

thoroughly examined, and the trace-elements determined, so that the preliminary conclusions given above can be supported. Specific attention should be given to the range of possible annealed structures in large and small fragments from known localities within the crater field.

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### Morden, New South Wales

30°30'S, 142°20'E

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An undescribed mass of 2.6 kg is in the South Australian Museum, Adelaide (Hey 1966: 317). The following analysis was, without further details, recently published by Reed (1972b): 6.6% Ni, 81 ppm Ga and 329 ppm Ge. The analysis suggests that Morden is a group I iron related to Cranbourne, Gladstone and Youndegin.

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### Morito, Chihuahua, Mexico

27°3'N, 105°26'W; 1,600 m

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Medium octahedrite, Om. Bandwidth 1.05±0.15 mm. e-structure. HV 300±40.

Group IIIA. 7.61% Ni, 0.53% Co, 0.12% P, 18.7 ppm Ga, 35.8 ppm Ge, 9.2 ppm Ir.

#### HISTORY

A beautiful conical monster of 10.1 tons had been known for many centuries as a landmark, about 25 km northeast of (Hidalgo del) Parral, but exact information as to its size, locality and history was for the most part lacking, until Smith (1871) furnished a sketch of the exterior and a map sketch. Castillo (1889) provided further information and a map, and Fletcher (1890a) supplied a remarkable historical examination.

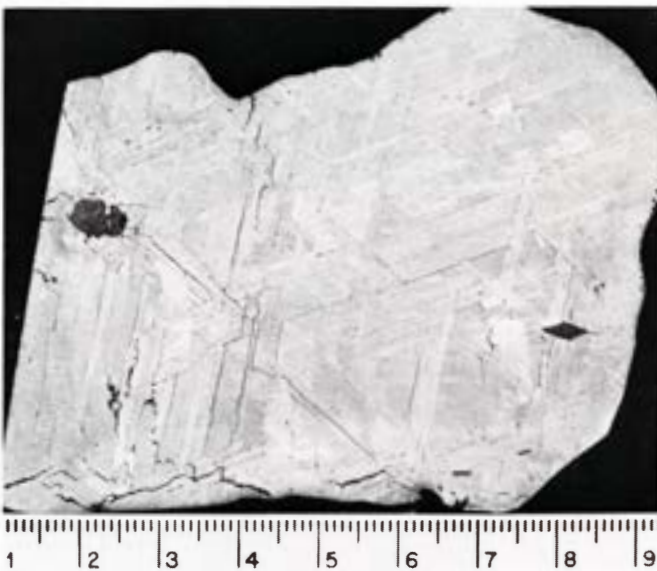
It appears that the mass was first mentioned in The History of Philip II by Luis Cabrera de Cordoba (1619: Libro 13: 1163) and by Salmeron (Journal of 1629, as

quoted by Fletcher 1890a: 129). The metallic iron was a venerated memorial on the Indian's route when, in ancient time, they moved from the north to settle in Mexico. About the year 1600 it was partly excavated, and a blacksmith detached a few pieces. It must be borne in mind that there was considerable activity in the region at that time because of the exploration for noble metals and the actual mining operations carried out since 1547 at Santa Barbara, about 35 km in a southwesterly direction.

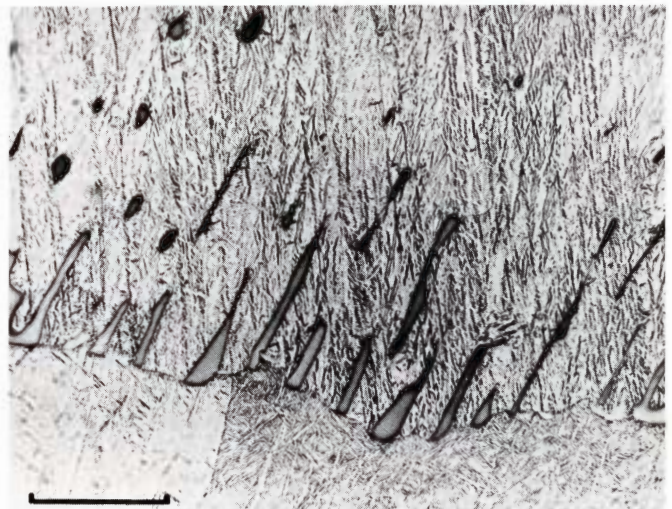
Later on the mass was almost forgotten, until Humboldt in a paper (1811: volume 1: 293) noted the existence of a large mass in the neighborhood of Durango. On his authority an extensive search for this mass was undertaken, but all was in vain. As Fletcher (1890a: 134) pointed out, Humboldt did not actually see the iron, but included it in his writings of northern Mexico. On the map Morito was reasonably near Durango, and in the prerevolutionary days when Humboldt lived, the place was also in the Province of Durango, which has been divided at a later date. We must conclude that Humboldt was reporting what he had heard of Morito from Mexican mineralogists and that he had no really precise information about the mass. His loose statements resulted in numerous misinterpretations and mislabelings in the nineteenth century. As late as about 1900 it was commonly accepted that Morito belonged to the "Huejuquilla group" of large irons; see, e.g., Wülfing (1897: 150) and Cohen (1905: 176, 348).

Hardy (1829: 481) traveled through the Valle de Allende in 1827 and was the first to report the exact location of the large mass to be on the San Gregorio hacienda. He wrote:

"Many attempts have been made to melt down this mass of iron, but without success. An Italian imagined that by heating one side of it he should be able to cut off as much of the metal as he wanted. Accordingly, he piled on the part where he intended to commence his operations an immense quantity of wood, to which he set fire, and by dint of united blast of five or six forge bellows he succeeded in giving it a red heat which indeed



**Figure 1161.** Morito (Tempe no. 375.1). A shocked medium octahedrite of group IIIA. Two monocrystalline troilite crystals with daubreelite lamellae appear black. Etched. Scale in centimeters. (Courtesy C.B. Moore.) See also Figure 32.



**Figure 1162.** Morito (Tempe no. 375.1). Edge of an open-meshed comb plessite field. Cloudy taenite lamellae and shock-hatched kamacite. Etched. Scale bar 100  $\mu$ .

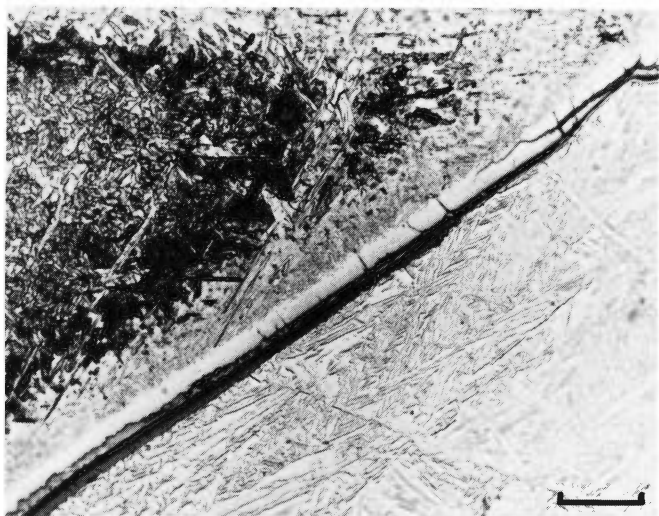


Figure 1163. Morito (Tempe no. 375.1). Edge of a plessite field. A narrow taenite rim (white) is followed by an indistinct martensitic transition zone and dark-etching duplex structures. Terrestrial corrosion follows the  $\alpha$ - $\gamma$  interface and penetrates the taenite along certain fissures. Etched. Scale bar 20  $\mu$ .

was so insupportable that, to his astonishment, he could not come near it. However, I am told that by applying a wall of thick boards before him he succeeded in obtaining 3 pounds of iron; which 3 pounds cost him \$130 and they were not worth \$4."

Butcher traveled through Valle de Allende in 1871 and reported and sketched the masses of San Gregorio (or Morito) and Concepcion in letters to Professor Baird (dated April 19, 1871 and filed in the Smithsonian Institution) and to J. Lawrence Smith. Smith (1871) published Butcher's account, which also mentioned for the first time the Spanish inscription which is chiseled in: "Only God in his might can destroy this iron, for none on Earth is able to divide it. 1821." The inscription probably dates from the despairing blacksmith mentioned by Hardy (1829) and later by Burkart (1871).

Castillo (1889) and Fletcher (1890a: 140) reported that the mass actually was discovered further east, in a place called El Morito, but that at an early date (~ 1750 ?), it had been transported a few kilometers to the hacienda of San Gregorio. On a modern map (1:250,000) Rancho El Morito is situated 11 km east-northeast of hacienda San Gregorio. The coordinates given above are those of El Morito. See the map sketch Figure 610.

On the initiative of Castillo, the meteorite was transferred in 1893 to the inner yard of the School of Mines in

Mexico City (Frenzel 1898). It has to date not been removed, although the Faculty of Engineering has moved to the new University City.

Brezina (1896: 272) gave a short description of the fragments in Vienna and stated erroneously that the main mass carried the inscription "1600." This is in confusion with Concepcion (Adargas). Farrington (1915) reviewed the literature. Berwerth (1914: 1080) included Morito with the artificially reheated irons. This is, however, an erroneous conclusion which probably was based upon the examination of small, near-surface fragments, which did not truly represent the main mass.

Nininger (in Haro 1931: 83) gave a brief description. In the same publication there are six good photographs of the exterior shape. The weight is given as 10,100 kg, apparently a figure obtained by actually weighing the mass. Nininger (1952a: plate 32) gave another view of the exterior, and Nininger & Nininger (1950: plate 16) presented a photomicrograph of an etched section. Henderson & Perry (1956) presented another photomicrograph and suggested that Morito and Loreto were a paired fall.

For further background, the references given by Fletcher (1890a) and Wülfing (1897) should be consulted. Morito's involved history is closely tied to that of the Chupaderos masses which were found only 50-75 km farther east and southeast. Quite recently the region attracted renewed attention when the carbonaceous chondrite (type III), Allende, scattered more than 2,000 kg fragments over Valle de Allende in a 50 x 10 km ellipse (Clarke et al. 1971a).

#### COLLECTIONS

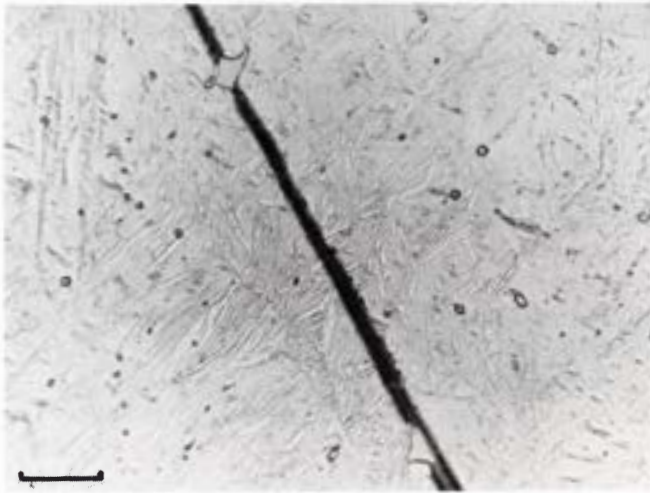
Mexico City (main mass of 10,100 kg), Washington (651 g), Tempe (633 g), London (491 g), Stockholm (56 g), Göttingen (56 g), Paris (47 g), Harvard (35 g), Canberra (33 g), Vienna (18 g on two samples; the 10 g sample no. G 3704 has been artificially reheated to 800° C), Chicago (13 g), New York (5 g).

#### DESCRIPTION

The large cone-shaped mass is mounted on its apex upon a pillar in Palazzo de Minería, Tacuba No. 5, in Mexico City. The light is unfortunately insufficient to warrant a thorough examination of the surface, but the following observations were made during two different visits in 1967 and 1968. The height of the cone is 100-105 cm, and the widths in two perpendicular directions

#### MORITO - SELECTED CHEMICAL ANALYSES

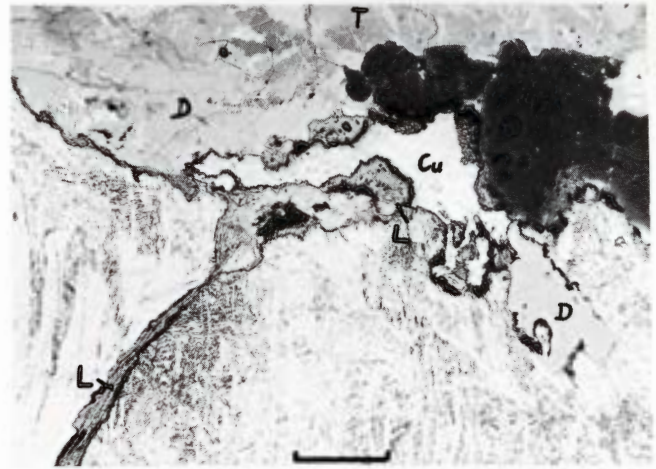
References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Goldberg et al. 1951	7.69	0.56							18.7			
Henderson & Perry 1956	7.76	0.56	0.01									
Lewis & Moore 1971	7.60	0.47	0.12	160								
Scott et al. 1973	7.38								18.7	35.8	9.2	



**Figure 1164.** Morito (Tempe no. 375.1). Cloudy taenite lamella with two minute schreibersite crystals. Tiny rhabdites in the shock-hatched kamacite. Etched. Scale bar 20  $\mu$ .

are about 190 and 140 cm. The cone is not fully symmetric, but somewhat flattened sidewise. The rear side or antiapex is almost flat and covered by very shallow, bowl-shaped depressions, 10-50 cm in diameter. The sides of the cone are deeply fluted by furrows and ridges that radiate from the apex. Typical furrows are 10 cm long, 2 cm wide and 2 cm deep and represent the ablational carving in the atmosphere of the solid iron. Additional pits, 10-20 mm in aperture and 10-35 mm deep, represent the site of troilite nodules which melted out. A total of 32 troilite pits was observed. The surface is covered with metallic and oxidic fusion crusts, which frequently attain a thickness of four millimeters. The warty and striated crusts are best preserved in the pits and in the bottom of the furrows, while in other places it is removed by abrasion (transport), corrosion and artificial peeling. Judging from the still adhering yellow-orange caliche, the mass has for a long time been buried with the apex obliquely downwards and only one-fourth of the mass protruding above the ground. It is possible that the orientation in the ground reflects the actual orientation during the stabilized flight. It is difficult to say when the fall took place, but it appears to have been within the last two thousand years, estimating from the state of corrosion and caliche covering. See also Willamette for a comparison of the external sculpture.

As mentioned above, the iron has been attacked on numerous occasions by hammer, chisel and hacksaw, and possibly heated once by an inefficient fire. At least six different cuts have resulted in the removal of specimens of a few kilograms weight each, generally leaving scars of 20 x 10 cm along the edges between the cone and the flat rear side. In one place is the dated, four-line inscription in Spanish: "Solo Dios con su poder - este fierro destruirá - porque en el mundo no abra - que lo pueda deshacer. A<sup>o</sup> 1821." Directly opposite is a two-line inscription "Xaviercora - Hermann" (?), but the interpretation is uncertain due to rust and poor lettering. As discussed below

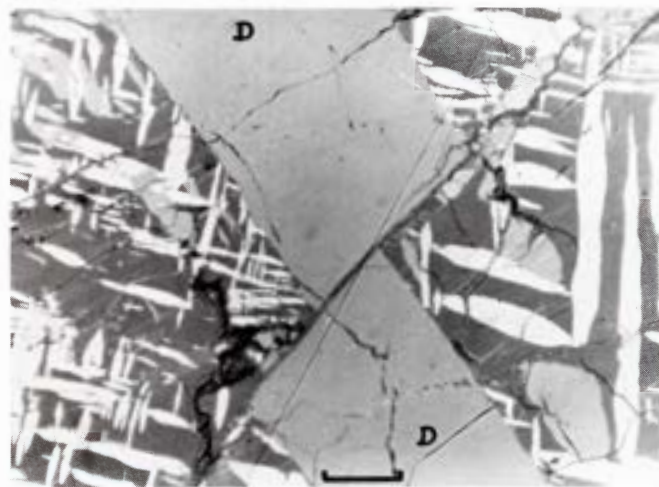


**Figure 1165.** Morito. Detail of Figure 1161. A highly peculiar aggregate for a group IIIA meteorite. Troilite with multiple twinning (T), brecciated daubreelite (D), native copper (Cu) and unidentified silicates or phosphates (black). Limonite from terrestrial corrosion (L) along several boundaries. Etched. Slightly crossed polars. Scale bar 200  $\mu$ .

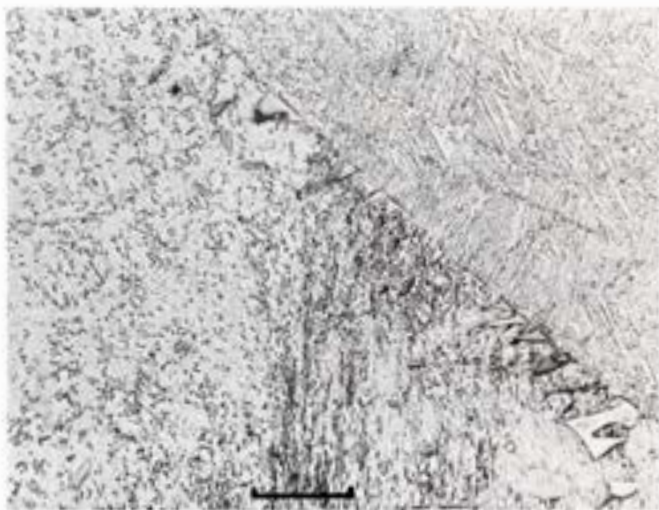
under Parral one of the detached fragments apparently found its way to the Munich Collection and was described as an independent meteorite by Heide & Förstel (1953).

Etched sections display a medium Widmanstätten structure of straight, long ( $l \sim 30$ ) kamacite lamellae with a width of  $1.05 \pm 0.15$  mm. The kamacite has subboundaries decorated by a few  $1 \mu$  rhabdites, and it is strongly marked by the hatched  $\epsilon$ -structure, due to shock above 130 k bar. The microhardness is  $300 \pm 40$ .

Taenite and plessite cover about 35% by area. Most of the fields are open-meshed comb plessite with discontinuous taenite frames, but net plessite and taenite wedges with martensitic interiors are also common. The taenite frequently etches in blue and brownish stained patches except in the heat-affected rim zone where it etches clear yellow. The cause is probably carbon in solid solution in the taenite.



**Figure 1166.** Morito. Detail of Figure 1161. Severe brecciation of a troilite-daubreelite nodule. The daubreelite lamella (D) is shear-displaced and the troilite on either side exhibits multiple twinning. Crossed polars. Scale bar 20  $\mu$ .



**Figure 1167.** Morito (Tempe no. 375.1). Transition between heat-affected  $\alpha_2$  zone (left) and shock-hatched interior (right). An open-meshed net plessite field occupies 3/4 of the picture. Etched. Scale bar 200  $\mu$ .

Schreibersite is absent as larger bodies but common as 10-50  $\mu$  wide grain boundary precipitates and as 5-10  $\mu$  irregular bodies inside the plessite fields. Rhabdites occur locally in significant numbers as 1  $\mu$  prisms.

Troilite is present as scattered nodules 5-20 mm in diameter, and as angular, frequently rhomboidal, bodies 0.1-5 mm in diameter. The troilite is monocrystalline but beset with lenticular twin sparks that indicate considerable plastic deformation. Daubreelite covers about 10% by area, mostly as 10-100  $\mu$  parallel lamellae; they are somewhat brecciated and displaced by deformation. The enveloping kamacite shows deformation bands and minor bending. In the kamacite are numerous fine, hard platelets, 20 x 1  $\mu$  in size, of the chromium nitride, carlsbergite.

The fusion crust was examined in two sections from near the edge between the cone sides and the flat rear side. It is composed of about 20 consecutive, parallel laminae, each about 50  $\mu$  thick, of dendritic, cellular metal, followed by an exterior whirlpool layer, 1-2 mm thick, of sintered metallic droplets, each 100-500  $\mu$  in diameter, interbedded and enveloped in oxidic fusion crusts. While the inner 20 layers only contain scattered, frequently hollow, oxide spherules, 1-10  $\mu$  in diameter, oxides become increasingly important outwards and apparently form low-melting iron-oxide eutectics locally. Terrestrial corrosion products are abundant in the interstices of the exterior cavernous layer. The inner metallic layers are martensitic and dense and have a microhardness of 260 $\pm$ 25.

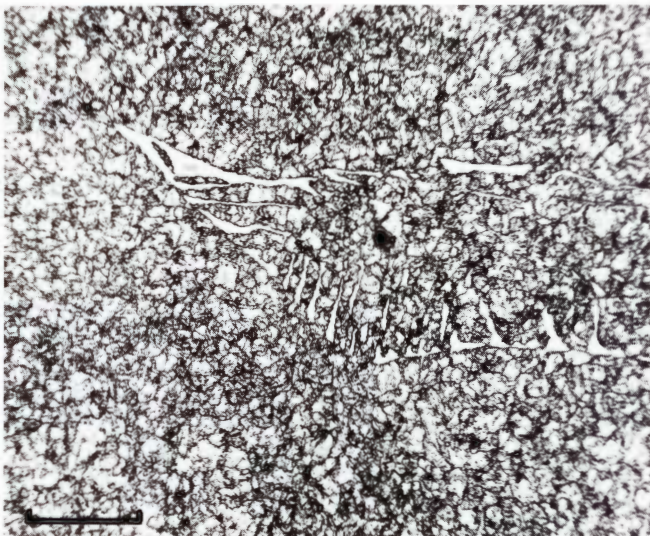
Under the fusion crust is a 2-4 mm thick heat-affected  $\alpha_2$  zone with a microhardness of 185 $\pm$ 10. The troilite that happens to be located in the heat-affected zone is partly melted, partly recrystallized to 10-100  $\mu$  units. The phosphides are micromelted in the exterior 50% of the  $\alpha_2$  zone.

Corrosion has penetrated several centimeters along grain boundaries and troilite inclusions, but the general state of preservation is very good.

Morito is a shocked, medium octahedrite which is closely related to Loreto, Boxhole, Canyon City, Picacho and Merceditas. Chemically, it is a typical group IIIA iron. It is a cone-shaped individual which probably fell without breaking up and scattering other specimens around. However, specimens were at different times cut from it and incorporated in collections under various names such as Durango, Chihuahua, Parral and possibly others. No trace of the artificial reheating which took place in the eighteenth century could be traced in the structure, except perhaps in a minor sample, No. G3704, in the Vienna Collection, which had apparently been briefly reheated to about 800° C, and in the Parral material, see the following paragraphs.

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

333 g edge slice (no. 1383, 10 x 6 x 1.5 cm) } originally one  
228 g slice (no. 1383, 11 x 7 x 0.4 cm) } 636 g piece



**Figure 1168.** Morito (Vienna no. G3704). An artificially reheated Morito fragment. Diffuse comb plessite and fine-grained unequilibrium  $\alpha_2$  matrix. Etched. Scale bar 300  $\mu$ .

**MORITO (PARRAL FRAGMENT) – SELECTED CHEMICAL ANALYSES**

Reference	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Heide & Förstel 1953	7.41	0.57	0.21	700	1400	700	300			700		

The analysis is probably a little low in nickel, a little high in cobalt and phosphorus, and much too high in germanium.

### Morito (Parral fragment), Chihuahua, Mexico

Medium octahedrite, Om. Bandwidth  $1.10 \pm 0.20$  mm.  $\epsilon/\alpha_2$  structure. Group IIIA, judging from the structure. About 7.6% Ni, 0.12% P. Reheated artificially to about  $800^\circ\text{C}$ .

#### HISTORY

A fragment of 496 g, detached from some larger mass, was described with chemical analysis, microhardness measurements and photomicrographs by Heide & Förstel (1953) who had the fragment on loan from the Mineralogical Museum of Munich. In a letter from the Museum it was stated that the meteorite came from Parral, but apparently no other information as to its origin was preserved.

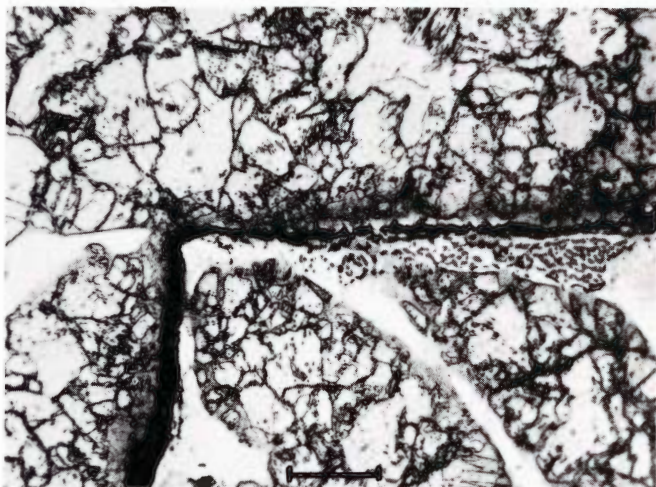
The fragment, now about 400 g, is in the Mineralogical Museum in Munich. A 36 g slice from it was kindly lent to the author by Professor F. Heide, Jena.

#### DESCRIPTION

According to Heide & Förstel the 496 g mass is a fragment chiseled and broken from a larger mass. The 36 g part slice which was cut from this fragment and which I examined showed the following characteristics.

Part of the original fusion crust is locally preserved as up to 1 mm thick, laminated, metallic deposits. The metal of the crust has, however, lost its normal, cellular, dendritic structure and is in the form of homogenized, columnar grains with  $\alpha_2$  interior. The grains are so large (e.g.,  $200 \times 50 \mu$ ) that they spread over several adjacent laminae which clearly indicates that the mass has been reheated after the fusion crust solidified.

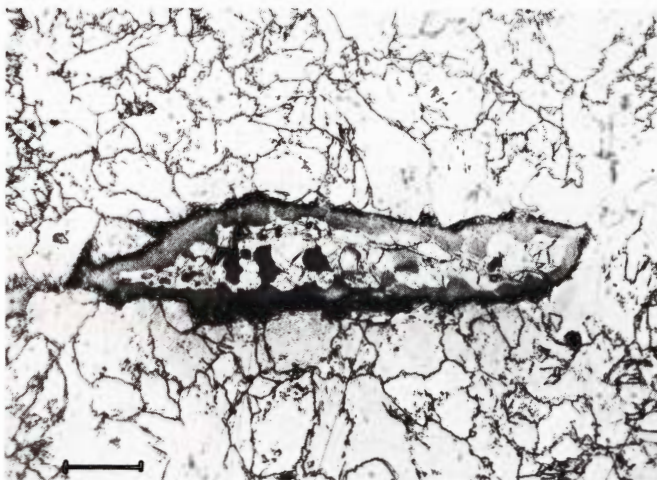
The same conclusion is reached after examining the interior. Although the original  $\epsilon$ -structure of the matrix is faintly observed in places, most of the Widmanstätten lamellae are converted to  $25\text{--}50 \mu$  serrated  $\alpha_2$  grains, with



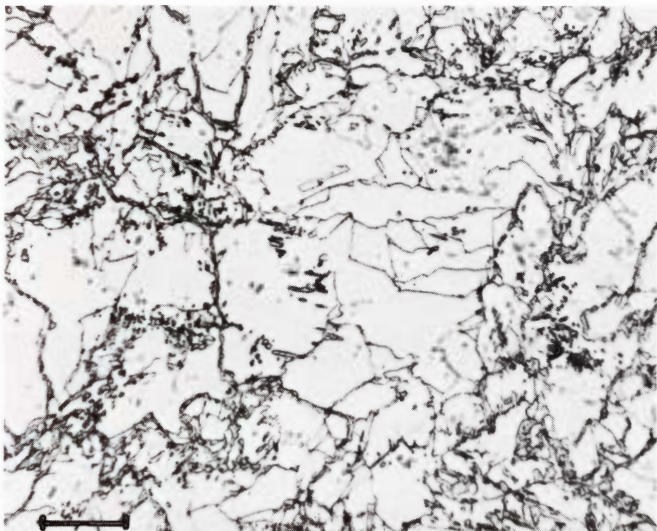
**Figure 1169.** Morito (Vienna no. G3704). Artificial reheating caused nickel to diffuse away from the taenite lamellae, so that they now display blurred edges. The horizontal black line was terrestrial limonite which at high temperature decomposed and reacted with the metal to form lace-like intergrowths. Etched. Scale bar  $40 \mu$ .

no indication of the usual steep temperature gradient from the atmospheric friction heating, leaving little doubt that the mass was uniformly reheated to about  $800^\circ\text{C}$  artificially.

The Widmanstätten structure, which has lost its oriented sheen, shows straight, long ( $\frac{l}{W} > 20$ )  $\alpha$ -lamellae of 1.10 mm average width. Since the iron is hammered somewhat, the linear elements of the Widmanstätten structure are bent and distorted near the surface. The iron is also opened along octahedral planes as a result of the working. Plessite occupies about 40% by area, mostly in the form of open-meshed comb plessite fields with discontinuous taenite rims. Around many of the taenite wedges are  $20\text{--}50 \mu$  wide rim zones of bainitic-martensitic structures, indicating a certain carbon percentage in harmony with the analysis. Although 0.07% C appears low, it becomes significant when most of it is assumed to be in solid solution in



**Figure 1170.** Morito (Vienna no. G3704). A schreibersite crystal that melted by the artificial reheating. The kamacite transformed to unequilibrated  $\alpha_2$ . Etched. Scale bar  $50 \mu$ .



**Figure 1171.** Morito (Vienna no. G3704). Close-up of the unequilibrated  $\alpha_2$  structure, in this particular case formed from shock-hatched  $\epsilon$  by brief reheating to about  $1000^\circ\text{C}$ . Etched. Scale bar  $20 \mu$ .

the rather small amount of taenite. When the meteorite was reheated, some of the carbon diffused from the taenite to the adjacent lamellae which, upon cooling, transformed to the observed structures.

Schreibersite occurs as 10-50  $\mu$  wide grain boundary precipitates and is also present as 5-10  $\mu$  vermicular bodies in the open plessite network. Rhabdites are rare but occur locally as 1  $\mu$  tetragonal prisms; further as 0.2-1  $\mu$  precipitates on the subboundaries of the ferrite. The last two forms are particularly easy to identify in the rim zones which were sufficiently heated in the atmosphere to melt the phosphides.

Carlsbergite platelets, typically 20 x 0.5  $\mu$  in size, are common and little affected by the artificial reheating. They are common in the Morito main mass, too.

The fragment is very little corroded; if it had not been hammered and reheated by man, it would have been a beautifully preserved specimen. Unfortunately the hardness determinations of the individual phases, carried out by Heide & Förstel, become less meaningful as a result of the reheating. The values do not in any way reflect original cosmic cooling conditions.

Another important point is whether Parral deserves its own entry in the catalogs. A comparison with specimens of Morito, point for point, shows that the macro- and microstructures are identical, that the state of preservation (corrosion) is the same, that the chemical composition – within analytical error – is the same, and that the preservation of good fusion crusts is the same. The artificial reheating of Parral distorts the comparison slightly, but the author feels safe enough to conclude that the structures were originally identical.

This leads inevitably to the conclusion that the larger mass near Parral, east of Sierra Madre, from which the specimen reportedly came, is, in fact, the 10 t Morito mass which has been known for generations lying about 25 km east of Parral until 1893 when it was moved to Mexico City. An inspection by the author of the enormous, cone-shaped mass showed that several kilogram-sized fragments have from time to time been chiseled off the rim, so no doubt one of these fragments in due time reached Munich – however, with poor information as to the parent mass.

Parral is, no doubt, a fragment of the medium octahedrite Morito of group IIIA.

## Morradal, Opland, Norway

61°59'N, 7°28'E; 1100 m

Nickel-rich ataxite, D. Scattered  $\alpha$ -needles, 10  $\mu$  wide. HV 205 $\pm$ 15. Anomalous. 19.0% Ni, 1.00% Co, 0.15% P, 47 ppm Ga, 119 ppm Ge, 0.61 ppm Ir.

### HISTORY

A mass of 2.75 kg was found on the surface by Ole Lövstuen in 1892 near Morradal Creek, about 10 km west of Grotli, in Jotunheimen (Brögger 1894). It was fully described with three photographs of the exterior and a map sketch by Cohen & Brögger (1898) who, however, had difficulty in resolving the fine, ataxitic structure and erroneously compared it to Smithland which, as we now know, presents an effectively reheated structure. Also Brezina (1896: 297) stressed the resemblance to Smithland. Cohen (1905: 100, 122, 126) built his very heterogeneous Morradal group around this meteorite. The meteorites included in it had little else in common than a poorly resolvable structure. Berwerth (1918) discussed the structure and gave an early photomicrograph of what he estimated to be similar to Cape of Good Hope, Iquique and Kokomo. Perry (1944: plate 28) gave two good photomicrographs from which it is clearly seen that Morradal is different from the mentioned meteorites and from other

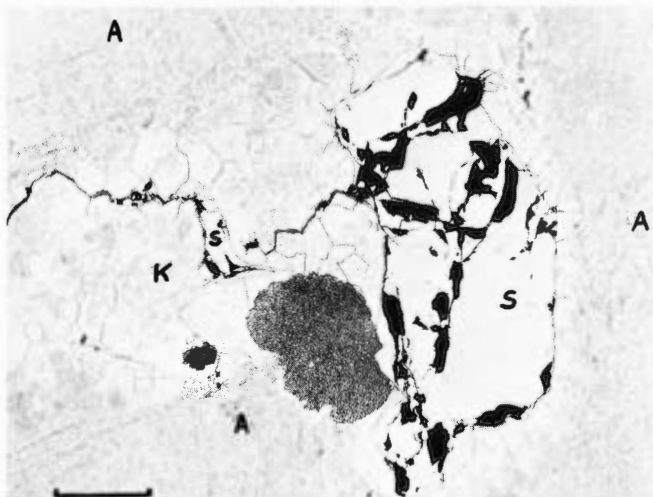


Figure 1172. Morradal (Oslo). A fissured schreibersite crystal (S) in recrystallized kamacite (K). Further out duplex ataxite matrix (A). A shock-melted troilite nodule below center. Etched. Scale bar 300  $\mu$ .

### MORRADAL – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Sjöström in Cohen 1898e	18.77	1.18	0.18		2700	600	600					
Buchwald 1967, unpublished	18.69	0.91	0.12				580		48	106		
Wasson 1969, pers. comm.	19.54								46.3	119	0.61	

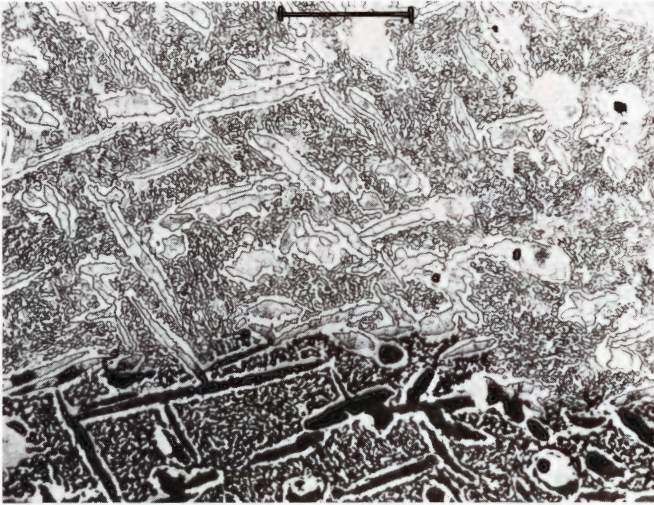
group IVB irons. Vilcek & Wänke (1963) found a cosmic ray exposure age of  $120 \pm 10$  million years by the  $^{36}\text{Ar}/^{36}\text{Cl}$  method, and Chang & Wänke (1969) found  $120 \pm 15$  million years by the  $^{36}\text{Ar}/^{10}\text{Be}$  method. Voshage (1967), on the other hand, found by the  $^{40}\text{K}/^{41}\text{K}$  method 200 million years with a considerable uncertainty. Hintenberger & Wänke (1964) determined the noble gas isotopes. Frigstad (1969) recently included Morradal in his review of all Norwegian meteorites.

#### COLLECTIONS

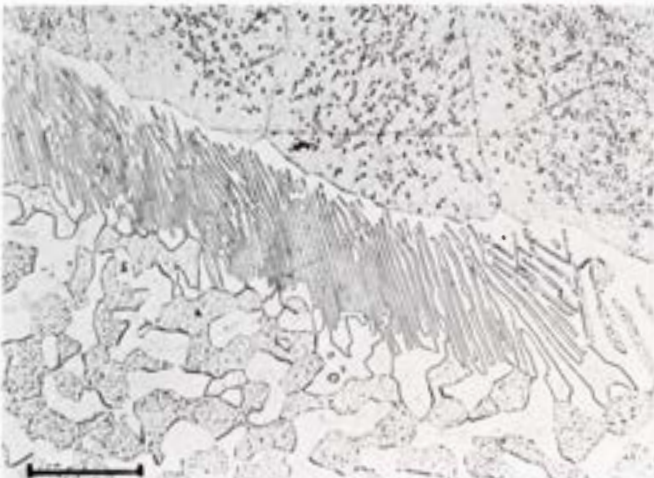
Oslo (1,460, 760 and 9 g), London (92 g), Washington (58 g), Chicago (22 g), Vienna (21 g), Greifswald (14 g).

#### DESCRIPTION

The average dimensions of the lightly rusted mass are approximately  $17 \times 7 \times 6$  cm. It is shaped as a thick

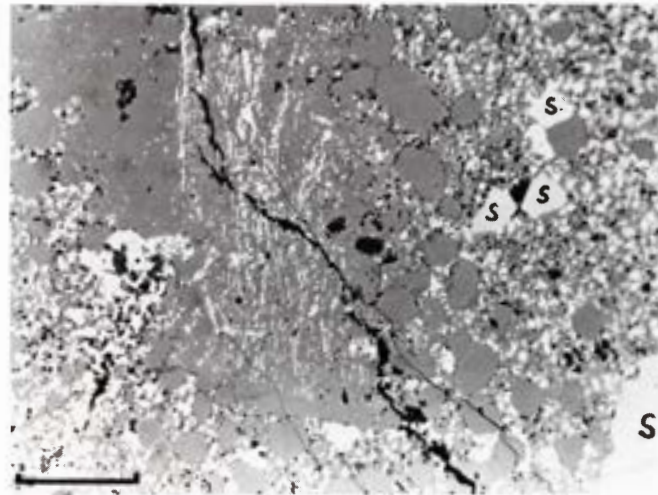


**Figure 1173.** Morradal (Oslo). Heat-affected  $\alpha_2$  zone with numerous small fused schreibersite crystals. Upon solidification a gashole usually formed in each melt (black dot). Terrestrial corrosion has selectively transformed the near-surface  $\alpha$ -phase to limonite. Etched. Scale bar  $200 \mu$ .

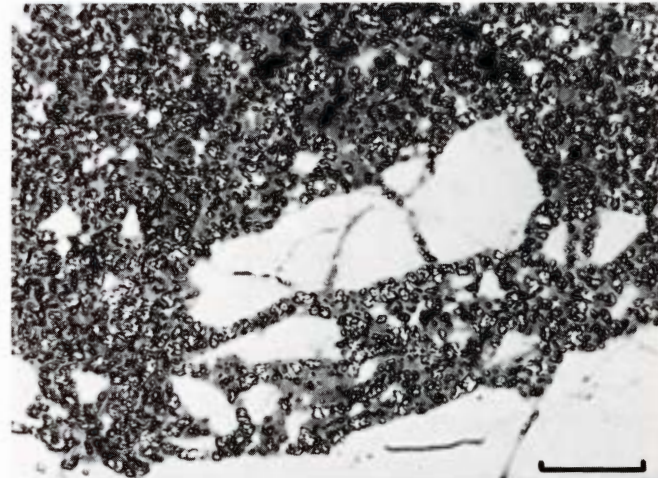


**Figure 1174.** Morradal (Oslo). Above, the edge of a schreibersite-kamacite field. Below, the ataxite matrix which is easily optically resolved. The taenite edge is decomposed to a pearlitic pattern. Etched. Scale bar  $20 \mu$ .

banana, although an irregular one, and it is rather smoothly rounded on all sides except on the concave interior which is covered by shallow depressions, 5-15 mm in diameter. There are several millimeter-sized pits caused by the selective burning out of troilite and schreibersite. A section through the surface discloses remnants of the fusion crust in several places, so the shape of the iron is due to ablation in the atmosphere during stabilized flight and not to corrosion. The fusion crust consists of  $50\text{-}100 \mu$  metallic laminae, overlain by about  $50 \mu$  fused oxides. Under the crust is a 2-3 mm heat-affected zone in which the  $\alpha$ -phase is converted to  $\alpha_2$ , while the phosphides and sulfides are micromelted in the exterior half of the zone. The zone is exceptionally soft, displaying microhardness values of  $140 \pm 10$  in the duplex structure as compared to 205 in the interior. The iron is little corroded, showing selective corrosion of the  $\alpha$ -phase to a depth of 1 mm locally. Chang



**Figure 1175.** Morradal (Oslo). Shock-melted aggregate like that in Figure 1172. Dark gray denotes daubreelite which is shattered and invaded by mobile iron-sulfur eutectics (white). Schreibersite fragments (S) are also present. Polished. Scale bar  $30 \mu$ .

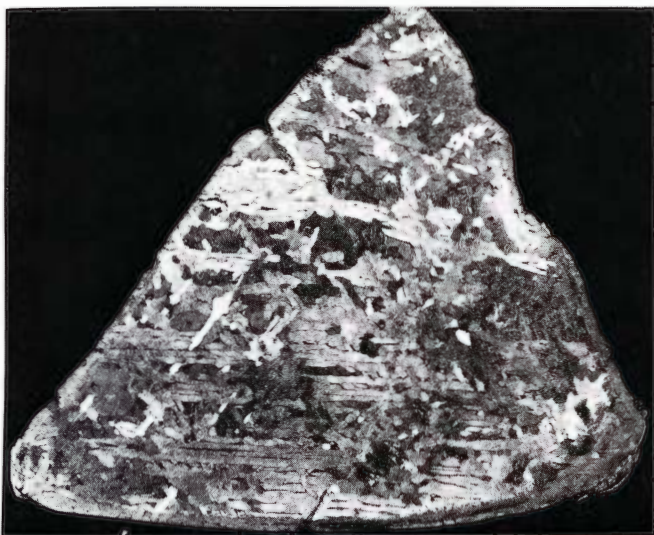


**Figure 1176.** Morradal (Oslo). Shock-melted aggregate where the mobile iron-sulfur eutectic has penetrated the shattered schreibersite (white). Fragments of it are now dispersed through the melt. Etched. Scale bar  $20 \mu$ .

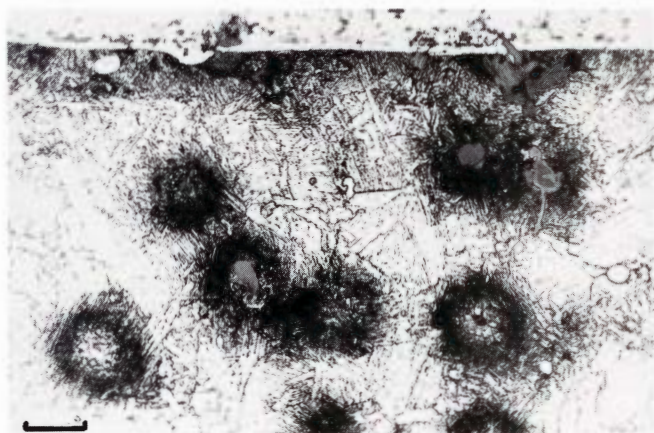




smoothly rounded, triangular pyramid with a few shallow regmaglypts, 1-2 cm in cross section. It is very little corroded. The black, oxidic fusion crust is well-preserved over large areas and shows fine hairlines locally. Where sulfide and phosphide inclusions happen to be situated in the ablation zone, they have burned out leaving 1-2 mm deep scars partly filled with dendritic, two-phased oxide melts. Sections through the ablation zone show that the 20-100  $\mu$  thick fusion crust of oxides is irregularly underlain by numerous layers of dendritic, metallic laminae that wedge out and overlap in unpredictable ways. They have a microhardness of  $425 \pm 25$ . The melt must have had a high carbon activity, since the immediate contacting zone has become carburized significantly to a depth of 20-50  $\mu$  within seconds. The heat-affected  $\alpha_2$  zone covers the whole periphery of etched slices as a 2-4 mm wide, matte rim.



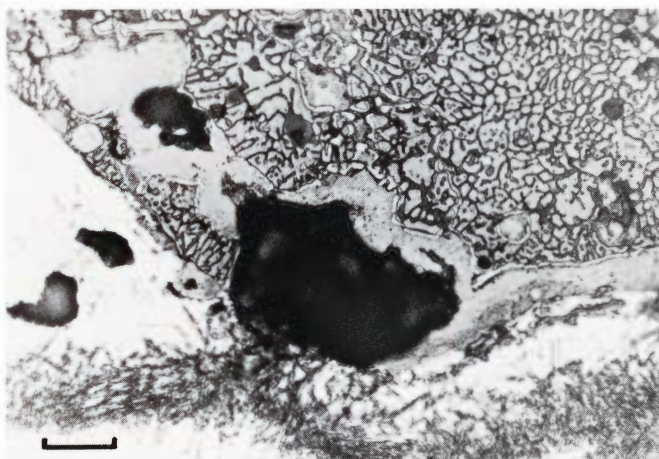
**Figure 1178.** Morrill (Tempe no. 195.1x). An anomalous medium octahedrite with much disseminated graphite. Fusion crust and heat-affected  $\alpha_2$  zone along the whole periphery. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)



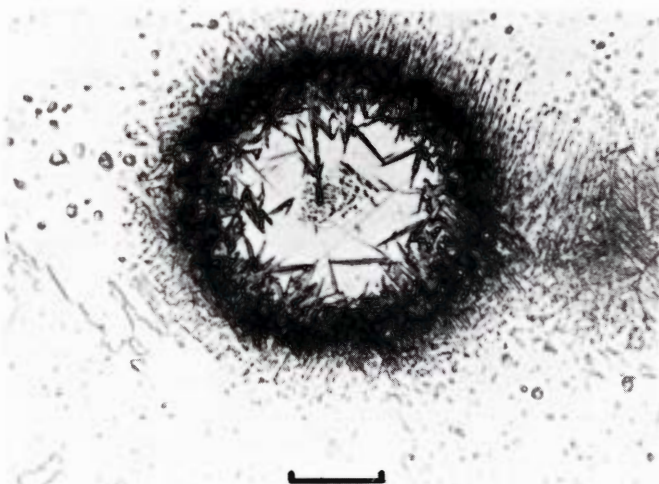
**Figure 1179.** Morrill (Tempe no. 195.1x). Metallic fusion crust (above) and heat-affected A zone with fused phosphides and martensitic-bainitic nests (black) formed from graphite. The surface has been slightly carburized by diffusion of carbon from the superimposed fusion crust. Etched. Scale bar 50  $\mu$ .

Micromelted phosphides are present in the exterior 40-50% of this zone. Numerous martensitic nests, 20-100  $\mu$  in diameter, are also present in the heat-affected zone as will be discussed below; they have a microhardness of  $500 \pm 25$ .

Etched sections display an irregular Widmanstätten pattern of poorly defined, long ( $\frac{l}{w} \sim 30$ ) kamacite lamellae with a width of  $0.90 \pm 0.20$  mm. The kamacite has Neumann bands and numerous grain boundaries which are decorated by 1  $\mu$  phosphides. The interstices between the kamacite lamellae are filled with taenite ribbons and wedges covering about 5% by area; they are unusually dense with a homogeneously high nickel content. Nowhere is the taenite decomposed to comb or net or pearlitic plessite types, which is unusual. All taenite displays, upon etching with nital, a 20  $\mu$  wide brownish-blue zone, presumably due to a high concentration of carbon in solid solution in the taenite. The microhardness is  $300 \pm 20$ . A hardness track



**Figure 1180.** Morrill (Tempe no. 195.1x) Fusion crust of iron oxides, with shrinkage cavities (black). Heat-affected  $\alpha_2$  zone below. Etched. Scale bar 20  $\mu$ .

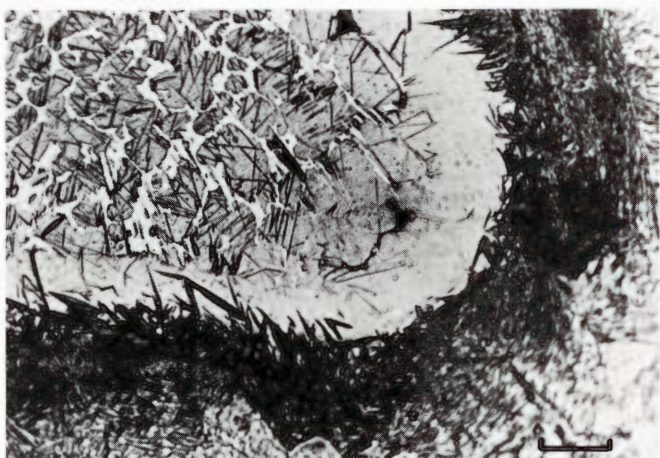


**Figure 1181.** Morrill. Detail of Figure 1179. A graphite flake was dissolved in the high temperature austenite phase and gave, upon flash cooling, rise to various structures. At center, ledeburite followed by retained austenite with scattered martensite needles and by a bainitic black mantle. The peculiar development is due to imperfect homogenization with steep carbon gradients from center to the periphery. Etched. Scale bar 20  $\mu$ .

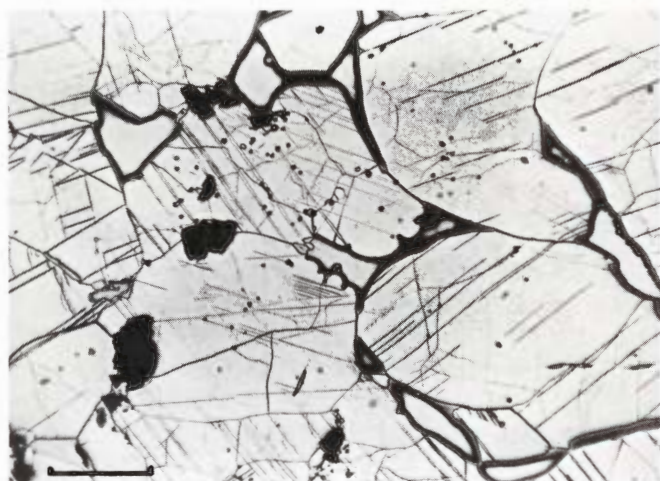
through the kamacite perpendicular to the ablated surface is of type II, with  $190 \pm 10$  in the  $\alpha_2$  zone, a minimum of 160 in the transition zone, and an interior value of  $193 \pm 10$ .

Schreibersite occurs as skeleton crystals, that reach a size of  $15 \times 1$  or  $8 \times 1.5$  mm with a microhardness of  $900 \pm 50$ . It is further common as  $30$ - $100 \mu$  wide grain boundary precipitates, while rhabdites proper were not observed.

Morrill's characteristic feature, almost unknown in other irons, is the large number of graphite crystals dispersed through the matrix. It is not difficult to find fields where they occur with a frequency of 80 per  $\text{mm}^2$ , and higher concentrations do occur. They seem to occur in all phases: kamacite, taenite, schreibersite and troilite; so they were probably very early precipitates in the homogeneous austenite. They appear to have cubic outlines,  $10$ - $30 \mu$  in diameter, and are mostly seen as triangles and hexagons in the sections. They are thus an unusually fine form of



**Figure 1182.** Morrill (Tempe no. 195.1x). In a different part of the heat-affected zone a phosphide-graphite aggregate was dissolved and partly fused. The present structure is steadite, with retained austenite and dark bainitic zones. Similar structures are present in Arispe and Canyon Diablo fragments. Etched. Scale bar  $20 \mu$ .



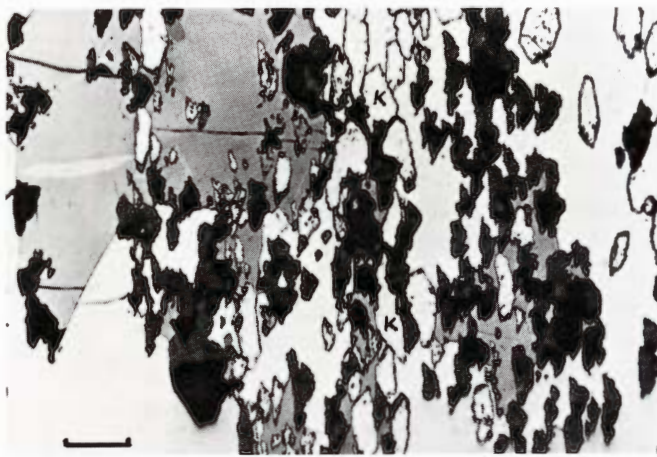
**Figure 1183.** Morrill (Tempe no. 195.1x). Anomalous plessite fields in polycrystalline kamacite with Neumann bands. Graphite (black) occurs as aggregates with schreibersite and troilite and as scattered arrow-shaped crystals in both kamacite and taenite. Etched. Scale bar  $400 \mu$ .

cliftonite. They are often associated with small wedges and crescents of phosphide – which fact is particularly clearly seen in the heat-affected rim zone. Here, part of the graphite dissolved in the austenite and created martensitic-bainitic nests of larger dimensions than they themselves had. In other places where the sudden flash of heat was able to melt the carbon-loaded austenite, before carbon could diffuse too far out, the melt solidified to ledeburitic eutectics enveloped in retained austenite and martensite-bainite. In still other places the associated phosphide assisted in creating steadite eutectics, the typical ternary or quaternary eutectics of Fe, Ni, P and C. Similar developments from Santa Rosa and Arispe were briefly mentioned by Buchwald & Wasson (1968) but have otherwise not been reported.

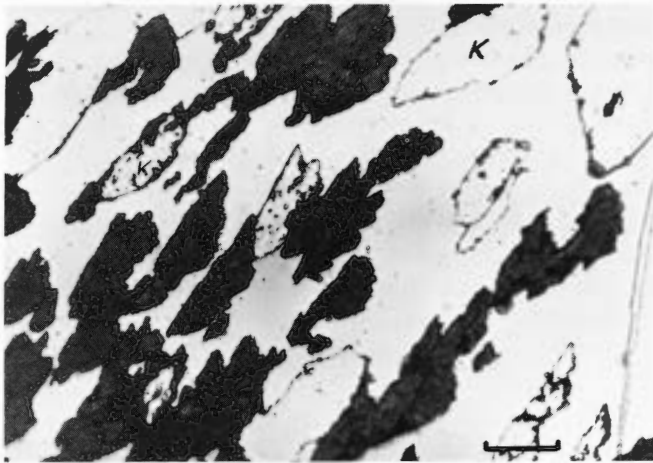
Graphite is also present as a  $2$  mm solid nodule and as intricate intergrowths with schreibersite, troilite and kamacite, surrounded by a  $1$ - $3$  mm thick rim of swathing kamacite. The troilite blebs are  $0.1$ - $1$  mm across, monocrystalline, but with a few lenticular twins, indicating some



**Figure 1184.** Morrill (Tempe no. 195.1x). A dense plessite field with cloudy taenite edges. Graphite crystals (black) occur within kamacite, taenite and plessite. Etched. Scale bar  $200 \mu$ .



**Figure 1185.** Morrill (Tempe no. 195.1x). Arrow-shaped graphite crystals occur in both troilite (twinned, to the left) and schreibersite (white). The graphite is apparently flaky and is easily torn out on polishing, leaving kamacite windows (K) in the minerals. Etched. Slightly crossed polars. Scale bar  $50 \mu$ .



**Figure 1186.** Morrill (Tempe no. 195.1x). Arrow-shaped graphite flakes in kamacite; a Neumann band at the extreme right. The graphite has in many places (K) been torn out by polishing. Etched. Scale bar 20  $\mu$ .

slight deformation. The well developed troilite-graphite nodules with rims of schreibersite plus cohenite so common in other group I irons are not present in Morrill.

Morrill is structurally anomalous and has no immediate relatives – except perhaps Pine River. The main structure and the minerals, particularly the graphite, do indicate that it is also related to, e.g., Kendall County, Mertzson, Santa Rosa and Toluca; and the trace element analysis by Wasson points in the same direction, but Morrill has certainly had its own, independent story. The enigmatic development and distribution of the graphite deserve further study. It may be compared to that of Waterville, Kendall County and Mundrabilla.

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

87 g slice (no. 1195, 7 x 4 x 0.5 cm)

### Mount Ayliff, Cape Province, South Africa

30°48'S, 29°23'E

Coarse octahedrite, Og. Bandwidth 1.6±0.4 mm. Neumann bands. HV 215±15.

Group I. 7.76% Ni, 0.12% P, 70 ppm Ga, 250 ppm Ge, 1.8 ppm Ir.

#### MOUNT AYLIFF – SELECTED CHEMICAL ANALYSES

The carbon was reported as “carbonaceous” matter. The nickel determinations are widely apart. Since Prior’s cobalt value is almost certainly 40% too high, it is probable that part of his nickel was not completely separated from cobalt. Still, the values of say 6.8 and 7.7% Ni disagree more than is easily explained. Since the bandwidth and microstructure of Mount Ayliff correspond rather well to

#### HISTORY

A mass of not over 30 pounds (13.6 kg) was found before 1907 in the vicinity of Mount Ayliff, in Griqualand East. It was presented to the Kaffrarian Museum in King Williams Town with very little background information and was described by Prior (1921) who also presented two photomicrographs. Ebert & Wänke (1957) measured the amounts of the noble gases. Stoenner & Zähringer (1958) deduced a cosmogenic age of  $6.9 \times 10^9$  years from their studies of the  $^{41}\text{K}/^{40}\text{Ar}$  isotopes. Their data were discussed by Marshall (1962) and by Rancitelli & Fisher (1968) who concluded that ages measured by this technique were doubtful, reflecting mainly potassium loss by terrestrial corrosion rather than an event in the meteorite formation. Honda & Arnold (1964) measured various nuclides, as  $^{36}\text{Cl}$  and  $^{59}\text{Ni}$ , the presence of which showed Mount Ayliff to have a rather low terrestrial age, maybe similar to the order of Grant. Voshage (1967) estimated, by his  $^{40}\text{K}/^{41}\text{K}$  method, a cosmic ray exposure age of  $920 \pm 70$  million years.

#### COLLECTIONS

King Williams Town, South Africa (787 g and 683 g), Cape Town (1 kg), Bonn (546 g), Paris (400 g), Heidelberg Max-Planck-Institute (about 0.5 kg), New York (207 g), London (189 g), Washington (95 g). Evidently one half of the original mass can not be accounted for.

#### DESCRIPTION

An examination of the cast which is preserved in the South African Museum reveals that the meteorite, before it was divided, was of a flat, lenticular shape with the dimensions 22 x 20 x 10 cm, corresponding to a weight of 13-14 kg. It is not clear whether the original fusion crust and heat-affected zones are preserved; on the U.S.N.M. specimen they are lost to corrosion. Many specimens in collections are irregular, broken pieces, displaying hammered and chiseled surfaces. Some samples, such as those in King Williams Town, show high-temperature iron oxides, suggesting artificial reheating to above 800° C.

The etched section displays a coarse Widmanstätten structure of bulky, short ( $l/w \sim 10$ ) kamacite lamellae with a width of  $1.6 \pm 0.4$  mm. The kamacite has numerous Neumann bands. Subgrain boundaries decorated with 1-3  $\mu$  phosphide rods are plentiful, and the hardness is  $215 \pm 15$ ,

Bischtübe, Ogallala and Toluca, which contain 7.50% Ni or more, the present author prefers Wasson’s analytical values. It appears, however, that able analysts working with group I irons again and again wind up with wide ranges in nickel; compare, e.g., Bischtübe, Canyon Diablo, Magura and Toluca. So there must be a real variation which is also reflected in the heterogeneous structure of large sections.

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Prior 1921	6.59	0.69	0.12	5100								
Wasson 1970a	7.76								70	250	1.8	

indicating a mild lattice damage. Taenite and plessite cover 5-10% by area. The taenite etches to brownish-bluish tones, indicating a significant amount of carbon in solid solution. The interiors of the wider taenite wedges are martensitic (HV 400±50) or pearlitic (HV 255±15), with rhythmically alternating lamellae of 0.5  $\mu$  wide taenite and kamacite. Some comb plessite and acicular plessite occur also, normally associated with the cohenite. The taenite rims and ribbons are relatively soft (HV 300±20).

Schreibersite is present as a few skeleton crystals, up to 25 x 5 x 2 mm in size, but it is also common as 20-100  $\mu$  wide grain boundary precipitates. No large rhabdites were observed, but numerous small ones, less than 1  $\mu$  across, appear to be distributed through the kamacite.

Cohenite is dominant in form of 0.5 mm wide and 2-8 mm long, smoothly rounded bodies, that are aligned along the kamacite lamellae. They have, as usual, small "windows" of kamacite and taenite and also irregular 50-100  $\mu$  wide inclusions and rims of schreibersite. Both cohenite and schreibersite appear to be monocrystalline. The cohenite displays minute oxidized cracks, but no decomposition to graphite has begun.

Troilite is present as 1-10 mm nodules, which may have centers or margins of graphite. Irregular 1-4 mm wide rims of schreibersite and cohenite envelop the larger bodies.

Mount Ayliff is a typical cohenite-rich coarse octahedrite, closely related to, e.g., Bischtübe and Toluca, and in a broader sense also to Magura and Wichita County, as noted by Prior. Chemically, it belongs to group I. It comes from the same general region as Matatiele and Kokstad but has nothing to do with them.

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

95 g slice (no. 1556, 9 x 6 x 0.2 cm, figured by Prior 1921: plate 4, figure 2)

### Mount Dooling, North Yilgarn, Western Australia

29°27'S, 119°43'E

Coarse octahedrite, Og. 1-2 mm wide lamellae and 1-2 cm equiaxial grains. Neumann bands. Partly recrystallized. HV 158±12.

Anomalous. 6.22% Ni, 0.46% Co, 0.27% P, 56 ppm Ga, 239 ppm Ge, 1.2 ppm Ir.

#### HISTORY

A mass of about 31.5 kg was found in 1909 by A.P. Brophy when he was prospecting for gold 8 km east of Mount Dooling and near Lake Giles (Simpson 1912).

According to Hodge-Smith (1939: 21), the coordinates are those given above, a little different from the original ones by Simpson. The whole mass and two fragments, broken off by Brophy and totaling about 500 g, were acquired by the Geological Survey of Western Australia where they were described with photomicrographs and an analysis by Simpson (1912). A brief review of the literature and analyses was given, with two figures, by McCall & de Laeter (1965).

The Mount Dooling case has recently been reexamined by De Laeter et al. (1972) on occasion of finding a 1.5 kg Gosnell's Iron in 1960. Although separated from the original finding place by 400 km, the authors convincingly demonstrated, with analytical and structural data, that the new fragment belongs to Mount Dooling, but at an unknown occasion was broken from it and was transported almost to the coast-town of Perth.

#### COLLECTIONS

31 kg main mass in Perth; Sydney (411 g), Los Angeles (100 g), Canberra (20 g). Gosnell's Iron is almost entirely in private hands.

#### DESCRIPTION

The original mass has, estimating from the pictures given by Simpson (1912) and McCall & de Laeter (1965), the overall dimensions of 35 x 20 x 15 cm. It is lenticular and flat with deep pittings on both sides. On one side they are 2-4 cm in diameter, on the opposite 4-8 cm in diameter. At one point the meteorite is perforated by a hole about 2 cm in diameter. The mass is covered with a 0.1-0.3 mm thick coating of terrestrial oxides from weathering. Simpson (1912) observed some fusion crust and concluded that the sculpture was due to sculpturing in the atmosphere. In this study no fusion crust and no heat-affected  $\alpha_2$  zone could be found, but the examined sections may, of course, come from more severely corroded parts of the mass. It appears, however, that the recovered transition zone with a hardness as low as 135±3 is preserved, and that, therefore, only 2-3 mm of the surface is lost.

Etched sections display a mixed structure of very coarse, almost equiaxial grains, 5-20 mm across, and indistinct Widmanstätten patterns. Somewhat similar structures may be found in parts of Union County, Santa Rosa, Sikhote-Alin and Sandia Mountains.

The reason for the Widmanstätten pattern being so ill-defined is the almost entire absence of taenite and

#### MOUNT DOOLING – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Simpson 1912	5.96	0.64	0.27	tr.	900		200					
Lovering et al. 1957	6.41	0.48				28	166		61	193		
Wasson 1970a	6.26								51.5	234	1.2	
Rosman 1972								12				
De Laeter et al. 1972	6.1	0.45							60	233		
ibid. Gosnell's Iron	6.1	0.45							51	249		

plissite fields. This is in harmony with the nickel analyses, showing 6.2% on the average. Whatever there is left of a former Widmanstätten structure is mainly seen because the 1-2 mm wide and 5-15 mm long lamellae are oriented differently from the adjacent lamellae and, therefore, display a differently oriented sheen. Locally, a trifle coarse plissite may be observed, and in other places the remnants of a former plissite field may be suspected because vermicular, 10-20  $\mu$  wide phosphide bodies still lie scattered along the outlines.

During the last stages of Widmanstätten precipitation some favorably oriented kamacite grains may be assumed to have started growing at the expense of their neighbors. In due time the mixed structure, as we now see it, developed. Schreibersite was precipitated as 10-25  $\mu$  wide veinlets in the grain boundaries; and numerous sharp-faceted rhabdite prisms, 2-15  $\mu$  across, were precipitated in the grain interiors. A shock event created a profusion of Neumann bands through the whole mass.

Troilite is present with daubreelite. A 15 x 5 mm nodule with (the remnants of) several 10-100  $\mu$  wide daubreelite lamellae was observed. In the metallic matrix are also scattered 20-100  $\mu$  daubreelite blebs without associated troilite. Further, numerous tiny, hard plates, 15 x 2 x 0.5  $\mu$  of the chromium nitride, carlsbergite, are present.

While the structural elements discussed above may be called primary and correspond somewhat to those of Union County, New Baltimore and Nocolche, Mount Dooling also shows significant secondary structures, namely, recrystallization of the metal and shock-melting of the troilite. The recrystallization has led to the formation of new ferrite grains, which are 50-300  $\mu$  in diameter and cover 5-10% of the etched sections. They occur singly in the junctions of Neumann bands, or they cluster around the larger phosphide and sulfide inclusions. They are further common along original high angle grain boundaries. Similar recrystallization occurs, e.g., in Indian Valley and Seelägen, as shown by Buchwald (1967a: 43, 59); but here in Mount Dooling the concentric growth rings within each new grain were not observed. The rhabdites inside the recrystallized grains have rounded faces, contrary to those outside. Most of the recrystallized grains display a second generation of Neumann bands, easily distinguishable from the first generation by their smaller width, general sharp contours and differing directions. They are of a younger age than the first generation and may have been produced during the atmospheric, violent deceleration. The kamacite has a hardness of 158 $\pm$ 12.

In the unrecrystallized parts of the mass the heat input was only sufficient to recover the metal and to decorate both sides of the Neumann bands with numerous 0.5-1  $\mu$  phosphides. Also, several bands became separated from the grain boundaries and broke down into shorter band units, evidently a way of restoring partial order to the crystal lattice without leading to recrystallization. The hardness is

not significantly different from the visibly recrystallized areas.

The troilite nodules are shock-melted and have dissolved part of the surrounding metal as well as part of the daubreelite. The resulting eutectic mixtures consist of 1-2  $\mu$  sulfide and metal grains in which 2-4  $\mu$  droplets of daubreelite are dispersed, and the hardness is 215 $\pm$ 15. The daubreelite bars show heavy attacks from the sulfur-metal melt and are subdivided in cells and fragments by the invading melt.

The partial recrystallization of the metal and the shock melting of the troilite probably took place at the same cosmic shock event.

Mount Dooling appears to be a coarse octahedrite with a primary structure similar to that of Union County, Seelägen or Sikhote-Alin. In its chemical composition it is anomalous, but slightly related to both groups I and IIB. It is interesting because of its well-developed shock effects and the associated recovery and recrystallization. The original classification as a medium octahedrite by Simpson, which was accepted in most later catalogs, e.g., McCall & de Laeter (1965) and Hey (1966), should be abandoned.

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**Mount Edith, Ashburton District,  
Western Australia**  
22°30'S, 116°10'E

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Medium octahedrite, Om. Bandwidth 0.80 $\pm$ 0.10 mm.  $\epsilon$ -structure. HV 325 $\pm$ 15.

Group IIB. 9.36% Ni, 0.61% Co, about 0.8% P, 20 ppm Ga, 37 ppm Ge, 0.016 ppm Ir.

**HISTORY**

A mass of 161 kg was found in April 1913 by James Bourke of Boolaloo Station. It was buried in an upright position in schists, but five inches of the thinnest edge showed above the surface. The locality was about 80 miles southeast of Onslow, near Mount Edith, which has the coordinates given above. The mass was acquired by the Foote Mineral Company of Philadelphia, and was described by Foote (1914), who presented figures of the exterior and of large, etched sections. The mass was cut and is well distributed. Hodge-Smith (1939: plate 7) gave a figure of the exterior; the caption erroneously states that the picture figures mass No. 2. Wasson & Kimberlin (1967) presented a photomicrograph. A second mass, of 165 kg, was found a year later by Mr. Bourke, about two miles from the site of the first discovered mass. It was analyzed by Simpson (1916: 140) and figured by McCall & de Laeter (1965: plate 2), but has otherwise not been described nor been cut and distributed.

Goldstein (1965) examined the detailed composition of the kamacite phase with respect to nickel, while Reed (1967; 1969) examined the phosphorus distribution. Reed found 7.2% Ni and 0.095% P in solid solution in the kamacite and correctly noted that the experimental values of Buchwald (1966) were somewhat high at 350-500°C, evidently because even long laboratory heat-treatment

(three to six months) at these temperatures fail to achieve the degree of equilibrium that is present in many iron meteorites.

Begemann (1965) determined the amount of occluded noble gases in both the metal and the troilite and noted systematic differences between the content of the two phases. It was estimated that the troilite had lost very substantial amounts of the  $^3\text{He}$  and Ne gases. Schultz & Hintenberger (1967) reexamined Mount Edith and confirmed Begemann's data for the metal phase. Voshage (1967) estimated a  $^{40}\text{K}/^{41}\text{K}$  cosmic ray exposure age of  $710 \pm 65$  million years.

#### COLLECTIONS

Perth (the whole mass of No. 2; 6.70 kg of No. 1), Harvard (30.5 kg), Chicago (9.86 kg), New York (8.75 kg), Philadelphia (8.10 kg), Ottawa (5.40 kg), Budapest (2.74 kg), Vatican (1.54 kg), Washington (1.50 kg), London (1.00 kg), Amherst (1.00 kg), Utrecht (about 600 g), Tübingen (440 g), Paris (257 g), Yale (205 g), Sydney (145 g).

#### DESCRIPTION

Mass No. 1 of 161 kg measured about 60 x 45 x 18 cm and was somewhat shield-shaped. Mass No. 2 of 165 kg measured about 40 x 35 x 30 cm and was a more angular mass. Judging from the figure given by McCall & de Laeter (1965: plate 2) mass No. 2 is far better preserved than No. 1. It has smoothly rounded regmaglypts, 3-4 cm in diameter, and it shows two or three pits, each one inch in size where troilite nodules burned out in the atmosphere. It also shows characteristic, 1 mm wide and rather long straight grooves which resemble chisel marks but actually originated from schreibersite lamellae that partly burned out in the atmosphere.

Mass No. 1 is weathered. The sections and pieces studied by me had no fusion crust and no heat-affected  $\alpha_2$  zones. The high hardness of the interior was found unaltered to the very rim, which suggests that on the average more than five millimeters have been lost by terrestrial exposure. The conclusion is supported by the fact that several troilite nodules appear flush with the surface, a situation which is only possible when several millimeters of the adjacent and covering metal have been

removed by corrosion. Foote (1914) observed that one side had four hemispherical pits, 12-15 cm across and 7-8 cm deep. One of these almost perforated the mass, leaving only a 2 cm thick wall; the bottom was covered by 1 cm thick crusts of terrestrial oxides. The controversial, hemispherical cavities, present on many iron meteorites, may have different origins, but at least in the case of Mount Edith it appears certain that they are mainly a result of terrestrial corrosion. It is interesting to note that mass No. 2 is so little corroded. The mass ought to be cut and examined in order to verify that it really belongs with mass No. 1. If a modern structural and analytical study confirms that it is a Mount Edith specimen, we have here a fine example of differential weathering. Mass No. 2 was probably only slightly buried, if at all, while No. 1 was buried in the schists and evidently more exposed to the ground water.

Etched sections display a medium Widmanstätten structure of straight, long ( $l/w \sim 20$ ) kamacite lamellae with a width of  $0.80 \pm 0.10$  mm. The kamacite has subboundaries decorated with  $1 \mu$  phosphides. It is of the crosshatched  $\epsilon$ -variety due to shock above 130 k bar, and it is very hard,  $325 \pm 15$ . No annealing has occurred at all.

Taenite and plessite cover about 40% by area, as comb and net plessite and as martensitic fields. A typical field will show a yellow or slightly tarnished taenite rim (HV  $340 \pm 10$ ) which is followed by light-etching acicular martensite (HV  $440 \pm 25$ ). Then follow brown-etching martensite developed as plates parallel to the bulk Widmanstätten structure (HV  $420 \pm 30$ ) and dark-etching unresolvable duplex structures (HV  $390 \pm 30$ ). The central parts of the fields are frequently developed as net plessite with 10-25  $\mu$  masks of ferrite and 2-5  $\mu$  taenite and schreibersite blebs in the grain boundaries. These easily resolvable structures have the same hardness as the adjacent kamacite lamellae.

Schreibersite is abundant as Brezina lamellae precipitated in dodecahedral planes. The lamellae are up to 75 x 15 x 6 mm in size and are enveloped in 0.8-2.5 mm wide rims of swathing kamacite. They are brecciated and often displaced in successive subparallel steps, each 5-20  $\mu$  wide. Schreibersite is also present as 20-50  $\mu$  wide grain boundary veins and as 2-40  $\mu$  blebs inside the plessite. Rhabdites are absent. The bulk phosphorus content is estimated to be about 0.8%.

#### MOUNT EDITH - SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Whitfield in Foote 1914	9.45	0.63	0.32	170	50		130					
Simpson 1916*	9.18	0.66	0.50									
Lovering et al. 1957	9.40	0.55				< 1	147		15	33		
Smales et al. 1967					< 5	5.6	147	1.2	20.5	34		
Crocket 1972											0.15	2.1
Scott et al. 1973	9.4								20.1	37.5	0.016	

\*This analysis was on weathered fragments of No. 2. The others were performed on material from No. 1. No significant differences occur, except that the iridium values differ by a factor of ten.



**Figure 1187.** Mount Edith (U.S.N.M. no. 528). A medium octahedrite of group IIIB. Numerous Brezina lamellae of schreibersite with swathing kamacite rims. Troilite nodules with phosphate crystals and with rims of schreibersite and kamacite. Deep-etched. Scale bar 20  $\mu$ m. S.I. neg. M-371.

Troilite is common as nodules that range from 5-40  $\mu$ m in diameter; some of them have prongs of metal intruding from the matrix. The troilite is monocrystalline but shows fine twinning from slight plastic deformation. It is surrounded by 0.5-1 mm thick schreibersite rims, which in turn have nucleated 1-2 mm wide rims of swathing kamacite. In the troilite there are several 0.05-2 mm grayish-blue, angular phosphate crystals which, upon etching, acquire pitted grooved surfaces.

Reichenbach lamellae are very common, typically forming almost straight lamellae 15 x 10 x 0.02  $\mu$ m in size. They occur with a frequency of about one per six  $\text{cm}^2$ , a density which is rather high. They are enveloped by asymmetric 0.5-2 mm wide rims of swathing kamacite and apparently occur in three directions only, probably parallel to the cubic planes (100) $\gamma$ . The lamellae are surprisingly often corroded, and it is difficult with certainty to determine their components. It seems, however, that 10-20  $\mu$ m thick troilite lamellae were the major component,

and that irregular, 5-500  $\mu$ m wide schreibersite crystals later precipitated upon them. Indications are that a grayish-blue, lamellar, isotropic mineral, only 2-10  $\mu$ m thick, is also present. This may be a phosphate similar to the phosphates dispersed in the troilite nodules, but X-ray diffraction and/or electron microprobe examination is necessary to identify it and to distinguish it from the associated, very similar looking corrosion products. The minerals of the lamellae were severely brecciated by the  $\epsilon$ -forming shock event, and the fissures never closed completely again which is why the terrestrial water found such easy access to the lamellae. The mineral fragments were altered and cemented together by limonitic products.

Mount Edith is a shock-hardened medium octahedrite which is closely related to Augustinovka, Grant and View Hill. Chemically, it is a typical group IIIB iron. Due to its large number of troilite and schreibersite inclusions and to the Reichenbach lamellae, that all served as nuclei for the formation of swathing kamacite, the Widmanstätten

