Both Breece and Grant show external, hackly fracture zones which fit together and indicate where the masses separated late in flight or upon hitting the ground. If we accept the reported localities, the distance between the falls appears to have been about 50 km; however, the circumstances of discovery are uncertain and will probably continue to remain so.

The present author must conclude that Breece is a large fragment of Grant and should not, in future work, be regarded as an independent fall.

Specimen in the U.S. National Museum in Washington:
541 g part slice (no. 1482, 8 x 7 x 1.2 cm)

Greenbrier County, West Virginia, U.S.A.

Approximately 37°50'N, 80°18'W; 700 m

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm. α_2 matrix. HV 173±7.

Group IIIA. 7.38% Ni, 0.08% P, 18.1 ppm Ga, 33.3 ppm Ge, 10 ppm Ir.

The whole mass was heated to about 900° C by a blacksmith.

HISTORY

A mass of 5 kg was found about 1880 in the Allegheny Mountains, 5 km north of White Sulphur Springs, in Greenbrier County. The meteorite was taken to a country smith's shop, heated and cut with a cold chisel. The pieces were distributed as specimens of iron ore, but when two of them were seen by M.A. Miller, a civil engineer of Richmond, he recognized them as being of meteoritic origin. It was, however, too late to recover more material. The two fragments, of 1,780 g and 880 g, respectively, were acquired by the British Museum, where they were examined by Fletcher (1887b). He reported a bandwidth of 0.8-1.2 mm, but Brezina's erroneous statement (1895) upon much less material carried evidently more weight, since the meteorite in all later catalogs is listed as a coarse octahedrite. Fletcher observed a tiny chromite crystal, one of the early well-founded reports of chromite in meteoritic irons. Berwerth (1905; 1914) included Greenbrier County in his metabolitic group of artificially reheated irons, and I came to the same conclusion (Hey 1966: 183), as will be discussed below.

COLLECTIONS

London (1,810 g), Washington (473 g), Harvard (64 g), Calcutta (33 g), Chicago (21 g), Vienna (3 g).

DESCRIPTION

Two specimens of Fletcher's original material are in the U.S. National Museum. The larger shows how the blacksmith has hammered and chiseled the iron in order to split it. The exterior surface shows fragmentation along octahedral planes, and the interior shows fissures and cracks along similar planes. Small troilite inclusions (1-2 mm in diameter) have reacted with oxygen and melted. Where near the surface, they have been able to seep out, leaving empty cavities. The cavities, reported by Fletcher as something unusual for the meteoritic irons, are thus artificial, partly from violent opening along $\{111\}$ planes, partly from the emptying of mineral-filled spaces.

Etched sections display a medium Widmanstätten structure with no oriented sheen. The kamacite lamellae are long ($\frac{L}{W} \sim 20$) and straight, except where distorted by the blacksmith. The average bandwidth is 1.00±0.15 mm. The matrix is a 10-30 μ granulated α_2 structure, indicating heating into the austenite region. The original matrix was probably a hatched ϵ-structure from a cosmic shock wave. Its present hardness is 173±7.

The plessite fields occupy about 30% by area, mostly in the form of extremely open-meshed comb and net plessite. Due to the reheating, the interior of the taenite is blurred, and the rims are ragged with thorny spikes protruding into the surrounding α_2 phase.

Schreibersite is not present as large crystals but does occur as scattered 10-25 μ grain boundary precipitates. Rhabdites occur as 1-3 μ prisms in some grains, but both schreibersite and rhabdite are partly resorbed by the reheating, although not melted. The reheating temperature probably was 850°-900° C. Locally a few 50-100 μ daubreelite bodies may be seen in the metallic matrix.

In the matrix are numerous oriented, hard plates, typically 15 x 2 x 0.2 μ, and often slightly distorted. They are, no doubt, the carlsbergite as reported from Costilla Peak, Schwetz and other irons.

The reheating has given rise to high temperature intergranular oxidation along the surface and along fissures. Also, various reaction products between previously existing limonite (in cracks and around schreibersite and troilite) and the meteoritic material may be observed, often in forms of delicate oxidic laceworks with scattered 0.5 μ metal grains.

Greenbrier County is a medium octahedrite related to Costilla Peak and Henbury. It was already somewhat corroded when the country smith reheated it and thoroughly altered its microstructure. It is a normal member of the phosphorus-poor end of group IIIA.

GREENBRIER COUNTY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	7.38								18.1	33.3	10	

Fletcher (1887b) reported 0.08% P, which is in harmony with my structural observations.

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

11 g part slice (no. 118, 2.5 x 1.5 x 0.3 cm, from Fletcher 1888)
462 g irregular fragment (no. 1546, 8 x 5 x 4 cm, from British Museum no. 55239)

Gressk, Minsk Oblast, White Russian S.S.R.
53°14'N, 27°20'E

Hexahedrite, with incipient recrystallization, H. Neumann bands. HV 180±20.

Group IIA. 5.73% Ni, 0.45% Co, 0.28% P, 62 ppm Ga, 177 ppm Ge, 7.7 ppm Ir.

HISTORY

A mass of 303 kg was found in 1954 by plowing upon a collective farm, situated about 800 m from the village of Pukovo in the Gressk district of the Minsk region. The following year two young girls in the collective loaded the mass upon a wagon and, after having cleaned a thick crust of terrestrial oxides from it, delivered it to the central magazine, where it was stored among other iron items. It would have been dispatched for remelting with the scrap iron had not a director, Lopuchov, drawn attention to it and sent it to the White Russian Academy of Sciences in Minsk. Here it was briefly described with two photographs of the exterior and a preliminary analysis by Ryng (1957). It was later analyzed by Dyakonova & Charitonova (1960), while the lead and lead-isotopes were examined by Starik et al. (1960). Sobotovich (1964) discussed the lead composition in a broader context.

COLLECTIONS

Main mass in White Russian Academy of Sciences, Minsk. Washington (1,935 g), Moscow (1,831 g), Tempe (1,296 g), Yale (1,071 g), Albuquerque (892 g), Canberra (730 g), Prague (590 g), New York (541 g), Chicago (538 g), Perth (500 g), Copenhagen (125 g), Los Angeles (53 g).

DESCRIPTION

The mass is irregular and somewhat bowl-shaped, with an overall length of 92 cm and a width of 54 cm. It attains a thickness of about 23 cm along the edges but is only 13 cm thick near the center. One side is relatively flat and has few grooves; the opposite side is deeply carved and has circular pits that meet along sharp edges. This is probably the underside of the meteorite – although Ryng (1957) believes it is the topside – which during thousands of years has become deeply pitted by terrestrial oxidation, while the topside has remained relatively little attacked.

Etched sections show that Gressk is a hexahedrite. Characteristic are the parallel zones of precipitates that penetrate the mass and are best observed on large sections. The rhabdite plates, ranging from 3 x 0.2 mm to 0.2 x 0.2 mm in size, are mostly arranged in parallel planes that are 1-2 mm wide and 1-20 mm apart. The matrix immediately around these primary rhabdites is low in phosphorus and free of additional small rhabdites. The volume between the zones of primary rhabdites is, however, loaded with fine rhabdites, each 1-3 μ across. It is mainly this difference in concentration of small phosphides that is responsible for the varying degrees of oriented sheen on an etched surface.

Neumann bands penetrate the whole mass, and many rhabdites are significantly faulted by the bands. A 3 x 0.1 mm prismatic crystal is thus displaced stepwise in 13 places along its length, each step being about 10 μ wide and in the same direction. The Neumann bands are distinctly marked by decoration with numerous 0.5-1 μ rhabdite particles along both sides of the bands. Some Neumann bands have completely disappeared and only parallel rows of 3 μ prisms and rods mark the original location. Numerous subgrain boundaries in the kamacite are likewise decorated with 1-3 μ wedges and rods of phosphides.

Recrystallization has started in numerous places, particularly from Neumann band intersections and around the large phosphides. The new ferrite grains are slightly elongated along the Neumann bands, are 25-100 μ in diameter and show concentric growth rings. The rhabdites within the recrystallized units have rounded, instead of sharp, facets. The recrystallized grains are barely visible to the naked eye. They occur scattered and cover an estimated 1% of the sections. The hardness of the kamacite is rather variable, ranging from 160 to 205. It appears that the lower values occur in the nickel- and phosphorus-depleted zones around the phosphides, irrespective of visible recrystallization. This would be expected if the whole alloy is annealed and recovered to a hardness level determined by the amount of Ni and P in solid solution, while visible recrystallization has only occurred in the Ni- and P-depleted zones.

GRESSK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Dyakonova & Charitonova 1960	5.80	0.43	0.28				600					
Buchwald 1965, unpublished	5.73	0.49	0.28		60		210			184		
Wasson 1969	5.61								62.1	177	7.7	
Lewis & Moore 1971	5.79	0.44	0.28	90								

A few 0.1-0.5 mm schreibersite crystals with irregular outlines may be found, but most phosphides are present as a primary generation of long 100-300 μ thick rhabdite plates and a secondary generation 1-3 μ in diameter. The difference is striking and characteristic for Gressk, Hex River, Indian Valley, Mayodan and some other hexahedrites which apparently also have a restricted iridium content in common, namely, 2-16 ppm. All phosphides are monocrystalline but often faulted, as mentioned above.

Troilite occurs as scattered irregular grains, 1-5 mm in cross section. They are enveloped in 100-200 μ schreibersite and contain on the average 10-20% daubreelite in form of 50-200 μ wide, parallel bands. Due to a late shock-reheating, the troilite has melted and partially dissolved the daubreelite. Some 1-10 μ wide troilite veins were simultaneously injected into the surrounding schreibersite which became partly shattered. The present troilite nodules, therefore, display a fine-grained eutectic of 2-5 μ troilite cells with dispersed, rounded daubreelite grains of the same size and a few fragments of the enveloping schreibersite. Where the troilite was in direct contact with ferrite, some solution of the metal took place, and the solidified material now contains minute grains of iron. Terrestrial corrosion has particularly attacked the metal of the sulfide nodules, but the troilite itself is also partly converted to cream-colored pentlandite.

Corrosion has removed the fusion crust and the heat-affected α_2 zone. It also penetrates many centimeters into the mass, particularly along the decorated Neumann bands and the troilite inclusions. As mentioned above, corrosion is probably also responsible for removal of large quantities of material and creation of sharp-rimmed, deep pits.

Gressk is a hexahedrite, that shows phosphide precipitation in parallel zones. It further shows that the shock wave, which produced the Neumann bands, was locally attenuated in the compressible sulfide inclusions that thereby rapidly melted and solidified. Later a rhythmic repetition of mild reheating (to about 400-450° C ?) caused the hexahedrite to recrystallize at favorable places. Gressk is probably of high terrestrial age, that is, tens of thousands of years. It is closely related to Hex River, Indian Valley and Mayodan.

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

1,816 g part slice (no. 1721, 10 x 6 x 5.5 cm)
119 g corner and fragments (no. 1721, 3 x 3 x 2 cm)

Guadaloupe County. See Supplement

Guffey, Colorado, U.S.A.

38°45'N, 105°27'W; 2500 m

Ataxite with parallel band structure, D. HV 187±10.

Anomalous. 10.3% Ni, 0.55% Co, 0.02% P, 0.15 ppm Ga, 0.08 ppm Ge, 5.0 ppm Ir.

HISTORY

A mass of 309 kg was discovered in 1907 by two cowboys while they were riding after their cattle in the 2,500 m high ranges between Currant Creek and Cripple Creek. In 1908 the mass was transported to the town of Cripple Creek and then purchased by the American Museum of Natural History. It was described by Headden (1908) and by Hovey (1909), who also presented photographs of the exterior shape. The exact locality of find is reported differently by the two authors and there are internal inconsistencies in the given distances from known towns and in the locality being reported in Township 35, Fremont County (Hovey 1909). The locality appears rather to be three and one-half miles east of Guffey in Section 16, Township 15, Range 72 W, in Park County, and the corresponding coordinates are given above.

Perry (1944: plate 19) gave two photomicrographs and remarked that the nickel content was unusually low for this kind of ataxitic structure.

COLLECTIONS

New York (main mass, about 303 kg), Washington (5.09 kg), Tempe (18 g), Chicago (15 g).

DESCRIPTION

The mass is a flattened, elongated box with sides rather perpendicular to each other and with a softly pointed end. The average dimensions are 90 x 37 x 20 cm, the thickness being fairly constant over the entire length. Although the general appearance is that of a flat mass with smooth sides the meteorite is pitted and grooved on several faces. The grooves are shallow, 2-8 cm wide and generally less than 8 mm deep; Hovey (1909) interpreted them as regmaglypts produced during the atmospheric flight. I am rather of the opinion that they are severely modified from long time

GUFFEY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Headden 1908	10.0	0.55	tr.			480						
Booth, etc., in Hovey 1909	10.55	0.55	0.02	250	160	180						
Schaudy et al. 1972	9.94								0.146	0.082	5.0	

The composition is extremely anomalous, exhibiting very low P, Ga and Ge values.

exposure to terrestrial oxidation. No fusion crust and no heat-affected α_2 zone is found; on the contrary, there are adhering oxide deposits, developed as laminated corrosion products, up to 2 mm thick. In the oxides are embedded the more resistant taenite phase in form of vermicular, 1-2 μ wide ribbons.

Etched sections have a dull matte appearance without any macroscopic structure, except for the numerous, irregular troilite inclusions. Tilting the etched plate relative to a light source conveys the impression of a band structure, where subparallel bands, not parallel to any exterior face, cross the entire section. The full "period" from dark, via light, to dark maximum is about 6 mm, but it is difficult to see the reason for the banded microstructure.

With an objective of 2-5x magnification another band structure, parallel to the first mentioned, becomes visible. The period is 100-200 μ, and there is no doubt that the light bands are associated with a low taenite concentration, while the dark bands are associated with a high taenite concentration. Therefore, the band structure probably reflects a real, rhythmic nickel variation. The band structure does, in many respects, resemble the band structure of hot-rolled 0.2% carbon steels, where ferritic zones alternate with pearlitic due to alloy and carbon segregation. It appears then that Guffey still contains indications of a previous directional loading and compression, and that, surprisingly enough, the homogenization of the nickel content never was completed.

The matrix is, at high magnification (40x objective), seen to be decomposed to a fine-grained, duplex structure of ferrite and austenite. The ferrite is veined by precipitation-free subboundaries that form a network of 5-20 μ meshes. In the network are numerous, angular 1-5 μ taenite blebs, and in the darker parts of the bands are, in addition, poorly resolvable microplessite resembling coral islands – atolls, somewhat. With a low frequency of about 0.5 per mm^2 there occur bar-shaped kamacite lamellae, typically 300 x 15 μ. These are inclusion-free, and they are segregated in six (or more) different directions in the original austenite single crystal, so they can not be part of the normal Widmanstätten pattern, which would only account for four directions. The whole morphology strongly suggests an extraterrestrial worked alloy, supercooled to form α_2 crystallites, which then decomposed to a duplex, fine-grained $\alpha + \gamma$ structure. The very few ferrite lamellae would have nucleated separately but have had no time for growing to any significant size. The hardness is 187±10, with a tendency for the higher values to occur in the dark bands of microplessitic atolls and the lower values in the more open, nickel-poorer, light bands.

Figure 827. Guffey (U.S.N.M. no. 4832). The banded structure of this ataxite is indistinctly visible. The darker bands have a higher ratio of taenite to kamacite. Etched. Scale bar 200 μ. (From Perry 1944: plate 19.)

Schreibersite is apparently not present under any form, in accordance with the analytical results.

Altered troilite-daubreelite nodules are common as serrated, irregular masses 3-15 mm in size. In addition, there is a homogeneous distribution of 0.1-0.3 mm sulfides all over the sections, with about two per cm^2. All the nodules are micromelted, probably due to shock, and they have dissolved part of the surrounding metal. The resulting eutectics have a grain size of 1-5 μ, in which more or less broken, 2-50 μ, daubreelite fragments are rather evenly dispersed. The hardness is 175±7.

Guffey is an ataxite with an anomalous composition. It is unrelated to the group IVB meteorites but may be related to such ataxites as Babb's Mill (Blake's Iron), Nordheim and Tucson. It appears to be unrelated structurally to Del Rio and Monahans, which have approximately the same nickel content as Guffey.

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

5.09 kg slice (no. 4832, 35 x 22 x 0.9 cm)

Guilford County, North Carolina, U.S.A.

Approximately 36°N, 80°W

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Annealed ϵ. HV 200±20.

Group IIIA. About 7.9% Ni, 0.5% Co, and 0.15% P, judging from the structure. Perhaps a fragment of Uwharrie.

HISTORY

In the collection of rocks from North Carolina, formed by Professor Olmsted (1822), two samples of "native terrestrial iron" were incorporated (Shepard 1830). One weighed about two pounds and was labeled Randolph County; from the brief description it appears to have been some artificial, nickel-poor product. It was not later examined and seems to have disappeared entirely already in the nineteenth century. The other was of a distinct octahedral shape and weighed seven ounces (~ 200 g). It was said to come from Guilford County and had been detached from a mass weighing 28 pounds (~ 13 kg). The main mass had been wrought into horse-nails by a blacksmith in the neighborhood. Upon reexamination of the sample, Shepard (1841) found a significant nickel content and compared the material to Buncombe County. By this he must have meant the meteorite presently labeled Asheville, which was in his collection and had a similar structure, as judged by the standards of those days.

COLLECTIONS

Amherst (21 g), Yale (16 g), London (15 g), Chicago (13 g), Vienna (8 g), Göttingen (8 g), New York (4 g), Calcutta (1.4 g), Tübingen (0.3 g), Moscow (oxide-shales).

ANALYSES

Except for an inadequate analysis (3.15% Ni, 0.75% FeS) by Shepard (1841), the material has never been examined. Judging from the structure the present author would expect 7.9±0.2% Ni, 0.5% Co, 0.15±0.02% P and trace element concentrations characteristic for group IIIA.

DESCRIPTION

The preserved specimens are octahedral fragments of 1-21 g size. Many of them show indentations and markings from the work with hammer and chisel, confirming the information about the blacksmith's activities (Shepard 1830). Sections through the fragments show distorted lamellae locally, and some fragments are fissured along grain boundaries due to handling. The Yale specimen (no. 12 of 16 g) measures 2 x 2 x 1 cm and is a triangular fragment after $\{111\}$; the Chicago specimen (no. 2143 of 13 g) is an irregular fragment measuring 2 x 1.5 x 1 cm. The following observations are based on these fragments.

Etched sections reveal a medium Widmanstätten pattern of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 1.10±0.15 mm. The kamacite shows subboundaries and etches very easily to a densely hatched structure which resembles a highly shocked ϵ pattern. Oil immersion (100x objective) discloses that the kamacite is somewhat decomposed by annealing and now extremely rich in 0.1-1 μ precipitates which mainly line the shear planes and thereby enhance the contrast. The precipitates are either fine γ-beads or phosphides, the first being more plausible. The hardness is 200±20, corresponding to a shocked and partially annealed kamacite.

Taenite and plessite cover 25-30% by area, mostly as comb and net plessite. A typical field will exhibit a yellow, non-tarnished, 10-50 μ wide taenite rim (HV 270±30) followed by unresolvable, dark-etching, duplex $\alpha + \gamma$ interiors (HV 280±30). The yellow taenite shows at high magnification (oil immersion) a dense grid in the Widmanstätten directions, probably due to decoration of slipplanes by exceedingly fine particles; compare Uwharrie and Anoka. Martensitic plessite is not present, it has been annealed away.

Thus, kamacite, taenite and plessite appear to be annealed after some severe, cosmic shock event.

Schreibersite occurs in modest quantities as 10-80 μ wide grain boundary precipitates and as 10-40 μ irregular blebs inside some of the plessite fields. It is brecciated and often heavily damaged by terrestrial corrosion. Rhabdites proper were not observed, but some of the almost submicroscopic precipitates noted above in the kamacite appear to be rhabdites. The bulk phosphorus content is estimated to be 0.15±0.02%.

Carlsbergite occurs in small amounts as hard 20 x 1 μ lamellae which are frequently kneaded and bent by the deformation that produced the other damage to the structure.

Troilite and other meteoritic minerals were not observed in the available sections.

The meteorite is corroded and some of the material in the collections is nothing other than oxide-shales. On sections, the fusion crust and the heat-affected α_2 zone are lost, and oxide veinlets up to 0.1 mm thick penetrate along many grain boundaries. The samples examined have, however, not been artificially reheated by the blacksmith but seem to have escaped damage by an early detachment.

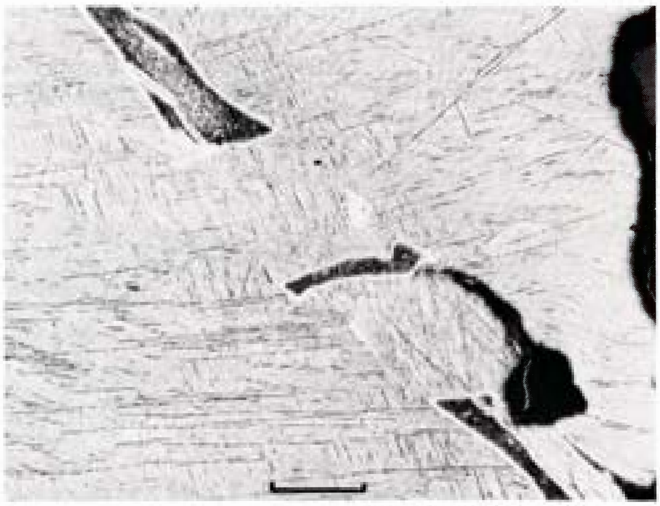

Figure 828. Guilford County (Chicago no. 2143). Near-surface section. The deformation to the right is due to hammering and chiseling. The interior is unaffected and shows cosmic shock-hatched kamacite. Etched. Scale bar 400 μ.

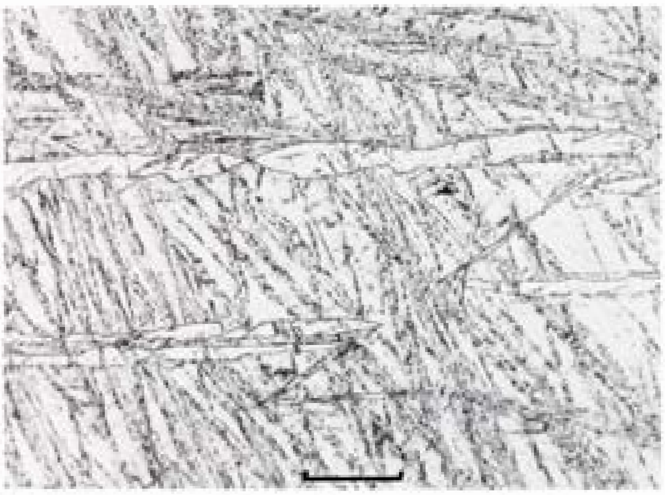

Figure 829. Guilford County. Detail of Figure 828. The shock-hatched kamacite at higher magnification. Etched. Scale bar 40 μ.

Guilford County is a medium octahedrite of group IIIA with a shocked and annealed structure. Although unanalyzed, there is little doubt that it is closely related to such irons as Uwharrie, Bagdad, Trenton, Merceditas and Loreto. It is a remarkable fact that the Uwharrie mass was found only about 50 km south of Guilford County. In structure – and no doubt in composition, too – the two meteorites are almost exact duplicates and could well be fragments of the same fall. Since so little is preserved of Guilford County and its history is very poorly known, it is of little interest at this date to follow up the possible relationships further.

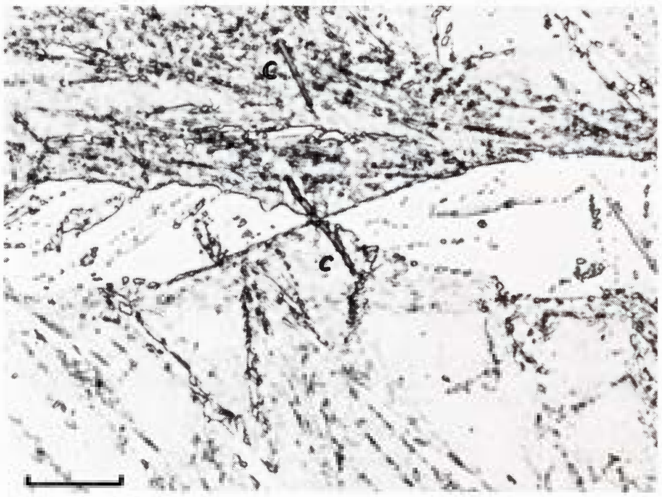

Figure 830. Guilford County. Detail of Figure 829. In the shock-hatched kamacite there are numerous very fine exsolved particles, probably mainly of austenite. Two deformed carlsbergite platelets (C) are in center. Etched. Oil immersion. Scale bar 10 μ.

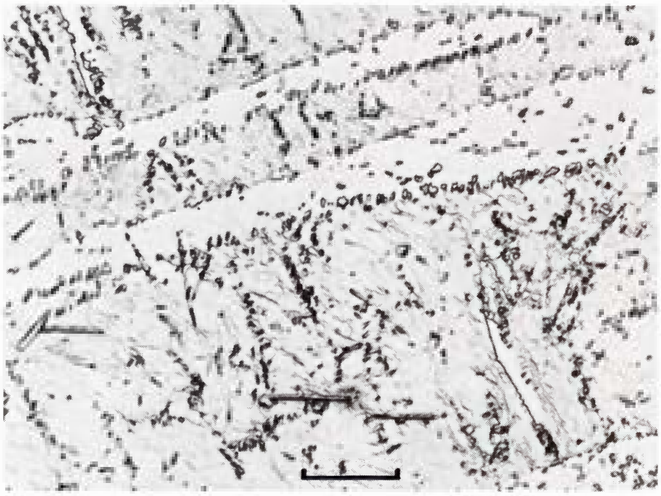

Figure 831. Guilford County (Chicago no. 2143). Another view of the annealed shock-hatched structure with numerous (γ) particles lining the shear planes. Two horizontal carlsbergite platelets just above the scale bar. Etched. Oil immersion. Scale bar 10 μ.

Gun Creek, Arizona, U.S.A.

34°1'N, 111°15'W; 1100 m

Medium octahedrite, Om. Bandwidth 0.75±0.10 mm. Decorated Neumann bands. HV 175±10.

Anomalous. 8.45% Ni, about 0.4% P, 23 ppm Ga, 70 ppm Ge, 0.05 ppm Ir.

HISTORY

A mass of about 20 kg was found by Anwell Lefave in 1909 near Gun Creek, Gila County. Gun Creek is a 20 km long, winding tributary of Tonto Creek in the northern part of the Sierra Ancha range, so the coordinates can only be given approximately as above, representing one point of Gun Creek near its junction with Tonto Creek. The meteorite was donated to the Harvard Mineralogical Museum in 1919 but was first mentioned and briefly described by Palache (1926a). At that time a few slices were cut and exchanged with the U.S. National Museum and the British Museum. Marvin (1963) identified akaganeite (β-FeOOH) associated with goethite and magnetite.

COLLECTIONS

Harvard (16,813 g main mass and a few slices), Washington (1,166 g), London (294 g), Tempe (42 g).

DESCRIPTION

The overall dimensions of the somewhat elongated mass were 21 x 16 x 13 cm (Palache 1926a). The end specimen, U.S.N.M. no. 976, shows that Gun Creek is severely corroded and covered with 0.2-2 mm thick, adhering terrestrial oxides. All fusion crust and all heat-affected α_2 zone have long since been removed. Corrosion also penetrates many centimeters into the interior, particularly along the schreibersite crystals. A large, platy crystal, 50 x 20 x 2 mm, is now so altered that it is difficult to tell whether it was pure schreibersite originally or whether troilite was also present.

Etched sections reveal a somewhat unusual, medium Widmanstätten structure of straight, long ($\frac{L}{W}\sim 25$) kamacite lamellae with a width of 0.75±0.10 mm. There is a strong oriented sheen, and a large amount of Neumann bands. At

GUN CREEK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson & Kimberlin 1967	8.45								22.4	69.7	0.052	
Smales et al. 1967						5.3	99	1.9	23.7	71		
Crocket 1972											0.052	4.0

high magnification the Neumann bands are seen to be discontinuous and partly obliterated. They are heavily decorated along both sides with 1-2 μ rhabdites, and the kamacite subgrain boundaries are likewise decorated. The alpha matrix itself is everywhere filled with a profusion of rhabdite precipitates, generally less than 1 μ across. The kamacite has a hardness of 175±10. Plessite occupies about 40% by area, mostly in form of comb and net plessite of a particular shape. It is thus noteworthy that the common, ultrafine-grained martensitic and duplex $\alpha + \gamma$ (black taenite) fields do not occur. Instead, the plessite interiors are decomposed to clearly defined, contrast-rich mixtures of angular-to-spheroidized taenite (1-5 μ across) in kamacite. The framing taenite is of an unusual, delicate structure, decomposed to gamma with pointed, oriented "windows" of alpha on an almost submicroscopic scale (HV 190±20). The taenite rim is extremely ragged; it is easy to visualize a later stage where it would decompose completely to a row of isolated, spheroidized grains, such as seen in Hammond. Some plessite fields are subdivided in many cells of individually oriented alpha grains, as seen in, for instance, Chinautla.

Schreibersite is a dominant mineral, occurring as numerous thin lamellae, typically 20 x 10 x 0.5 mm, that are probably arranged dodecahedrally relative to the original austenite single crystal (HV 930±20). Schreibersite is also very common as rows of 0.1-0.2 mm crystals centrally in 1 mm wide kamacite lamellae. Indications are that apparently isolated, adjacent grains are, in fact, part of the same, intricately branched schreibersite crystal. Schreibersite is further common as 2-20 μ wide grain boundary veinlets, and it is characteristic for Gun Creek that 2-5 μ schreibersite grains are very evenly distributed along the taenite-plessite rims, substituting for taenite and, thereby, incessantly breaking the otherwise smooth rim. Rhabdites are ubiquitous, but extremely small, less than 1 μ in diameter. The high amount of phosphides would indicate that the meteorite as a whole contains about 0.4% P.

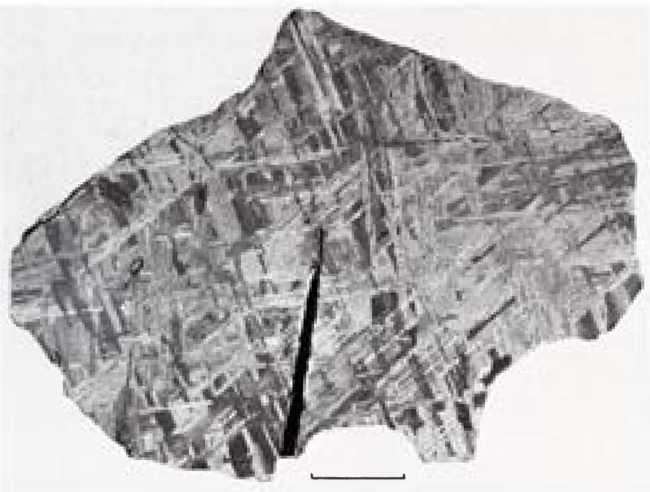

Figure 832. Gun Creek (U.S.N.M. no. 776). A full slice through the 20 kg mass. Numerous schreibersite crystals are situated along the center of the kamacite lamellae. The prominent black wedge is a terrestrially altered mineral, not identified. Deep-etched. Scale bar 20 mm. S.I. neg. M-330.

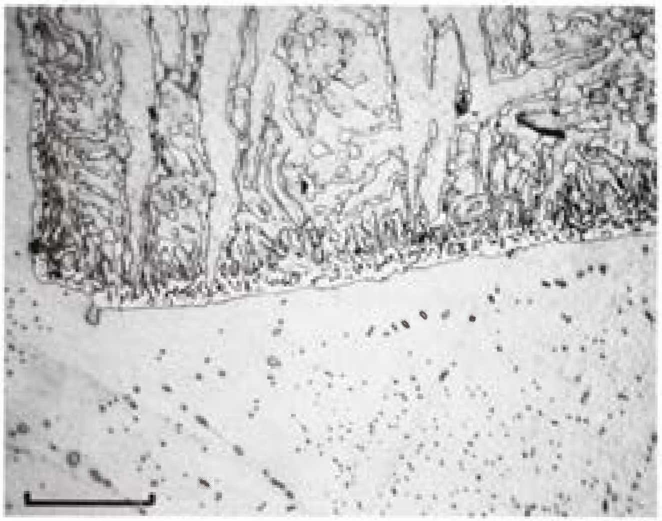

Figure 833. Gun Creek (U.S.N.M. no. 776). Annealed and partly spheroidized plessite field. Neumann bands in the kamacite have disappeared, but phosphide precipitates suggest their former positions. Etched. Scale bar 40 μ.

Cohenite and troilite were not observed.

Gun Creek is unusual by its 0.75 mm bandwidth combined with 8.5% Ni. The detailed phosphide and plessite development is different from that of other medium octahedrites, and probably caused by a mild cosmic reheating (400-500° C?). Gun Creek may be related to Hammond but represents a less violent alteration.

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

1,072 g endpiece (no. 776, 14 x 9 x 2 cm)
94 g part slice (no. 1597, 5 x 4.5 x 0.6 cm)

Gundaring, Wagin, Western Australia
33°18'S, 117°40'E

Coarse octahedrite, Og. Bandwidth 1.40±0.25 mm. ε-structure. HV 260±15.

Group IIIA. 8.30% Ni, about 0.25% P, 20 ppm Ga, 43.9 ppm Ge, 0.31 ppm Ir.

Reported to fall in 1930, but this appears to be out of the question.

HISTORY

A mass of 112.5 kg (248 pounds) was found in 1937 by F. Quinn close to the Cancanning public hall, nine miles north-northeast of Gundaring and 16 miles east of Wagin. It is generally believed to have been an observed fall occurring in 1930 (Simpson 1938; Hey 1966: 188), but it is almost certain that this can not be the case, because: (i) the mass was found right on the surface; (ii) if it fell "close to the Soldier's Hall" (Mc Call & de Laeter 1965), it should have been heard, felt and found immediately; and (iii) it is corroded in a way that requires much more than seven years under the climatic conditions of the locality.

Gundaring was described with a photograph of the exterior and a photomacrograph of an etched section by Simpson (1938). Additional photographs were presented by Mc Call & de Laeter (1965: plates 2 and 10). Jaeger & Lipschutz (1967b) found a microstructure corresponding to shock pressures between 130 and 400 k bar. Lämmerzahl & Zähringer (1966) found by the $^{40}Ar/^{38}Ar$ method a cosmic ray exposure age of 660±220 million years, while Voshage (1967) by the $^{40}K/^{41}K$ method found 630±90 million years. Schultz & Hintenberger (1967) measured the concentration of various noble gases.

COLLECTIONS

Perth (about 110 kg main mass), Washington (237 g), London (168 g), Sydney (specimen).

DESCRIPTION

The angular mass has the overall dimensions of 43 x 42 x 23 cm and is covered by coarse regmaglypts, ranging from 3 to 8 cm in diameter. A few, hemispherical pits, 5-10 mm in diameter and 5-15 mm deep, indicate where troilite inclusions wholly or partly burned out during the atmospheric ablation. It appears, however, that terrestrial weathering, too, has taken its toll. The fusion crust is removed, and so is the heat-affected α_2 zone, at least on the material available to the author. Selective corrosion has attacked the alpha phase of the near-surface plessite fields, and some of the schreibersite inclusions are also weathered. In places a 0.3-0.6 mm thick, laminated oxide crust is preserved, and this is not a fusion crust but a product of terrestrial weathering. The belief of Simpson (1938), who first reported and described the iron as an authentic fall in 1930, can, therefore, not be supported. The iron probably fell many thousand years ago and penetrated the soil about half a meter; later erosion of the surface of the land eventually left it exposed on the surface.

Etched sections display a medium to coarse Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 1.40±0.25 mm. The few sections which have been cut happen to be almost parallel to an octahedral plane, so the fourth direction of the Widmanstätten pattern crop out as irregular, broad ribbons, 4-5 mm wide. This is probably why Simpson originally described Gundaring as a coarse-coarsest octahedrite. The kamacite displays numerous subboundaries, decorated with 0.5-2 μ rhabdites. The kamacite is of the shock-hardened variety where Neumann bands and dense, indistinct cross-hatching intermix. Plastic deformation is present in many areas, with flow of the kamacite particularly pronounced around the sheared schreibersite inclusions. The hardness is 260±15, supporting the impression of intense plastic cold-deformation. Taenite and plessite cover about 35% by area. The larger fields are developed as very coarse comb plessite, where the taenite ribbons repeat the gross Widmanstätten pattern. Other fields are duplex $\alpha + \gamma$ varieties, ranging from unresolvable black taenite, to easily dissolvable two-phase structures with 1-5 μ wide taenite blebs. Some fields are martensitic with the individual platelets occurring only in the octahedral directions. The taenite rims and ribbons have hardnesses of 360±25.

Schreibersite is rather common as 0.5-1 mm wide blebs, located centrally in the wider kamacite lamellae and often associated with a tiny, 10-50 μ daubreelite crystal. It is further very common as island arcs, located 5-15 μ in front of taenite and plessite. The individual islands are 5-40 μ wide and of various lengths. Schreibersite is also present inside the plessite fields as irregular blebs, 5-50 μ across, but rhabdites proper are not present. The bulk phosphorus content is estimated to be 0.25-0.30%. All phosphides are sheared or partially crushed, probably by the same "slow" shock, which created the deformed kamacite structure.

Troilite occurs as scattered 1-10 mm nodules, partly surrounded by 0.1 mm schreibersite crystals. The troilite is monocrystalline but shows some lenticular twinning due to mild plastic deformation. Daubreelite covers about 10% by area of the inclusions, partly as sheared crystals. In one place is a 12 mm long and only 0.2 mm wide chromite plate. It has served as a nucleus for the solidification of 1 mm nodules of troilite at both ends, and smaller sheets of troilite along its surface. The troilite has later precipitated daubreelite irregularly, and on the troilite surface schreibersite has precipitated. Daubreelite also occurs alone as small, scattered inclusions in the kamacite. One nodule, 20 μ in diameter, was observed to be composed of a stack of extremely, fine ($< 1/2\ \mu$ wide), parallel laminae of troilite and daubreelite. Cohenite has been reported by Simpson (1938), but this seems to be an erroneous interpretation of the schreibersite blebs located centrally in the kamacite lamellae.

Gundaring is a cosmically cold-worked meteorite, which is related to Aggie Creek and Campbellsville. Chemically, it is a member of group III, intermediate between the typical IIIA and IIIB irons.

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

237 g slice (no. 1755, 10 x 7 x 0.4 cm)

GUNDARING – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957	8.32	0.61				48	156		19	38		
Scott et al. 1973	8.27								20.0	43.9	0.31	

Haig, Rawlinna, Western Australia
31°23'S, 125°38'E

Medium octahedrite, Om. Bandwidth 0.90±0.15 mm. Unusual, indistinct ϵ-structure. HV 325±20.

Group IIIA. 7.34% Ni, about 0.1% P, 18.8 ppm Ga, 33.2 ppm Ge, 10 ppm Ir.

HISTORY

A mass of 479 kg (1,057 lbs) was found in 1951 on the Nullarbor Plain near Haig, 36 miles south-southeast of Rawlinna on the Trans-Australian Railway Line (Glauert 1954; McCall & de Laeter 1965). It was donated by the finder, A.J. Carlisle, to the Western Australian Museum where it was briefly described with photographs of the exterior and of an etched section by McCall & de Laeter (1965). Cleverly (1968) revisited the locality and established the coordinate set given above. He presented a map and a general description of the limestone desert plain. A shallow pit indicated where the main mass hit the ground and then turned over and probably bounded and rolled 183 m to the place where it has been found. A major fragment of 22.88 kg and several minor fragments, totaling 390 g, were found in the vicinity of the impact pit. Cleverly was able to restore all fragments to position and reconstruct individual phases of the impact sequence. It was estimated that the 504 kg mass had a terminal velocity of 500 m/sec and came from the south at an angle of about 65° with the horizontal. The isotopic composition of the small amount of tin was examined by de Laeter & Jeffery (1965).

COLLECTIONS

Perth (about 475 kg main mass and 2 kg slices), School of Mines, Kalgoorlie (23.27 kg fragments), Washington (414 g), Tempe (45 g).

DESCRIPTION

The dimensions of the angular mass are, very approximately, 65 x 60 x 30 cm, and the weight is 479 kg. Only a small corner of a few kilograms has been cut from it. The mass is very well-preserved, being covered with fluted regmaglypts, 2-6 cm in diameter, and with warty and striated fusion-crusts being preserved locally. For a detailed description of the exterior of the main mass and the fragments, the reader is referred to Cleverly (1968). The specimen in the U.S. National Museum has locally a 75 μ thick, laminated crust of columnar, metallic dendrites, but the oxide fusion crust is lost. Following the 3-4 layers of melted metal is the normal heat-affected α_2 zone, 2.0 mm in thickness. In other places the width of the α_2-zone decreases to about 1.0 mm, but micromelted phosphides are still present in the exterior part, indicating that at the most, 1 mm has been removed at this place by terrestrial weathering. The hardness of the α_2 zone is 200±10. The hardness increases rapidly to the high interior level of 325±20 (hardness curve type I).

Etched sections show a medium Widmanstätten structure of very little contrast. The straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae are 0.90±0.15 mm wide and are divided into a large number of subgrains, the boundaries of which are decorated with 1 μ rhabdites. The kamacite matrix is indistinctly hatched or marked by numerous very densely spaced, narrow Neumann bands. It also appears as if the kamacite is loaded with submicroscopic particles. These peculiarities make an etched section appear dull and lacking in contrast. The microhardness is 325±20, indicating high shock-intensities without any annealing effect. Taenite and plessite fields occupy about 35% by area, but the taenite is almost resorbed. Previously existing comb plessite is now an open-meshed network of grain boundaries with scattered 2-10 μ wide taenite ribbons, and with a discontinuous taenite frame. Hardly any taenite wedges and no black taenite survive. The kamacite of the plessite areas is dull-etching as is the kamacite of the lamellae, and this contributes to the overall cloudy appearance of sections.

Schreibersite is rare. It is only present as scattered, 1-10 μ wide grain boundary precipitates, and it is estimated that the bulk phosphorus content is just below 0.10%.

Troilite is reported by McCall & de Laeter (1965), and by Cleverly (1968) who observed several nodules, the largest being 18 mm in diameter. Unfortunately, it was not present in the specimens examined by the author. Daubreelite crystals, of 20-30 μ, occur, however, scattered in the kamacite. In addition, 40 x 1 μ hard, platelets, precipitated in an oriented fashion in the kamacite, are very common. They could be shown to consist of chromium nitride, the new mineral carlsbergite.

Haig is a very well-preserved octahedrite, which has its nearest relatives in Davis Mountains, Henbury and Costilla Peak. It is a normal member of the chemical group IIIA. Its impact history, as deduced by Cleverly (1968) is very interesting. In the United States, Grant may have had a

HAIG – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
McCall & De Laeter 1965	7.44											
De Laeter 1972									16.2			
Rosman 1972								2.3				
Scott et al. 1973	7.24								18.8	33.2	10	

similar impact history, producing, among others, the important Breece fragment.

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

267 g part slice (5 x 4.5 x 1.5 cm)
147 g wedge-shaped part slice (3.5 x 3 x 2 cm)

Hammond, Wisconsin, U.S.A.
44°57'N, 92°29'W

Medium octahedrite, Om. Bandwidth 0.60±0.15 mm. Recrystallized. HV 160±7.

Anomalous. 8.23% Ni, 0.38% Co, 0.45% P, 26 ppm Ga, 58 ppm Ge, 0.10 ppm Ir.

HISTORY

A mass of about 27 kg was plowed up in 1884 on the farm of Mrs. Jenette Rattery, 5 km southwest of Hammond, Saint Croix County. Since the cornfield in which the meteorite was found had been cultivated for several years, it was supposed that the mass had fallen shortly before discovery. Several attempts were made to split the mass and one piece was detached and forged into a spike. The meteorite was described with a photograph of the exterior and a photomacrograph by Fisher (1887), and several slices were cut by Kunz. The main mass was, in 1887, presented by Professor H.A. Newton to the Peabody Museum of Yale University (Washington 1897).

Brezina (1896: 289) described the structure and gave a photomacrograph. He was well aware of the anomalous structure and based a separate group on the Hammond characteristics. The only other member of this group was Carcaria. As discussed herein, page 362, Cacaria is, however, an iron which has been extremely altered by artificial reheating, not recognized until now. Cohen (1905) gave a thorough description, and Brezina and Cohen (1886-1906: plate 40) presented three good photomacrographs. Klein (1906: 129) gave a brief description with a photomacrograph, and Berwerth (1918) concluded, erroneously, that the whole mass had been artificially reheated. Axon (1964) discussed the relative age of the extensive cracking, the Neumann bands and the heat-affected rim zone. Axon et al. (1968) gave a photomacrograph and concluded, after a discussion of the microstructure, that Hammond had been severely altered due to shock reheating in space. A similar conclusion is reached in the present study.

COLLECTIONS

Yale (22.7 kg main mass and 393 g slices), New York (842 g), Vienna (495 g), Tempe (378 g), Washington (293 g), Paris (240 g), Chicago (132 g), Harvard (111 g),

Figure 834. Hammond (Yale no. P396). Distinct regmaglypts on the main mass which now weighs 22.7 kg. Ruler measures 10 cm.

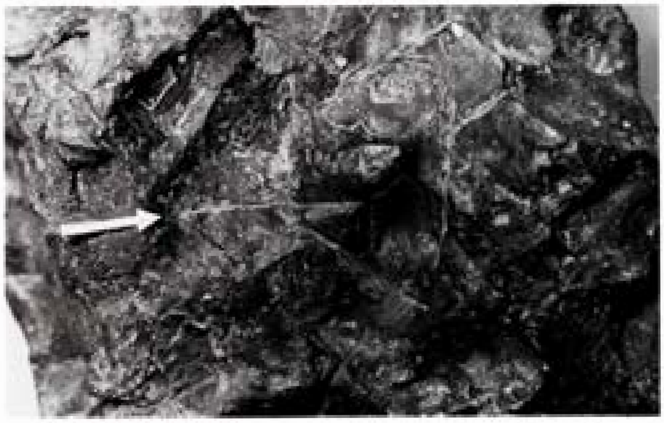

Figure 835. Hammond. Close-up of the main mass showing warty fusion crusts and a groove from an ablated schreibersite lamella (arrow). The arrow measures 2 cm.

HAMMOND – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Fahrenhorst in Cohen 1905	7.34	1.01	0.52	600	100	100	400					
Wasson & Kimberlin 1967	8.18								26.2	58.4	0.10	
Lewis & Moore 1971	8.27	0.38	0.37	160								

In the first analysis the separation of nickel and cobalt has probably been unsuccessful, but the five other determinations by Fahrenhorst may still be useful.

London (62 g), Budapest (40 g), Berlin (35 g), Stockholm (24 g), Rome (20 g), Vatican (10 g). The total weight of the recorded specimens is 25.8 kg. Since material was lost during cutting and some fragments were retained by the finders, the original weight was probably about 27 kg.

DESCRIPTION

The average dimensions of the irregular mass are 20 x 20 x 17 cm. Regmaglypts are clearly present all over the surface as 2-3 cm fluted grooves on several sides, and as more shallow, 3-4 cm depressions on the flat back side. Some sort of oriented, stabilized flight may have occurred. The fusion crust is visible on one side as wavy, 0.1-0.5 mm wide hair-lines. In several places there are characteristic cylindrical cavities, 10-15 mm wide and 5 mm deep, after ablation melted troilite. Numerous "chisel marks," 30 x 1 mm and 1 mm deep, indicate the location of ablation melted schreibersite lamellae. On sections, the ablation melted cavities are also clearly seen. One such location, where an original 400 x 100 μ schreibersite crystal perpendicular to the surface was melted out, is filled with oxidic fusion crust in which 1 μ metallic globules are embedded. Under the fusion crust is a 0.5-2 mm heat-affected zone. It is discontinuous because it has locally been removed by terrestrial pitting. Corrosion penetrates far into the interior along schreibersite and troilite inclusions, so it is out of the question that the fall is recent as believed by Fisher (1887); its terrestrial age probably runs in the hundreds of years, and possibly even more.

While the mass, as a whole, is compact and with no open cracks or fissures, some specimens in collections represent material damaged by the early chiseling. The main mass in Yale has at one end an area of about 8 x 4 cm from which the fragments were evidently broken by forceful chiseling. The 378 g slice in Tempe (no. 235a) displays severe hammer and chisel marks, and the metal is cold-worked (HV 240±20) to a depth of 3 mm, while the phosphides are fragmented and arranged in flow lines parallel to the worked surface.

Etched sections display an anomalous, indistinct Widmanstätten structure, which is heavily distorted and kneaded. At low magnification it is clearly seen that Hammond must originally have been a single austenite crystal, which, upon the primary cooling, transformed into an octahedral pattern with a kamacite bandwidth of 0.60±0.15 mm. The numerous Brezina lamellae of schreibersite, that originally may have been oriented in dodecahedral planes, are characteristic. Further, the numerous smaller schreibersite bodies, typically 0.5 x 0.2 mm, are arranged in the middle of the kamacite lamellae. And lastly, are the diffuse troilite nodules, that are 2-12 mm in diameter and more or less perfectly enveloped by 0.1-0.4 mm wide schreibersite rims. Altered plessite occupies 40-50% of the sections by area.

At high magnification the Widmanstätten structure disappears and reveals a finely polycrystalline pattern. The

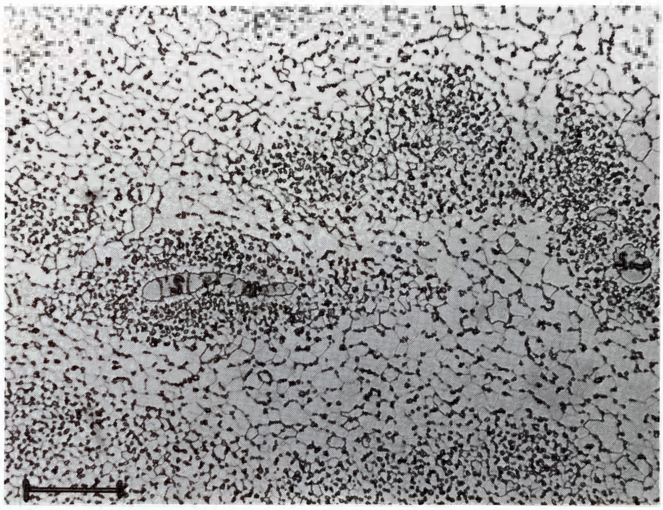

Figure 837. Hammond (Tempe no. 235a). Recrystallized kamacite with spheroidized taenite particles. The concentration of γ-particles is high in original taenite-plessite areas and around schreibersite (S) and low in original kamacite lamellae. Etched. Scale bar 200 μ.

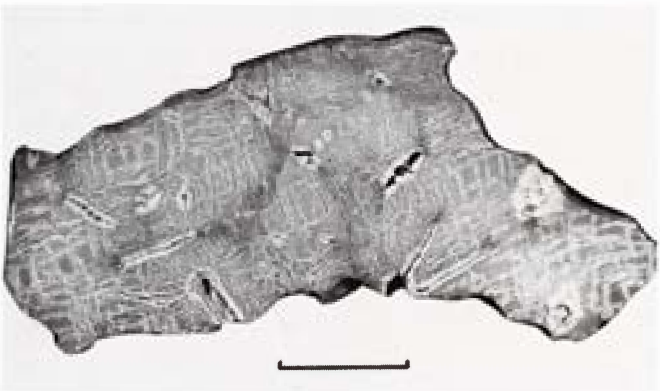

Figure 836. Hammond (Vienna no. F 6453). Severely distorted and annealed structure as a result of remote cosmic events. The dark streaks are altered schreibersite lamellae. The heat-affected α_2 zone is seen as a matte rim along the top side. Deep-etched. Scale bar 30 mm.

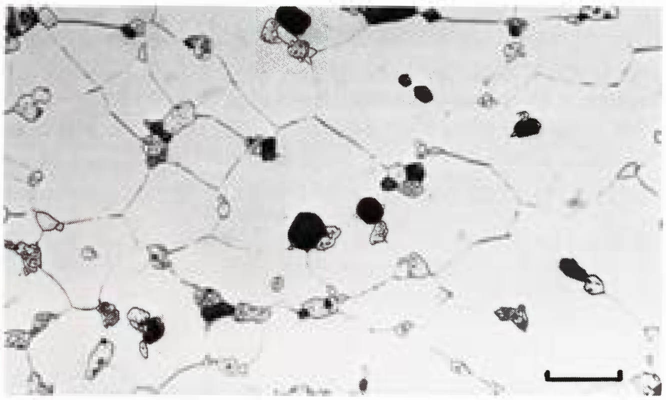

Figure 838. Hammond. Detail of a kamacite lamellae in Figure 837. Recrystallized kamacite grains with cavernous taenite particles (amoebae) and massive, angular phosphide particles at grain boundaries. The black holes are caused by imperfect polishing and etching. Compare Figure 839. Etched. Scale bar 20 μ.

building blocks are everywhere ferrite grains, taenite blebs and phosphide particles, but the ratio varies from place to place. In original taenite lamellae the taenite blebs comprise 20-30% by area, but in original kamacite lamellae they only constitute 2-5%.

The original kamacite lamellae display polycrystalline kamacite with a grain size of 25-60 μ. There are numerous 2-10 μ taenite blebs in the grain boundaries, with associated phosphide particles of about half the size of the taenite. The taenite blebs are cloudy, unequilibrated, serrated "amoebae" with 0.5-1 μ internal windows of kamacite. The phosphides are clear angular crystals. The hardness of the polycrystalline aggregates is 160±7, indicating thorough annealing in space. Neumann bands are absent, except in zones adjacent to such fissures as developed during the atmospheric deceleration.

The original taenite lamellae display polycrystalline networks, with a grain size of 10-20 μ, and with a dense population of the amoebae-like taenite particles. Phosphide particles occur occasionally. The hardness is 156±5. The original plessite interiors display structures transitional between the kamacite and taenite lamellae.

Occasionally, during microhardness testing, a very low value, i.e., about 140, turns up. Such low values are unexpected on this nickel- and phosphorus-level; they may be due to occasional micropores below the plane of sectioning, or they may reflect heterogeneities in the nickel- and phosphorus-distribution.

On routine polishing and etching of Hammond samples, one usually ends up with a micropitted surface, suggesting that micropores are, in fact, present. The pits are 1-10 μ across, usually angular and situated adjacent to taenite amoebae. However, the pits may be removed by careful mechanical polishing, so Hammond is certainly not porous in a normal sense. It appears that the pits are artificially introduced during the sample preparation and are of the same nature as those in Mejillones, Kopjes Vlei, Seneca Falls, Rafrüti and Forsyth County.

The schreibersite lamellae (HV 860±40), typically 30 x 10 x 0.8 mm in size, are faulted and violently distorted, but no open cracks appear on a carefully prepared section. They are scalloped along their entire length, i.e., partially dissolved in the kamacite matrix. The dissolved material is reprecipitated in a 50-100 μ wide zone immediately around the phosphides; the precipitates appear to be taenite amoebae and angular phosphides of much the same composition and density as along the original taenite lamellae. Terrestrial corrosion has attacked the phosphide-kamacite interfaces.

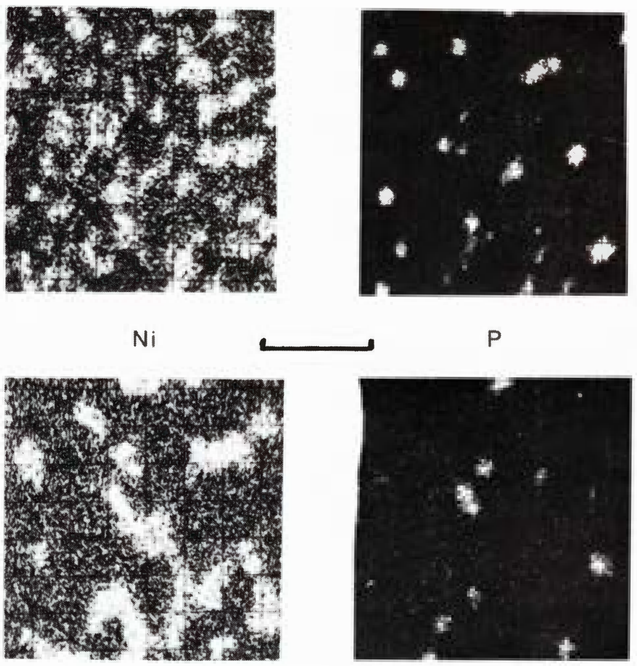

Figure 839. Hammond (U.S.N.M. no. 471). X-ray scanning pictures of decomposed kamacite lamellae. Above, one near schreibersite with high concentration of γ- and phosphide particles; below, one with low concentration. The analysis confirms that Ni-rich γ-particles dominate and are usually closely associated with small phosphide crystals. To the left NiK_{α} radiation, to the right PK_{α} radiation, 30 kV. Scale bar 15 μ.

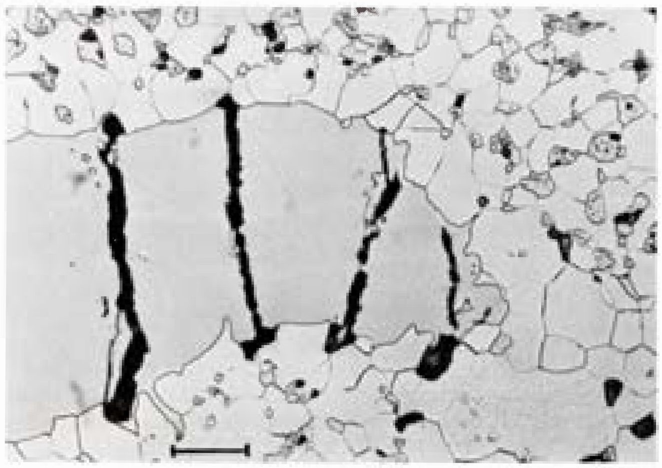

Figure 840. Hammond (Tempe no. 235a). A broken and decomposed schreibersite lamella surrounded by a high concentration of γ- and phosphide particles. Etched. Scale bar 20 μ.

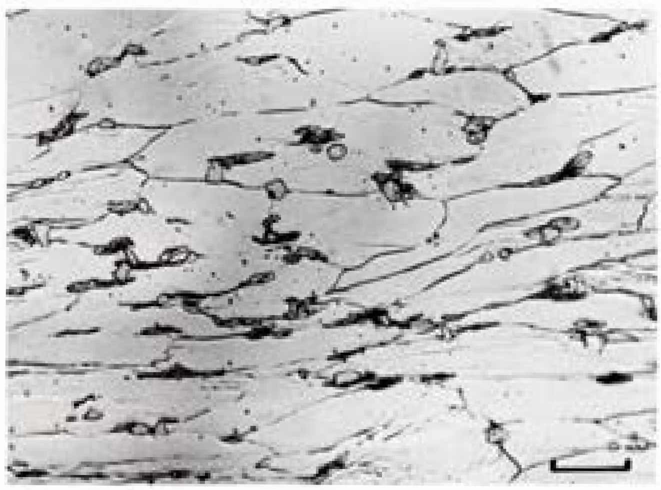

Figure 841. Hammond (Tempe no. 235a). Near-surface area showing artificial cold work due to hammering. The recrystallized grains are elongated and work-hardened to 240 Vickers. Etched. Scale bar 20 μ.

Troilite occurs as 2-12 mm spherical nodules. They have been remelted and have partly dissolved the surrounding metallic matrix, into which troilite fingers penetrate along kamacite grain boundaries. The nodules are now polycrystalline aggregates of 2-5 μ anisotropic sulfides with intercalated metal; this is mostly converted to limonite by terrestrial corrosion. The surrounding schreibersite rims are cracked; they are frequently torn loose from the metal and dispersed as 10-500 μ angular fragments in the troilite melts. Daubreelite occurs in some troilite nodules as dispersed, rounded grains, 2-5 μ across.

Troilite is also associated with many of the smaller phosphide bodies as 0.1-0.3 mm units. Again the troilite has been micromelted and the schreibersite interface is pitted and broken, but not melted. Due to terrestrial weathering, some of the near-surface troilite has been converted to pentlandite.

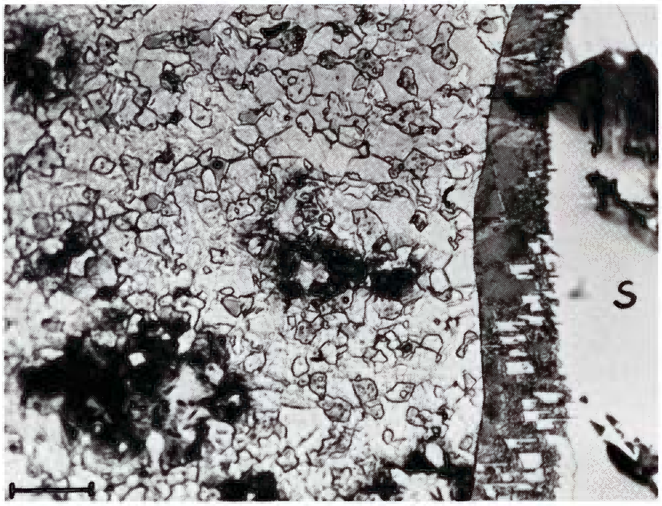

Figure 842. Hammond (Tempe no. 235a). Heat-affected surface zone A, with fused phosphides. The large schreibersite crystal to the right shows incipient melting in its exterior part only (the surface of the meteorite is outside the picture to the left). Dark nests are carbon-rich, compare Figure 843. Etched. Scale bar 20 μ.

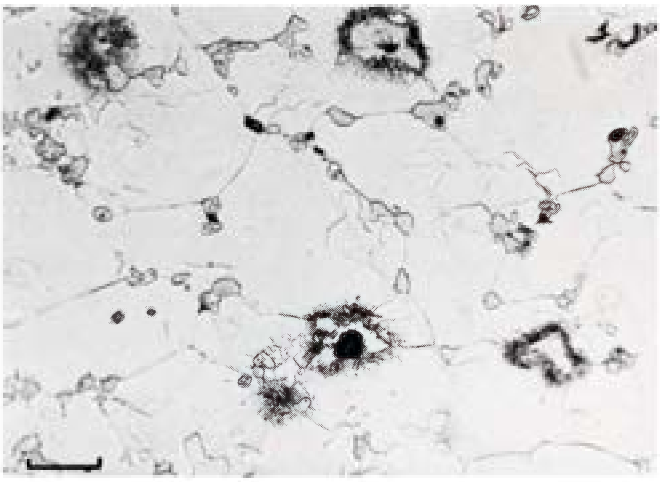

Figure 843. Hammond (Tempe no. 235a). Heat-affected surface zone with about 1100° C peak temperature. The recrystallized kamacite lamella transformed in the atmosphere to unequilibrated α_2. Fused phosphides particles with gas holes. Irregular taenite particles, some of which are surrounded by dark halos of carbon-rich nickel-martensite. The picture indicates that carbon is concentrated in the taenite particles and, further, that it is not equally distributed among them. Etched. Scale bar 20 μ.

The heat-affected rim zone is composed of serrated α_2 units with a hardness of 200±15 (hardness curve type III). Micromelted phosphides are present in the outer half of the α_2 zone. The taenite amoebae of the rim zone are interesting in that they give us additional information about their composition. While most appear unaltered, one out of ten has developed a martensitic-bainitic rim (HV 335±35) and appears as a fine-grained, dark-etching nest, 10-20 μ across. The appearance in connection with the unexpectedly high hardness suggests that carbon is irregularly distributed in the meteorite, being mostly concentrated in a small portion of the taenite amoebae.

After the primary structure developed – and even this was unusual with a combination of 8.2% Ni and 0.6 mm bandwidth – some violent cosmic event must have taken place, whereby the meteorite was reheated briefly and kneaded. The duration of the reheating was apparently short, since the meteorite was not homogenized. The peak temperature in the compressible sulfide phase was probably about 950° C since it melted, but cannot have been much higher, because the incorporated schreibersite fragments from the rim did not melt. The temperature of the metallic phases must have been above 500° C, so that nickel and phosphorus could diffuse sufficiently to create new grains by recrystallization. It is possible that the kamacite-taenite-phosphide microstructure was created by short-time reactions at about 750° C, possibly by the relaxation heat wave associated with a violent shock.

The structure is, in the author's opinion, not the result of a total remelting of the mass and clearly predates the atmospheric entry by countless numbers of years.

Hammond is structurally and chemically an anomalous iron. Gun Creek is another anomalous iron which bears some resemblance to Hammond.

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

293 g slice (no. 471, 16 x 5 x 0.5 cm)

Haniet-el-Beguel, Algeria

32°29'N, 4°24'E

Coarse octahedrite, Og. Bandwidth 1.6±0.3 mm. Neumann bands. HV 175±20.

Group I judging from the structure. About 8.0% Ni, 0.5% Co, 0.2% P.

HISTORY

A mass of 2,001 g was found in 1888 in the district of Oued Mzab, Algerian Sahara. The meteorite was discovered between sand and gravel at a depth of 5 m when excavating for a well about 80 km east of Ghardaia, on the main route to the Ouargla oasis. It was donated to the Muséum d'Histoire Naturelle in Paris, where a preliminary description was given by Daubrée (1889). The promised detailed description never appeared, and the meteorite has apparently never been reexamined. Lacroix (1927c: 451) summarized the previous data; like Daubrée, he doubted that such a small mass could have penetrated to the depth at which it was found, and therefore proposed that it had fallen early in the Quaternary, contemporaneously with the sand deposits in which it was found.

COLLECTIONS

Paris (main mass of 1,935 g), Chicago (11 g).

ANALYSES

No analytical work has been published. From an examination of the structure the present author would estimate the following composition: 8.0±0.4% Ni, 0.50±0.05% Co, 0.20±0.04% P with trace elements placing it in group I.

DESCRIPTION

According to Daubrée (1889), the 2 kg mass was an elongated quadrangular pyramid displaying a few regmaglypts. It was an entire monolith which measured 16 x 12 x 6 cm in its largest dimensions. Daubrée compared its general shape and surface features to those of Juncal, the 107 kg mass which he had previously examined in detail. Evidently Haniet-el-Beguel was assumed by Daubrée to be a well-preserved fall, although recovered from a significant depth.

This opinion was confirmed, when, in this study, I examined one of the few slices ever cut from the meteorite, an 11 g slice in the Field Museum of Chicago (Ward 1904a: 12; Horback & Olsen 1965: 229). The fusion crust is preserved along most of the surface; fine striae and warty protuberances are common, indicating that very little terrestrial weathering has occurred. The exterior part of the fusion crust consists of a 20-100 μ thick layer of magnetite and wüstite. The interior part consists of up to 300 μ thick multiple layers of dendritically solidified metal with interdendritic phosphide eutectics and gasholes. The microhardness of the metallic fusion crust is 380±20. Locally, the oxidic and metallic fusion crusts are intimately mixed and form intricate whirlpools, evidently created by eddies in the violently passing air stream during the later part of the fall.

Below the fusion crust a normal heat-affected α_2 zone is found. The serrated α_2 units are 50-150 μ across and display hardnesses of 175±10. In the outer 50% of the α_2 zone the phosphides appear in a micromelted form. Around the carbides and around some taenite fields, 20-30 μ wide, dark-etching and very hard bainitic zones have formed, due to the outward diffusion of carbon from the carbides and taenite. The blue-brown stained taenite has simultaneously changed to a yellowish taenite.

Thus, the overall state of preservation of Haniet-el-Beguel is extremely good and may be compared to what is found on Föllinge, Keen Mountain and Boogaldi, to name a few well-preserved finds. Whether shifting winds in the Sahara Desert near Ouargla can relatively quickly change the surface relief to such an extent that a meteorite within, say, 1,000 years became buried under 4-5 m sand is unknown to the author. Daubrée and Lacroix were no doubt correct in their theory that a 2 kg mass could not in its fall penetrate to a depth of 5 m. There remains, however, the possibility that the mass was originally located higher in the strata, but that it slid downwards during the digging of the well, before it was actually discovered.

The etched section displays a coarse Widmanstätten pattern of straight, bulky ($\frac{L}{W} \sim 12$) kamacite lamellae with a width of 1.6±0.3 mm. There are numerous subboundaries decorated with 1-10 μ phosphides, and Neumann bands are common. The hardness is about 175 but could not be satisfactorily measured because the 11 g slice was so small that it mainly consisted of fusion crust and heat-affected and recovered (HV 150±5) surface zones (hardness curve type II).

Taenite and plessite cover about 10% by area. Comb plessite forms up to 5 x 1.5 mm fields but elsewhere taenite wedges with decomposed interiors are more common. Some taenite interiors display 1-10 μ wide α bayonets in a matrix of light-etching acicular martensite and retained austenite. Other interiors show pearlitic development with 0.4-2 μ wide taenite lamellae, or show spheroidized patterns with taenite spherules, 2-20 μ in diameter. Carbide roses are present in some pearlitic plessite fields. For example a 200 x 50 μ area displayed an intimate intergrowth of taenite and kamacite with a cubic carbide, probably haxonite. All forms are typical for the resolved chemical group I, as found in, e.g., Toluca and Canyon Diablo.

Schreibersite occurs as 20-100 μ wide grain boundary veinlets; in addition it will probably be found as skeleton crystals when more of the meteorite is eventually cut. Rhabdites are common as 1-15 μ thick tetragonal prisms. The bulk phosphorus content is estimated to be 0.2±0.04%.

A 200 μ chromite crystal, associated with a 200 μ silicate grain (?) was noted in the section. The sample was too small to contain troilite-graphite-silicate nodules and cohenite crystals were not detected.

Haniet-el-Beguel is a coarse octahedrite, not medium as stated by Lacroix (1927c: 451) and Hey (1966: 191). It appears to be closely related to such well known irons as Bahjoi, Bischtübe, and Toluca, and will upon analysis for the trace elements probably be found to be a normal member of the resolved chemical group I. The 2 kg mass is surprisingly well-preserved for a find discovered under 5 m sand and gravel. On the other hand, the Sahara desert should be the ideal place for the preservation of iron meteorites.

Harriman (Of), Tennessee, U.S.A.
35°55'N, 84°30'W ?

Fine octahedrite, Of. Bandwidth 0.30±0.06 mm. Neumann bands. HV 200±30.

Group IVA. 7.96% Ni, about 0.06% P, 2.2 ppm Ga, 0.13 ppm Ge, 2.3 ppm Ir.

HISTORY

According to a note in the catalog of Texas meteorites (Barnes 1939a: 607) a 67 pound mass was found near Harriman, Roane County, Tennessee. The date and the circumstances of finding were not reported, and the name was tentative. It is not even absolutely certain that the place of discovery was in Roane County. The meteorite has not been described, and it is not mentioned in the catalogs of Prior (1953) and Hey (1966).

In the 1960s the mass was sent to the Smithsonian Institution for cutting; a control weighing registered 65 1/4 pounds or 29.5 kg; as only insignificant samples had been removed from it, the initial weight was probably just below 30 kg. Several thin slices were produced, while the main mass was returned to the owners.

COLLECTIONS

Oscar Monnig, Texas Observers, Fort Worth (about 28 kg), Washington (polished sections).

Figure 844. Harriman (Of). The 29.5 kg main mass shows weathered regmaglypts. Scale bar approximately 5 cm. S.I. neg 38852.

DESCRIPTION

I have not seen the main mass, but photographs indicate that it was of angular, lenticular shape with the approximate maximum dimensions 28 x 22 x 12 cm in three perpendicular directions. Much of the surface is covered with regmaglypts, 2-3 cm in diameter. Terrestrial corrosion has, however, somewhat modified the relief. Sections through the meteorite indicate that, on the average, 2 mm has been lost by corrosion. Somewhat deeper attacks occur occasionally, e.g., as shallow 1-2 mm deep pockets of terrestrial limonite with still surviving taenite ribbons and particles.

Etched sections show Harriman to be a fine octahedrite with long, straight ($\frac{L}{W} \sim 35$) kamacite lamellae with a width of 0.30±0.06 mm. There is a strong oriented sheen; the kamacite is very pure and Neumann bands are well developed and undecorated. The hardness is 180±10, but it increases locally in cold-worked zones to above 225 as discussed below.

Taenite and plessite cover 40-50% by area. Most plessite fields are of the comb and net varieties, or of the cellular variety with small oriented γ-particles. The yellow taenite borders are followed by narrow brown and dark-etching martensitic transition zones; indistinct, black duplex plessite is also present. The varieties indicate normal cooling with only slight subsequent annealing. The microhardness of the taenite (50 g) is in accordance herewith 270±25.

Schreibersite and rhabdite were not detected at all, suggesting a bulk phosphorus content well below 0.1%, and probably about 0.06%.

Troilite occurs as an occasional 2 cm nodule – which could not be examined under the microscope – and as scattered 0.1-2 mm angular or lenticular particles. Most of

Figure 845. Harriman (Of). Full slice through the mass, Figure 844. Fine octahedrite with a large troilite inclusion but with no schreibersite crystals at all. Deep-etched. Scale bar 3 cm.

HARRIMAN (OF) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Schaudy et al. 1972	7.96								2.21	0.13	2.3	

the small troilite blebs contain 50-500 μ chromite crystals, which evidently originally nucleated the troilite formation. The troilite once contained parallel exsolved daubreelite lamellae. Due to shock-melting the textures are now altered. The troilite dissolved part of the metallic walls and brecciated the daubreelite. The sulfide-metal melts solidified rapidly to fine-grained eutectics with 1 μ metal particles and serrated edges against the kamacite.

Except for a few 20-100 μ daubreelite crystals in kamacite, no other meteoritic minerals were observed.

The fusion crust is lost by corrosion, and only part of the heat-affected α_2 zone is preserved. It runs as a 0.1-0.5 mm wide surface zone discontinuously around the examined sections. Its hardness is 185±10 (hardness curve type IV). In several near-surface places, and to a depth of at least 20 mm, severe deformations are visible. The Neumann bands are bent and the taenite lamellae faulted; indistinct deformation bands are also present within the kamacite, where the hardness correspondingly increases to above 225. The damage does not appear to have been inflicted by artificial hammering, but rather resembles that present in, e.g., Gibeon, Cape York, Campo del Cielo and Wabar. Such deformation is usually attributed to cold-work during necking and disruption in our atmosphere. Perhaps Harriman (Of) is only one of many samples that formed a shower during fall.

An examination of the octahedrites from Tennessee and the adjacent Appalachian Mountains indicates that only Charlotte, Duel Hill (1854), Wood's Mountain and Bristol can be candidates among the known meteorites. Clinton is from the same general area, but it has not been possible to obtain information on it. Charlotte can be ruled out since it was observed to fall in 1835, and Duel Hill and Wood's Mountain can also be ruled out on account of the small but significant structural and chemical differences. Bristol remains as an intriguing possibility. Found 200 km farther east than the supposed site of Harriman, it presents a chemical composition and structures which are exact duplicates of Harriman. Moreover, it shows local deformation and work-hardening corresponding to that detected in Harriman. Future studies should examine the possibility that Harriman (Of) and Bristol belong to the same shower.

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

Harriman (Om), Tennessee, U.S.A.

35°55'N, 84°32'W; approximately 400 m

Medium octahedrite, Om. Bandwidth 0.95±0.10 mm. ϵ-structure. HV 300±25.

Group IIIA. 7.63% Ni, 0.14% P, 19 ppm Ga, 37 ppm Ge, 10 ppm Ir.

HISTORY

A mass of 12.9 kg was found before 1938 on Pine Ridge, about 4 km south of Harriman, but north of U.S. Highway 70, in Roane County. The mass passed from the finder, Mr. Davis, to the geologist, Walter F. Pond, who in 1947 donated it to the U.S. National Museum (Report, U.S. National Museum 1947: 43; and letter of 22 October 1946 from W.F. Pond to the Smithsonian Institution).

Only a few slices have been cut from the mass.

COLLECTIONS

Washington (12.3 kg), New York (121 g).

DESCRIPTION

The mass has the overall dimensions 20 x 14 x 11 cm and is roughly lens-shaped. It is covered by a crust of loosely adhering 1-4 mm thick terrestrial oxides; and the numerous shallow pits, which are 15-25 mm across with no marked ridges, are undoubtedly due to long corrosion that has removed several centimeters of the skin. Locally, the oxides invade the surface and create black, semicircular,

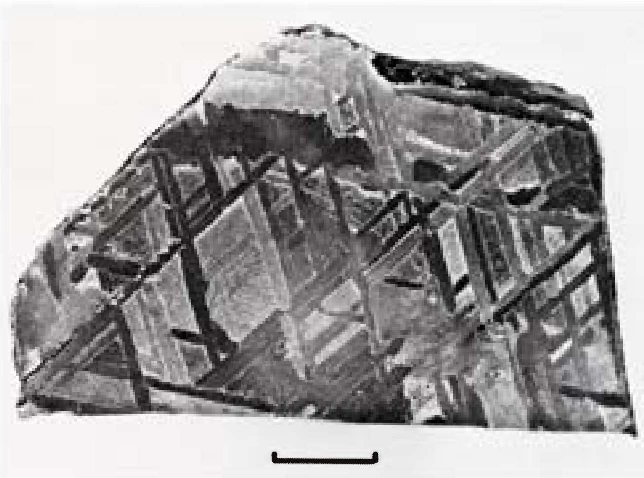

Figure 846A. Harriman (Om) (U.S.N.M. no. 1439). Medium octahedrite cut almost parallel to $(111)_\gamma$ so that the fourth set of Widmanstätten lamellae appear as irregular plumes. Deep-etched. Scale bar 10 mm.

HARRIMAN (OM) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson, 1950 pers. comm.	7.86	0.67	0.14		100							
Scott et al. 1973	7.41								19.2	36.8	10.0	

dense, corroded areas, that are apparently kept in place by a grid of still uncorroded taenite.

Etched sections show a characteristic medium octahedrite structure of long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 0.95±0.15 mm. Not all lamellae are straight, because a late grain growth on part of the α-phase has locally pushed the grain boundaries outward. The oriented sheen is silky, or like the sheen on a ripe field of barley, agitated by the wind. Such a macroscopic appearance is typical of the shock-produced hatched ϵ-structure, and examination under higher magnification confirms this conclusion. The subgrain boundaries of the kamacite are not marked and only decorated by a few 1-2 μ rhabdites. The ϵ-matrix appears to be loaded with a cloud of submicroscopic particles. A few, hard, thin plates of carlsbergite, typically 5 x 1 x 0.5 μ, occur as oriented precipitates in the kamacite. The microhardness of the shocked kamacite is 300±25.

Plessite covers about 30% by area, mostly in the form of very open meshed, almost resorbed comb and net plessite fields. The framing taenite rim is usually discontinuous. In the few larger wedges of plessite, the interior shows martensite and duplex $\alpha + \gamma$ mixtures with 1-2 μ individual taenite grains. The taenite rim frequently etches bluish-gray in irregular blotches. A few of the larger plessite fields are subdivided into irregular differently oriented cells, where the kamacite of each cell corresponds to the kamacite of the adjacent lamella.

Schreibersite is not visible to the naked eye but does occur as 5-10 μ wide and 50-100 μ long grain boundary precipitates. It is further present as 1-5 μ vermicular bodies, substituting for taenite in the plessite interiors.

Troilite was only seen as a few scattered 1-2 mm grains.

The heat-affected rim zone has long since been removed by corrosion, and grain boundary oxidation and selective attacks on the nickel-poorest part of the α-phase have occurred several centimeters below the present surface.

Harriman (Om) is a medium octahedrite which is related to such well known irons as Norfolk and Henbury. It is a normal member of group IIIA.

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

11.6 kg main mass (no. 1439, 20 x 13 x 10 cm)
376 g part slice (no. 1439, 11 x 10 x 0.7 cm)
276 g endpiece (no. 1439, 8 x 7 x 1.5 cm)

Hart Range, Northern Territory, Australia
23°S, 131°E

A 608 g fragment of a medium octahedrite was reported by McCall & De Laeter (1965: 65) as being in the Western Australian Museum.

Hassi-Jekna, Oued Meguiden, Algeria
28°57′N, 0°49′W

Fine octahedrite, Of. Bandwidth 0.47±0.07 mm. Neumann bands. HV 200±20.

Group IIIC. 10.5% Ni, about 0.25% P, 27 ppm Ga, 70 ppm Ge, 0.18 ppm Ir.

HISTORY

A mass of 1,250 g was purchased from Arab nomads by Captain Hélo, a French officer serving in southern Algeria, in 1890. The meteorite was donated to the Museum d'Histoire Naturelle in Paris and was briefly described by Meunier (1892; 1893a: 40). According to Hélo, the meteorite was observed to fall a few years earlier near an Arab tent camp which had been put up a few kilometers east of the Hassi-Jekna well. This well was

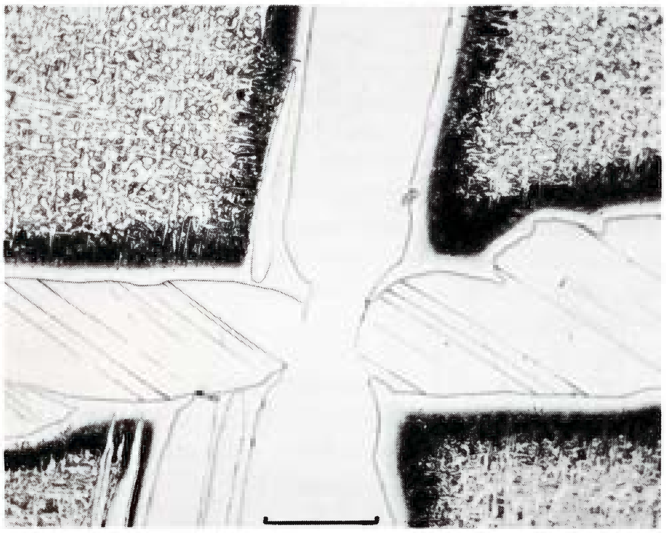

Figure 846B. Hassi-Jekna (Paris no. 2818). A fine octahedrite of group IIIC, related to Mungindi and Carlton. Four plessite fields with duplex interiors, and kamacite lamellae with Neumann bands. Etched. Scale bar 300 μ.

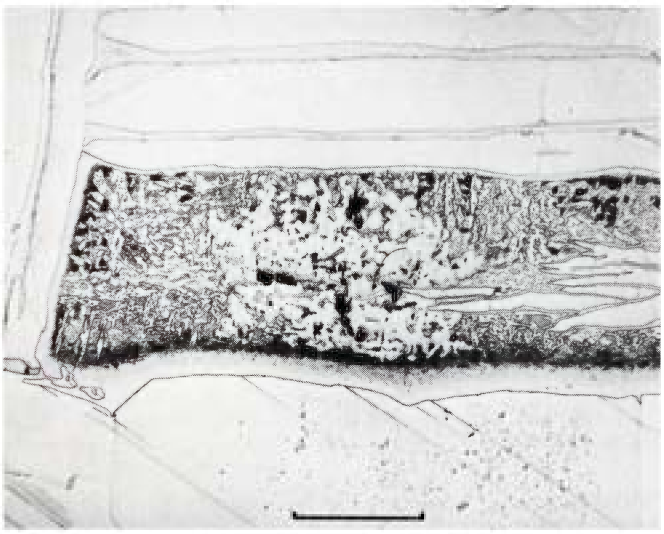

Figure 846C. Hassi-Jekna (Paris no. 2818). Plessite field with a haxonite rose, i.e., an intricate intergrowth of haxonite with fine particles of kamacite, taenite and schreibersite. Etched. Scale bar 200 μ.