below right is the rectangular impression of a tool, which must have penetrated while the mass was red-hot. Scale bar 5 cm.

CACARIA – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Fahrenheit in Cohen 1905	7.70	0.54	0.24		600	100	300					
Jarosewich 1968, pers. comm.	7.74	0.46	0.11									
Scott et al. 1973	7.56								19.1	35.6	8.7	

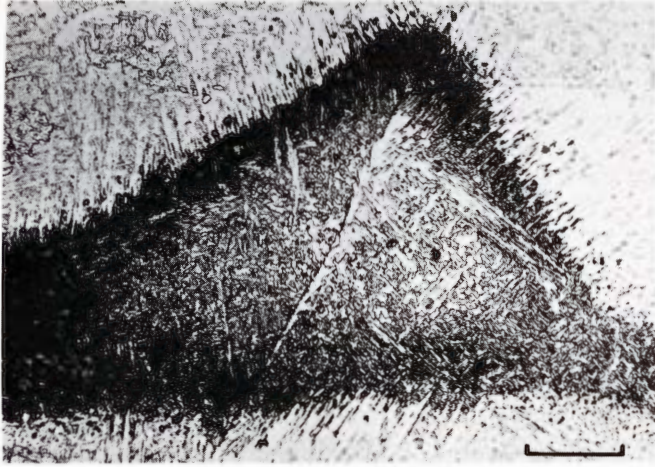


Figure 412. Cacaria (Tempe no. 19a). The thorough artificial reheating has completely altered this plesite field. Etched. Scale bar 200 μ . See also Figure 133.



Figure 413. Cacaria (Tempe no. 19a). In near-surface areas mechanical deformation twins, resembling Neumann bands, are quite common. They must have been caused by heavy machine blows. Etched. Scale bar 100 μ .

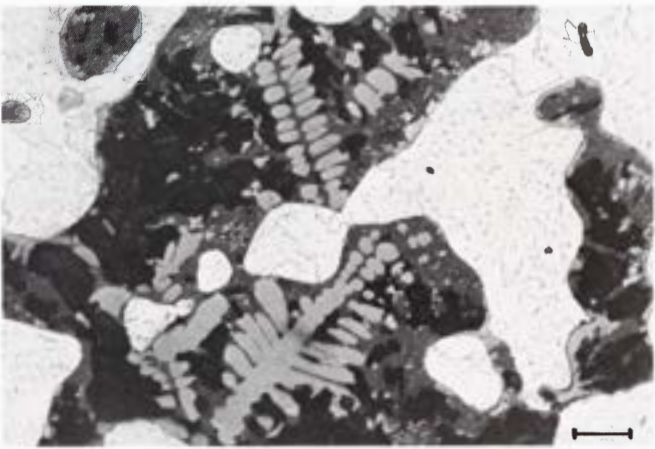


Figure 414. Cacaria (Tempe no. 19a). A complex nodule altered by forging. Various iron oxides and sulfides are present. The surrounding ferrite shows very fine platelike precipitates. Etched. Scale bar 50 μ .

detect the rectangular impression of a tool. The tool's mark is 35 x 8 mm in opening and 20 mm deep, and it has sharp edges. Such an impression could only be formed while the meteorite was red-hot and malleable and proves that this meteorite really was maltreated more than most other irons. In three places material has later been removed by cutting, the largest cut having left a plane surface of 15 x 12 cm (Ward, about 1895).

Etched sections display a blurred, medium Widmanstätten structure of straight lamellae with a width of 1.20 ± 0.20 mm. Due to compression and hammering, the structure shows, locally, gaping fissures along the octahedral planes, but surprisingly few lamellae have actually been bent in the action, so the forging was not deeply penetrating. Large inclusions are few, partly because they have melted and seeped out by the treatment. Small inclusions of schreibersite are melted and partly dissolved in the matrix, and the nickel-rich taenite is also mostly resorbed. While the Widmanstätten structure is reasonably well defined when inspected at low magnification, it becomes indistinct when examined at higher magnification because all phase boundaries are wiped out by diffusion. The time and temperature were, however, insufficient for complete homogenization. By cooling, the austenite transformed to large lobed α_2 grains, often 1 mm across, and due to continued hammering when cold, Neumann bands developed in some near-surface parts. The microhardness of the α_2 phase is 180 ± 10 . The former taenite ribbons may attain hardnesses of 400.

The similarity to Hammond has been stressed by former authors, but it is only a superficial resemblance. Hammond has about the same concentration of main elements, but the trace element concentration is different, and Hammond's bandwidth is only 0.55 mm. Hammond's peculiar structure is, furthermore, as will be shown, due to plastic deformation and reheating in Cosmos.

Cacaria shows a characteristic structure in parts which were corroded before the blacksmith got hold of it. Various reactions have occurred between the limonite, troilite,



Figure 415. Cacaria (Tempe no. 19a). Detail of Figure 414. The oriented platelets in the ferrite are perhaps nitrides. Etched. Scale bar 20 μ .

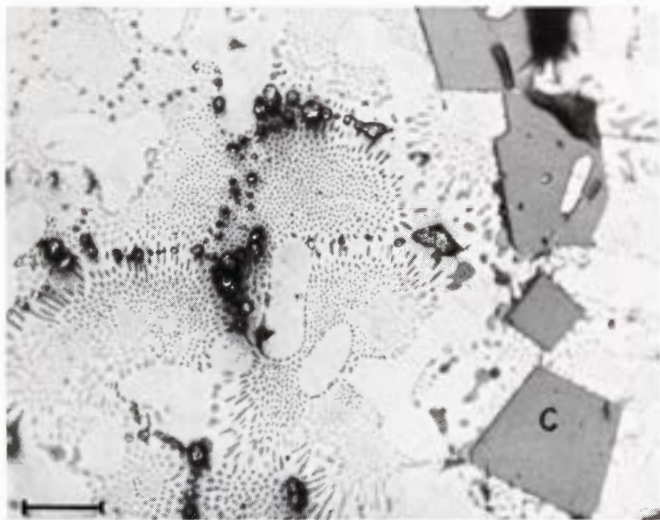


Figure 416. Cacaria (Tempe no. 19a). During forging an original troilite nodule melted and reacted with oxygen. Upon cooling, ternary Fe-S-O eutectics formed. The original chromite inclusions (C) survived unaltered. Polished. Scale bar 20 μ .

schreibersite and the metallic matrix at high temperature; the exact nature is, however, less interesting now that it is shown that they are due to artificial reheating. There is also significant high temperature intercrystalline oxidation to a depth of several millimeters below the surface. A heavy population of fine, oriented platelets (about $5 \times 0.5 \mu$) in the α_2 matrix may either be the preterrestrial chromium nitride, carlsbergite, or the result of the artificial reheating. The first possibility seems the most satisfactory. The mineral is, however, unusually well developed and densely spaced, relative to what is seen in, e.g., Cape York, Schwetz and Rancho de la Pila.

Cacaria was before the forging a normal medium octahedrite of group IIIA, very similar to, for example, Cape York. See also Rancho de la Pila.

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

165 g part slice (no. 1480, $9 \times 6 \times 0.5$ cm; cut by Ward about 1895)

Cachiyual, Atacama, Chile

Approximately 25°S , $69^\circ 30'\text{W}$

Medium octahedrite, Om. Bandwidth 1.30 ± 0.20 mm. Recrystallized. HV 200 ± 20 .

Anomalous group IIIA. 7.88% Ni, about 0.15% P, 16.9 ppm Ga, 30.3 ppm Ge, 3.1 ppm Ir.

Not a hexahedrite. Unrelated to other Chilean octahedrites.

HISTORY

From the very beginning there has been uncertainty about the classification of this iron, probably mainly due to an early misunderstanding or inadequate description in the original paper by Domeyko & Daubr e (1875). It was here stated that the meteorite was a “holosiderite” with no

Widmanst tten figures and with only 4.81% nickel. The same suppositions were repeated by Domeyko (1879:130). Also, the locality of find is inadequately known. According to Domeyko & Daubr e (1875) the meteorite was found late in 1874 in the Atacama Desert about 20 leagues (Chilean measure, i.e., a total of about 90 km) from the coast. The place was called Cachiyual and the coordinates were given as $25^\circ.1$ southern latitude and $1^\circ.21$ longitude west of Santiago. Since Santiago is $33^\circ 30'\text{S}$, $70^\circ 39'\text{W}$, the locality of find should be $25^\circ 6'\text{S}$, $71^\circ 51'\text{W}$. This is, however, well out in the Pacific Ocean. Evidently we must at this late date be satisfied with a general statement as to the locality. Perhaps the place is near to, or identical with Cachinal which is located 90 km from the coast on $24^\circ 59'\text{S}$, $69^\circ 33'\text{W}$ ($1^\circ.1$ east of Santiago).

The mass, which weighed 2.55 kg, was brought in its entirety to Santiago and purchased for the National Museum of Chile.

Brezina (1885:212; 1896: 350) examined briefly the 350 g sample acquired for the Paris collection, and concluded that Cachiyual was a medium octahedrite and a paired fall with Juncal, Joel’s Iron and Ilimaes. The present examination does not support the proposed relationship. Brezina (1885:213) gave the coordinates $25^\circ 23'\text{S}$, $70^\circ 2'\text{W}$, but did not reveal how he arrived at the set.

Fletcher (1889:259) also used these coordinates and plotted Cachiyual on his sketch map, on the road to Cachinal de la Sierra, the present Achinal. Fletcher could not, however, give an adequate description of the material because at that time the British Museum had not yet received any sample of the meteorite.



Figure 417. Cachiuyual (Chicago no. 958). The main mass with its characteristic pitting corrosion from exposure to the Atacama climate. Drill-hole for analysis below right. Scale bar 20 mm. S.I. neg. M-650A.

Meunier (1884: 116) classified Cachiyual together with a number of common octahedrites, e.g., Toluca, Juncal, Bear Creek and Dalton. This reference mainly serves to bring home the point that even Daubrée's pupil, Meunier, did not accept the classification as a non-octahedral mass, but realized the mistake in the original description.

Wülfing (1897:55) maintained Cachiyual as a separate fall and gave numerous references. Berwerth (1914:1080) noted that the kamacite lamellae were composed of many independently oriented subgrains and supported the general classification. Later generations have likewise maintained Cachiyual as a separate entry (Farrington 1916: 247); Horback & Olsen 1965: 198), but some general uneasiness as to the nature of the material has persisted (Mason 1962a: 135; Hey 1966: 78).

COLLECTIONS

Santiago de Chile (about 1 kg), Chicago (712 g), Paris (295 g), Budapest (49 g, lost in 1956?), London (23 g), Vatican (16 g), New York (12 g), Yale (2.5 g), Harvard (2 g).

DESCRIPTION

The two specimens in Chicago (no. Me 958 of 723 g) and in London (Brit. Mus. no. 71570) have been examined in detail. They are identical octahedrites and both come from the same mass from which the Paris specimen is also derived. The British Museum specimen was, in fact, cut from the Paris sample and acquired from Stanislaus Meunier by exchange in April 1893 (personal communication from Dr. R. Hutchison, British Museum).

Since it has been suggested that some Cachiyual material should have hexahedrite composition (see, e.g., Hey 1966: 78), special care was taken in checking the specimens in the museum collections. So far I have not been able to locate any such material. I am inclined to conclude that the hexahedrite hypothesis is based solely on the poor description originally published by Domeyko & Daubrée (1875) and has no solid background whatever.

The Chicago sample is an endpiece measuring 11 x 8 x 3.5 cm with a polished face of about 50 cm². The exterior surface is severely corroded in the way typical for the Chilean desert. Deep grooves and pits with sharp and ragged edges in between are densely clustered on the surface. The pits are 5-8 mm across and up to 5 mm deep. In one region several pits have coalesced to subparallel grooves or sinuous rilles, 6 cm long, 5 mm wide and 5 mm deep. A similar morphology due to chemical weathering is present on

Iquique, Maria Elena and a number of other Atacama meteorites.

The sample is hammered. Over two areas of 4 x 3 cm and 4 x 4 cm, respectively, the sharp-edged pits have been molested and almost flattened away. The cold work



Figure 418. Cachiyual (Chicago no. 958). Deep-etched section showing the regular Widmanstätten structure. Since the kamacite is recrystallized there is no oriented sheen. Scale bar 20 mm. S.I. neg. M-650B.



Figure 419. Cachiyual (Chicago no. 958). General appearance of an annealed plessite field. The cloudy taenite rims have disappeared. Etched. Scale bar 50 μ .

CACHIYUAL - SELECTED CHEMICAL ANALYSES

Reference	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	7.88								16.9	30.3	3.1	

extends to a depth of 2-3 mm below the present surface. No artificial heating has been applied. On the London sample there are several fissures and slightly bent kamacite lamellae. These features reflect the finder's activity with the sledge hammer.

Etched sections display a border case of medium-coarse Widmanstätten structure. The α -lamellae are straight and long ($\frac{l}{w} \sim 25$) with a width of $1.30 \pm 0.20 \mu\text{m}$. Since Cachiyual in most respects is related to the IIIA medium octahedrites, it is here decided to refer it to the medium octahedrites for classificational purposes.

The kamacite phase was originally coarse-grained, as in, e.g., Cape York, and rich in Neumann bands. It is, however, recrystallized to a large degree, due to a cosmic secondary reheating. Regions with 100% recrystallization alternate with regions virtually free of recrystallization within the same few square centimeters. The recrystallized grains are

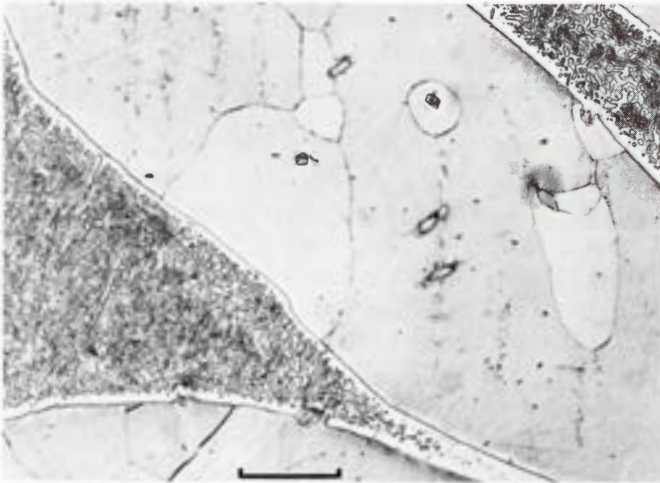


Figure 420. Cachiyual (Chicago no. 958). Two spheroidized plessite fields and recrystallized kamacite in between. Etched. Scale bar $100 \mu\text{m}$.

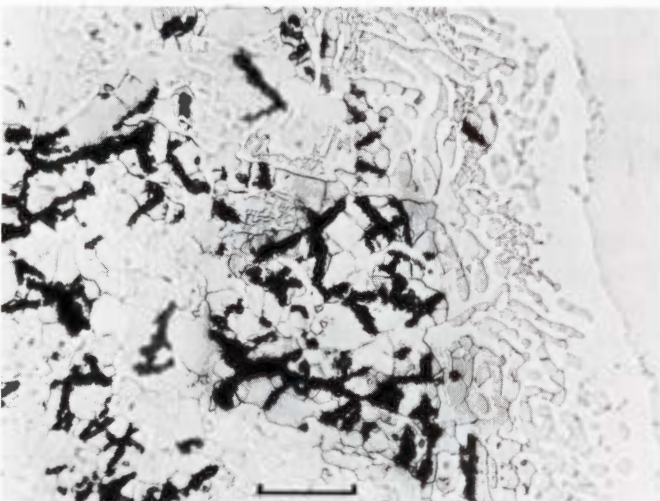


Figure 421. Cachiyual (Chicago no. 958). Some haxonite crystals were probably originally present in this plessite field. Cosmic annealing, however, decomposed the carbides to plumes of graphite and granular ferrite. See also Figure 97. Etched. Scale bar $30 \mu\text{m}$.

$50\text{-}400 \mu$ across and often elongated along pre-existing Neumann bands. Their growth has often been visibly impeded by the presence of nitride and phosphide precipitates. The recrystallized grains show numerous Neumann bands, independently oriented relative to the pre-existing bands. The hardness is 209 ± 10 .

Between the recrystallized grains the kamacite is rich in subboundaries which form a polygonization network. The pre-existing Neumann bands are degenerated and almost resorbed, showing soft, cellular outlines with a few submicroscopic precipitates. The hardness is 186 ± 8 . Apparently the polygonized ferrite is systematically about 20 points softer than the recrystallized ferrite. The reason for this is not obvious.

Taenite and plessite occupy about 30% by area, mostly as easily resolvable duplex structures. Tarnished taenite rims are absent; instead, the massive taenite is partially decomposed to a yellow taenite ($\text{HV } 207 \pm 10$) with minute ($1\text{-}10 \mu$ across) rounded windows of kamacite. Other fields display comb and net plessite, or areas with a micro-Widmanstätten structure of $1\text{-}10 \mu$ wide pointed α -lamellae in a dense felt. No martensitic zones are present. All taenite-kamacite interfaces are a little blurred and show ragged edges. The observed structures are well explained as the result of a thorough cosmic annealing.

Schreibersite occurs as $5\text{-}30 \mu$ wide grain boundary precipitates and as blebs of the same size inside the open-meshed plessite fields. Rhabdites are not uncommon as $2\text{-}10 \mu$ wide prisms. The bulk phosphorus concentration is estimated to be $0.15 \pm 0.03\%$. All phosphides are enveloped in a reaction halo, where numerous small beads ($0.5\text{-}1 \mu$), mainly of taenite, are precipitated densely on the phosphides, again a result of annealing.

Carlsbergite, the chromium nitride, is common as oriented, hard precipitates in the kamacite, reaching dimensions of $50 \times 2 \mu$ but normally of $25 \times 1 \mu$ size.

Troilite was not present on the available sections.

Very peculiar to Cachiyual is the graphite which is precipitated in one out of five plessite fields. The graphite forms microcrystalline ($0.5\text{-}1 \mu$) veins which attain sizes of $40 \times 5 \mu$. They form irregular branching aggregates in the open-meshed plessite and are often associated with angular, hard bodies ($1\text{-}10 \mu$) of high reflectivity. These particles appear to be the carbide under decomposition, from which the graphite has precipitated by annealing. Similar structures are present in Kokstad and Willow Creek.

No fusion crust and no heat-affected α_2 zone is present on the examined samples. Corrosion penetrates a few mm below the surface and attacks selectively the α -phase of the duplex fields and the vicinity of the shattered phosphides. The meteorite appears to be of high terrestrial age.

Cachiyual is an atypical medium octahedrite which is somewhat related to Rhine Villa, Kokstad, Coopertown and Willow Creek. In its peculiar recrystallization texture it also resembles Cambria, Indian Valley and pseudo-Apoala. Wasson's trace element data support the classification as an atypical medium octahedrite of group IIIA.

Calderilla. See Imilac (in the Supplement)**Calico Rock, Arkansas, U.S.A.**

Approximately 36°5'N, 92°9'W; 150 m

Hexahedrite, H. Single crystal larger than 15 cm. Neumann bands, HV 175±5.
Group IIA. 5.61% Ni, 0.45% Co, 0.28% P, 0.15% S, 57 ppm Ga, 185 ppm Ge, 8.6 ppm Ir.

HISTORY

A mass of 7.28 kg was found in 1938 by A. Harmon near Calico Rock, in Izard County. It was acquired in 1964 by R.A. Oriti, of the Griffith Observatory, Los Angeles, who reported it to the Meteoritical Bulletin (No. 33, 1965). It is undescribed but well analyzed. See below.

COLLECTIONS

Griffith Observatory (main mass), Washington (540 g), London (110 g), Copenhagen (90 g).

DESCRIPTION

The mass is shaped like a rectangular box with the average dimensions 15 x 9 x 9 cm. It has surprisingly plane sides, which are only slightly indented by regmaglypts, 1-1.5 cm across. It is somewhat weathered, being covered by crusts of terrestrial oxides 0.1-2 mm thick. The corrosion selectively attacks the α -phase around the near-surface rhabdites, but it does not attack the Neumann bands because they are unsensitized.



Figure 422. Calico Rock. Main mass in the background and a full slice in front. The box-like shape is clearly seen. The exterior faces are parallel to $(100)_{\alpha}$, the cubic cleavage planes. The side of the film box is 4 cm. S.I. neg. M-1296A.

Calico Rock is a normal hexahedrite single crystal with Neumann bands extending across the whole section. A comparison of the Neumann band orientations with the exterior box shape reveals that the exterior sides are cubic cleavage planes. This is confirmed by the presence of a few cubic cleavage fissures, slightly corroded, which extend deep into the mass. Also, the orientation of the rhabdite prisms and plates confirms the cubic form. We have here another example of a cubic cleavage fragment, which like Murphy and Edmonton (Canada), was only slightly modified by the atmospheric ablation.

The Neumann bands are undecorated and have disappeared in the α_2 zone, which on two sides is up to 2 mm wide. The hardness of the α_2 zone is 180 ± 10 ; it drops to 155 ± 5 in the recovered region just inside the α_2 zone, and then increases to the interior, unaffected level of 175 ± 5 (hardness curve type II). A hardness drop can be detected near all surfaces, even where no visible heat alteration zone is present. This shows that only 2-3 mm are lost by weathering, and on the average, for the whole mass, only 1 mm.

Schreibersite is found occasionally as 0.5 mm blebs or as 10-100 μ thick, discontinuous rims around the troilite nodules. Rhabdites are, however, common (i) as plate-shaped bodies, typically 5 x 4 x 0.04 mm in size, but ranging down to 200 x 100 x 2 μ , and (ii) as tetragonal prisms, 3-15 μ across. The plates are arranged parallel to $\{100\}$ and to $\{221\}$, as first shown by Böggild (1927), who studied some other hexahedrites. Characteristic for Calico Rock is the arrangement of the more conspicuous plates in parallel planes, spaced 5-30 mm apart. These planes appear to coincide with some of the Neumann planes $\{211\}$. The prismatic rhabdites have their axes parallel to the cube axes and their faces parallel to the $\{210\}$ faces of the cube. The prismatic rhabdites are particularly common between the rows of plate-shaped rhabdites.

Troilite occurs as nodules, 1-10 mm across, and as lenticular bodies, typically 4 x 0.6 mm in size. On a total of 163 cm² sections 19 inclusions, totally 110 mm², were counted, corresponding to 0.15% S in the bulk material. The troilite is monocrystalline and shows some straight outlines; nevertheless, the orientation of the troilite crystals appears to be quite arbitrary with respect to the metallic lattice. The troilite exhibits beautiful twins from slight plastic deformation. The surrounding kamacite displays well-developed subboundaries decorated with 1-2 μ rhabdites. Around the troilite is a zone which is 1 mm wide and free of large rhabdites and in which the kamacite hardness increases to 197 ± 7 , probably due to increased amounts of nickel and phosphorus in solid solution.

CALICO ROCK – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	5.76	0.45	0.28	135	50		140					
Wasson, 1969	5.45							57.3	185	8.6		

Daubreelite occurs as parallel lamellae, 5-50 μ wide, in all the troilite. It constitutes about 15% of the larger nodules and about 50% of the 0.4 mm nodules, while the small blebs, 20-50 μ across, consist of almost pure daubreelite. Some of them have served as nuclei for the precipitation of the large, plate-shaped rhabdites.

Cohenite is present as 10-100 μ wide, discontinuous rims upon the troilite-daubreelite-schreibersite nodules. Its hardness is 1125 \pm 25. It shows no graphite veining and is undecomposed.

Slight plastic deformation has sheared the rhabdites and displaced them 5-10 μ in places. Also, the troilite-daubreelite lamellar stacks may be slightly distorted. The deformation event, which appears to date back to the dislodging of the cubic fragment from its parent body, also produced a few internal cleavages, parallel to {100}. These are now filled with 5-20 μ wide veins of terrestrial corrosion products.

Calico Rock is an unannealed hexahedrite with parallel planes of rhabdite crystals. It is related to Hex River, Lombard and Okano, and is remarkable by its exterior shape, truly representing cubic cleavage planes of a presumably very high age.

Specimen in the U.S. National Museum in Washington:
540 g slice (9 x 8 x 1 cm, cut almost parallel to a cubic cleavage plane)

Calumet County, Wisconsin, U.S.A.

According to Read (1962) a mass "about the size of a baseball" was found before 1934. It was listed as Calumet County by Hey (1966:80), but a modern examination by Read (Meteoritical Bulletin, No. 47, 1969) disclosed that Calumet County is a pseudometeorite.

Cambria, New York, U.S.A.

43°12'N, 78°49'W; 125 m

Fine octahedrite, Of. Bandwidth 0.48 \pm 0.10 mm. Sliplines, deformed Neumann bands and partial recrystallization. HV 155 \pm 15.

Anomalous. 10.4% Ni, 0.54% Co, about 0.5% P, 1.8% S, 12 ppm Ga, 2 ppm Ge, 0.84 ppm Ir.

HISTORY

A mass of 16.3 kg was found when a field was cleared for cultivation on William Temple's property in Cambria. Cambria is about 12 km west-northwest of Lockport, Niagara County, and has the coordinates given above. The mass was found in about 1818, but passed through several hands before it was purchased by Silliman, who described it and presented two woodcuts of the exterior and of an etched slice (Silliman 1845; Silliman & Hunt 1846). It was subsequently divided and distributed to many collections, and it was discussed in many publications, e.g., by Reichenbach (1862a), Rose (1864a) and Brezina (1885). Cohen (1905: 312) and Farrington (1915: 93) reviewed the literature, and photomicrographs were given by Brezina & Cohen (Atlas 1886-1906: plate 34) and Mauroy (1913: plate 2). Thode et al. (1961) included Cambria in their sulphur isotope study. Agrell et al. (1963) showed with the microprobe that kamacite was not depleted in nickel near the α/γ interphase as had usually been found to be true. Reed (1965b) found the average nickel concentration of the central areas of fine plessite fields, which could not be resolved with the microprobe, to be 13%. Wasson & Schaudy (1971) gave a photomicrograph and a revised analysis. Schultz & Hintenberger (1967) measured the

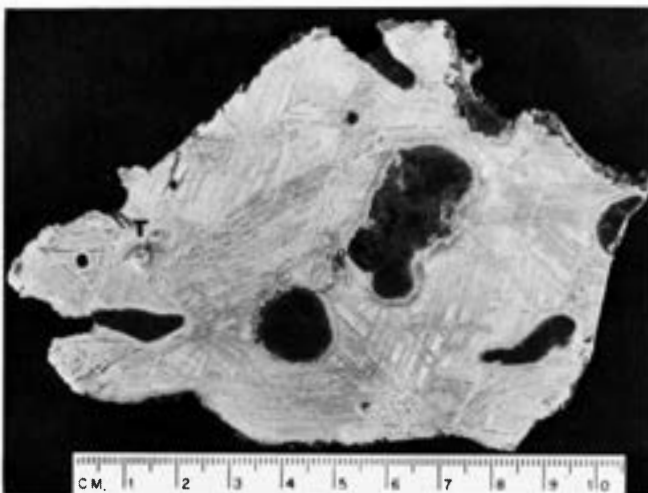


Figure 423. Cambria (Tempe no. 359.1). An anomalous, fine octahedrite with much troilite. Both large and small troilite nodules, e.g. at T, have nucleated significant schreibersite rims and rosettes. Deep-etched. Scale bar in centimeters. (Courtesy C.B. Moore.)

CAMBRIA – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moss & Bothwell in Hey 1966	10.5	0.52				11	158			<1		
Smales et al. 1967						8.1	149	<1	13	2.4		
Wasson & Kimberlin 1967	10.40								10.9	1.56	0.84	
Moore et al. 1969	10.35	0.55	0.21	60	20							
Crocket 1972											0.71	9.7

concentration of the noble gas isotopes ^3He , ^4He , ^{21}Ne , ^{36}Ar and ^{38}Ar , and Voshage (1967) estimated from these data a cosmic ray exposure age of 350-700 million years.

COLLECTIONS

London (5.2 kg), Amherst (1.18 kg), Tübingen (0.8 kg), Tempe (367 g), Washington (351 g), Vienna (299 g), Berlin (240 g), New York (210 g), Paris (160 g), Helsinki (88 g), Calcutta (67 g), Stockholm (39 g), Budapest (38 g), Ottawa (34 g), Philadelphia (30 g), Strasbourg (29 g), Torino (about 20 g), and Vatican (19 g).

DESCRIPTION

The irregular flattened block had the maximum dimensions 45 x 14 x 9 cm and had many cavities, 1-3 cm wide, as is clearly seen in the woodcut given by Silliman (1845). Most of the cavities have a partially preserved troilite body at the bottom. The beautiful thick slice,

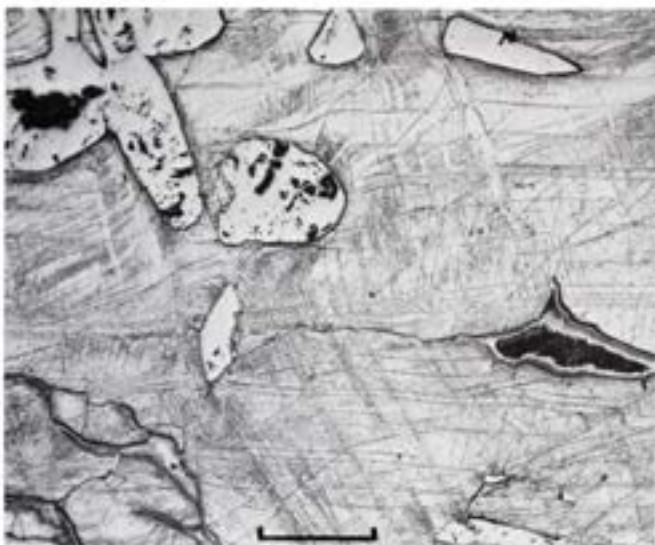


Figure 424. Cambria (U.S.N.M. no. 983). A portion with deformed and annealed Neumann bands, but no recrystallization. A group of schreibersite crystals above left. Etched. Scale bar 400 μ .

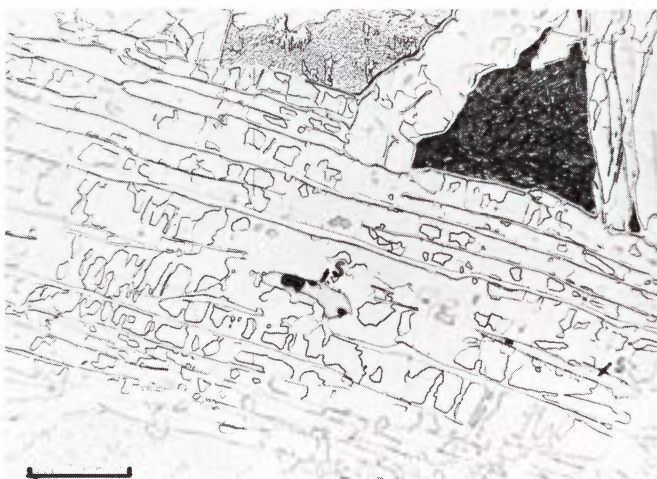


Figure 425. Cambria (Tempe no. 359.1). Open comb plesite. The kamacite is imperfectly recrystallized and the taenite fields are tempered. Two schreibersite crystals (S). Etched. Scale bar 400 μ .

measuring 12.5 x 8 x 2.2 cm in Amherst, clearly shows how those troilite nodules which happened to be situated in near-surface positions, were partly or completely burned out during the atmospheric flight. The meteorite is corroded, and an ochre to red limonitic mineral is present, especially in the cavities. Therefore, it has been generally inferred that the peculiar surface morphology was due to preferential corrosion of the troilite nodules. However, since approximately 0.5-1 mm of the ablation-heated rim zone is still preserved locally, even having small pools of rapidly melted and solidified phosphides, the mass cannot have been extensively corroded; and there is no doubt that almost all cavities were produced by partial ablatational melting of the troilite in the atmosphere. A similar morphology is described from the fresh fall, Bogou, page 330.

Etched slices show a distorted Widmanstätten structure; the α -lamellae are undulating and locally strongly bent. They are long ($\frac{l}{w} \sim 20$) and have a width of 0.48 ± 0.10 mm. Many lamellae contain angular central schreibersite crystals, 0.1-0.5 mm thick, and such lamellae often increase to widths of 1 mm. The intercalated taenite occurs as unusually wide ribbons, 20-80 μ which have hardnesses of 190 ± 10 . The taenite is tarnished in a yellow mosaic pattern which is rarely seen, except in the heat-affected α_2 zone.

The ferrite phase is either rich in Neumann bands, e.g., U.S. National Museum, no. 105, or it is excessively recrystallized (e.g., Tempe no. 359.1), or it may, within the same 4 x 3 cm section, show both structures (e.g., U.S.N.M. no. 983). The Neumann bands are heavily bent and sheared and irregular bundles of sliplines often cross the sections. They are particularly common around the larger schreibersite bodies. Here the metallic matrix is severely worked, while the brittle phosphides have been sheared. Locally a schreibersite crystal was observed to be displaced as much as 150 μ , through seven parallel thrust faults, while the surrounding matrix was heavily kneaded.

The recrystallized areas are particularly common near the troilite inclusions and are composed of almost equiaxial

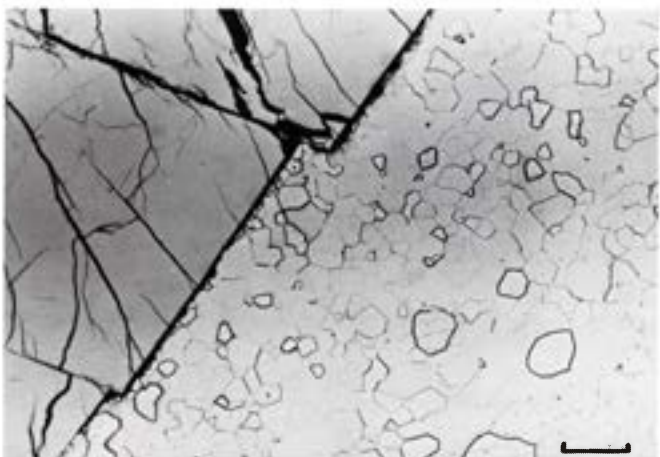


Figure 426. Cambria (Tempe no. 359.1). A large schreibersite crystal with two shear-displacements. The adjacent kamacite, low in Ni and P, is well recrystallized to equiaxial grains. Etched. Scale bar 50 μ .

ferrite grains, 10-50 μ in diameter. Locally they reach dimensions of 0.5 mm. The microhardness is 150 ± 10 , corresponding to well annealed kamacite with about 6% Ni. The microhardness of the non-recrystallized kamacite, which exhibits Neumann bands and sliplines, is generally about 10 points higher. This may be due to a slightly higher nickel concentration in these regions.

The plessite fields are developed as comb plessite in a micro-Widmanstätten pattern. Some fields show well recrystallized kamacite and slightly spheroidized taenite particles (HV 190). Other fields appear as dark-etching, unresolvable $\alpha + \gamma$ mixtures (HV 240 ± 15), sometimes with transitional zones of an annealed martensitic-bainitic character.

Schreibersite occurs as angular particles, typically 0.7×0.2 mm in size, within the kamacite lamellae. They are often centrally aligned in the lamellae. Schreibersite is



Figure 427. Cambria (Tempe no. 359.1). Partially recrystallized area. Original Neumann bands are still visible. Etched. Scale bar 50 μ .

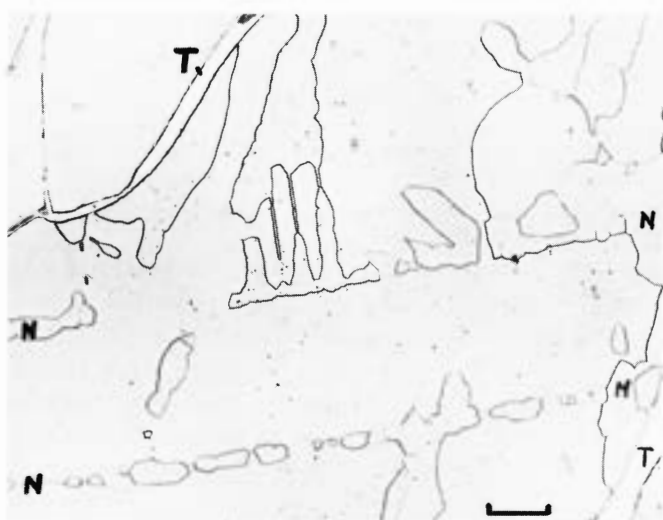


Figure 428. Cambria (Tempe no. 359.1). Another view of recrystallizing kamacite. Two original Neumann bands were located at N-N. Two taenite lamellae are marked T. Etched. Scale bar 50 μ .

also common as 20-50 μ wide grain boundary precipitates, and as 1-10 μ vermicular bodies inside the plessite fields. A point counting of the larger particles present on 60 cm^2 sections, gave an estimate of 0.3% P in "visible" inclusions. In order to get a bulk phosphorus value we may add 0.21%, obtained by Moore & Lewis (1968) on material free from large inclusions. We thus have about 0.5% P in the meteorite, corresponding to what is found in, e.g., Grant and View Hill.

Cohenite has been reported by Cohen (1905), but this could not be confirmed in the present study.

The dominating troilite bodies comprise about 8% by area, estimating from a total of 210 cm^2 sections. This corresponds to about 1.8 weight % S in the meteorite, a rather high value. Seven larger (10-20 mm in cross section) and eight smaller (1-10 mm) troilite nodules were observed; all were elongated and parallel to the long direction of the mass. Their length could not be established, because all sections have been cut perpendicular to the troilite inclusions and the sections have since been distributed all over the world. Indications are, however, that the troilite bodies have similar shapes to those of Cape York. The troilite is recrystallized to aggregates of 10-20 μ polyhedral, anisotropic grains, and apparently does not contain other minerals. The nodules have rim zones 0.2-1 mm wide, of brecciated, monocrystalline schreibersite, and the whole ensemble is wrapped in 0.5-1.2 mm of swathing kamacite.

Parallel, oriented troilite bodies are also present in Bendego, Cape York, Santa Rosa and other iron meteorites. They apparently indicate the solidification direction, while the mass at an early date cooled and solidified as an integrating part of its parent body.

Since the examined specimens bear no witness of artificial reheating and only show insignificant marks from hammering, and since the heat-affected α_2 zone is partially preserved, the complex structure of plastically deformed α -lamellae, faulted schreibersite and recrystallized kamacite and troilite must be a cosmic phenomenon. It is possibly related to the release of the meteorite from its parent body by some violent occurrence. The limited increase in temperature, which resulted in recrystallization of the ferrite, also allowed some diffusion of nickel, whereby the anomalous grain boundary concentrations noted by Agrell et al. (1963) occurred. A transient temperature of about 500° C would explain all the structural and chemical observations.

Cambria is unique in its structure and in its detailed chemical composition. For example, the relative ratio of germanium to gallium is here 1:6, while we normally find much more germanium than gallium.

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

- 151 g slice (no. 105, 11 x 6 x 0.5 cm)
- 33 g slice (no. 983, 4 x 3 x 0.5 cm)
- 167 g slice (no. 1581, 9 x 4 x 0.5 cm)