

Figure 1188. Mount Joy (Tempe no. 299.48). This 8.5 kg slice is sufficiently large for the extremely coarse Widmanstätten structure to be appreciated. Deep-etched. Scale bar approximately 5 cm.

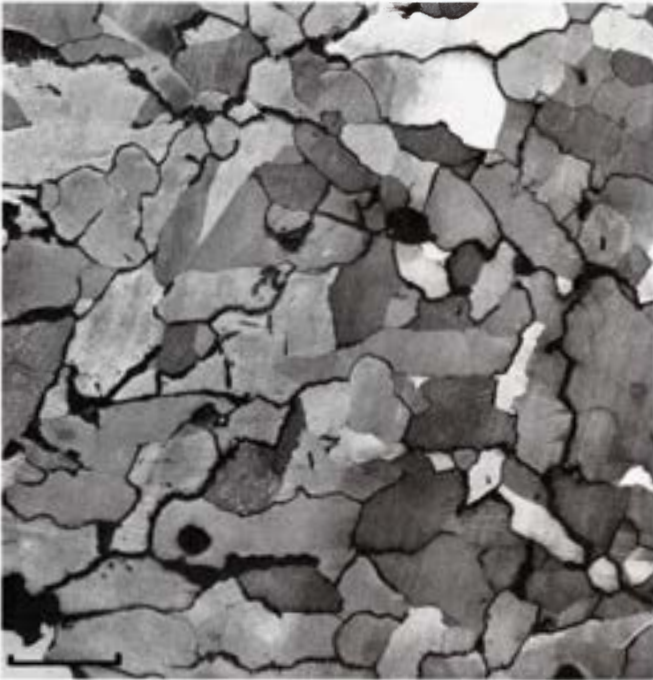


Figure 1189. Mount Joy. Detail of Figure 1188. Schreibersite is mainly present as veins in the grain boundaries. Characteristic is the terrestrial corrosion (black) that has weakened the cohesion across the grain boundaries, particularly where shock-fissured schreibersite was present. Deep-etched. Scale bar 30 mm.

that have been carefully washed with water and alcohol and which are kept in a dry and warm atmosphere (silicagel-cabinet at 20-25°C) appear to survive the best.

Etched sections display a very coarse Widmanstätten structure of irregular, bulky ($\frac{W}{\lambda} \sim 2-5$) kamacite lamellae with a width of 5-15 mm. Secondary grain growth of the ferrite phase has led to the elimination of many of the straight octahedral boundaries, so the Widmanstätten structure is only ascertained on larger sections, like the Vienna main mass and Tempe No. 299.48. Individual kamacite lamellae which have become detached by grain boundary

corrosion are flat fingers, typically 6 x 2 x 1 cm in dimensions. Their surface is indented by the crossing, finger-like neighbor crystals of the Widmanstätten structure. The grain boundaries are usually filled with schreibersite precipitates that range from 10 μ to 0.5 mm in thickness. The adjacent metallic matrix is depleted in phosphorus and nickel. The grain boundaries are susceptible to corrosion both on account of the chemical potential existing between the nickel-rich interior and the nickel-poor boundary metal and on account of the brittle inclusions, which most likely were fissured during preterrestrial and atmospheric shock events. Circulating ground water has found easily accessible highways along these fractured inclusions.

The kamacite lamellae evidently grew to the size we see today before the bulk of the phosphorus precipitated in the boundaries and thereby pinned them. Only rarely is schreibersite found inside the kamacite. The microhardness of the kamacite ranges from 140 to 170, depending mainly upon the crystallographic orientation of the particular crystal examined. Individual grains may be measured with a precision of 1-2%, depending somewhat upon the size and distribution of the rhabdites. Neumann bands are common. Subboundaries are common, but, since they are relatively free of precipitates and no significant composition gradient exists, they are only little corroded.

Plessite and taenite occur with one field per 10 cm² as 0.1-1 mm degenerated comb plessite fields or as short ribbons, 100 μ wide, with a martensitic interior. The presence of the gamma phase is surprising in view of the low bulk nickel value of 5.7%.

The boundary precipitates of schreibersite are monocrystalline, but brecciated, and their surroundings are heavily limonitized to many centimeters depth. Rhabdites occur everywhere in the interior as 5-15 μ thick prisms. A large local rhabdite attains the size of 1 mm, while some grains display only minute rhabdites, 1-2 μ across.

Troilite occurs as scattered 5-15 mm nodules and as 20 x 2 mm stringers. The troilite contains about 10% daubreelite in form of 0.1-4 mm wide, parallel daubreelite lamellae, and the whole aggregate has served as a nucleation site for a 0.1-0.3 mm wide rim of schreibersite. The smaller sulfide bodies, about 100 μ across, may be composed of stacks of alternating, 1-5 μ wide lamellae of troilite and daubreelite. The troilite is decomposed to a polycrystalline aggregate of 1-3 μ grains, possibly because of shock recrystallization. Whether the larger inclusions also have polycrystalline troilite could not be determined on the available, deep-etched sections. Cohen (1900b: 388) reported chromite in the residue after dissolving 300 g turnings, but the mineral is evidently rare.

Mount Joy is a coarsest octahedrite, formed by normal Widmanstätten precipitation in a large parent austenite crystal but developed to an extremely coarse array because of the low nickel content. Its closest relatives are, structurally and chemically, Navajo, El Burro, Sikhote-Alin and the Smithsonian Iron.

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

- 129 g endpiece (no. 160, 5.5 x 4 x 1 cm; gift from the finder 1891)
 1,231 g corner (no. 356, 11 x 8 x 3.5 cm)
 957 g part slice (no. 356, 10 x 5.3 x 4 cm)
 265 g slice (no. 2941, 9 x 6 x 1 cm)
 250 g fragments and detached, finger-shaped kamacite grains (nos. 213, 356, 1665, 2940)

Mount Magnet, Central Division, Western Australia

28°2'S, 117°58'E; 400 m

Polycrystalline, plessitic octahedrite, Opl. α -spindles $15 \pm 5 \mu$ wide. HV 195 ± 15 .

Anomalous. 14.6% Ni, 0.54% Co, about 0.15% P, 7.4 ppm Ga, 5.1 ppm Ge, 0.015 ppm Ir.

HISTORY

Two pieces, which fitted exactly together, were found by J. Connors in 1916 about 10 km east of Mount Magnet, towards Paynesville in the Murchison Goldfields. Both fragments, of a total weight of 16.5 kg (36 1/2 pounds), were donated to the Western Australian Museum, where they were described by Simpson, with a photograph of the exterior (1927). Axon (1961) presented a photomicrograph and Lovering & Parry (1962) examined the various phases during their thermomagnetic study. McCall & DeLaeter (1965) reviewed the literature and analyses and gave a photograph of the exterior and of an etched slice. Reed (1969) found 7.2% Ni and 690 ppm P in solid solution in the kamacite.

COLLECTIONS

Perth (about 15 kg main masses), Sydney (719 g), London (461 g), Canberra (370 g), Washington (100 g), New York (52 g).

DESCRIPTION

When the two pieces were fitted together, the mass was shaped as a sickle or a crane hook, with an interior aperture about 12 cm in diameter, and an overall diameter of about 30 cm. If stretched the approximate dimensions would be 70 x 10 x 6 cm (Simpson 1927). The shape is rather unique, approaching the ring form of one of the Tucson irons, but on a lesser scale. It evidently broke into two fragments when hitting the ground, or possibly terrestrial

corrosion along the schreibersite-loaded grain boundaries finished the job along a fissure created during atmospheric deceleration. The mass is irregularly marked with 2-5 cm shallow depressions, which are at least partially modified by corrosion. A 0.5-1 mm thick crust of terrestrial oxides covers the whole surface. No fusion crust and no heat-affected zones were observed.

Etched sections reveal an ataxitic structure, interrupted only by winding, 0.1-0.5 mm wide ribbons of schreibersite and occasional millimeter-sized clusters of silicates, troilite and schreibersite. It appears that the iron, at high temperature, was composed of several austenite crystals, each 2-5 cm across, and that an appreciable amount of schreibersite segregated in the grain boundaries. Upon cooling, each austenite grain independently developed a microscopic Widmanstätten structure, consisting of a dense basket-weave of kamacite needles in a fine-grained, duplex matrix. The needles are $15 \pm 5 \mu$ wide and 100-200 μ long, and they must have developed by homogeneous nucleation and growth. In addition, there is a significant amount of α -phase developed around the numerous, evenly scattered small schreibersite blebs. These occur with a frequency of about 40 per mm^2 , and are generally 2-25 μ in size. The associated kamacite forms irregular, bulky 10-50 μ wide rims around the schreibersite. Kamacite as a whole constitutes about 15% by area. The matrix in between is a duplex $\alpha + \gamma$ mixture, almost phosphide free, where oriented 0.5-2 μ wide taenite ribbons are situated in a veined kamacite. The matrix is rather easy to dissolve optically; martensitic structures appear to be absent. The microhardness (100 g) of the matrix, averaging over several $\alpha + \gamma$ units is 195 ± 15 .

Schreibersite occurs, besides in the forms mentioned above, as scattered skeleton crystals, typically 3 x 1 or 2 x 0.2 mm in size. They are monocrystalline. The bulk phosphorus content is estimated to be about 0.15%.

Troilite is present as 0.1-1 mm monocrystalline grains which frequently, however, show lenticular deformation twins. Troilite is often the nucleus for a 0.5-1 mm rim of schreibersite.

Unidentified silicate grains, 50-200 μ in diameter, occur singly or in clusters, some of them having trapped angular 2-10 μ troilite beads. Often, the silicates have nucleated a troilite rim and this, in turn, a schreibersite rim. Around the aggregate a 300-500 μ wide kamacite rim has

MOUNT MAGNET – SELECTED CHEMICAL ANALYSES

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957	14.72	0.54				< 1	162		6.4	< 1		
Smales et al. 1967						5.3	179	< 1	7.3	5.0		
Wasson & Schaudy 1971	14.56								7.53	5.26	0.012	
Crocket 1972											0.017	3.0
De Laeter 1972									7.3			
Rosman 1972								< 0.4				

grown. This has subboundaries decorated with $1\ \mu$ phosphides.

Cohenite was reported by Simpson (1927) but apparently erroneously.

Corrosion has followed the former austenite boundaries and the larger inclusions where there is a significant composition gradient. The kamacite needles are selectively attacked, too, but rarely to more than a depth of one millimeter.

Mount Magnet is structurally unique, although it bears a certain resemblance to Linville, Warburton Range and Tawallah Valley. Chemically, it is an anomalous iron, too.

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

100 g slice (no. 1746, 6 x 2 x 1 cm)

Mount Ouray, Colorado, U.S.A.

38°25'N, 106°13'W; 3,100 m

Medium octahedrite, Om. Bandwidth 0.80 ± 0.15 mm. Neumann bands. HV 265 ± 20 .

Group IID. 10.1% Ni, about 0.4% P, 71 ppm Ga, 84 ppm Ge, 15 ppm Ir.

HISTORY

A mass of about 900 g – or rather 1 kg – was found by a prospector in 1898 (see below) on the northeast slope

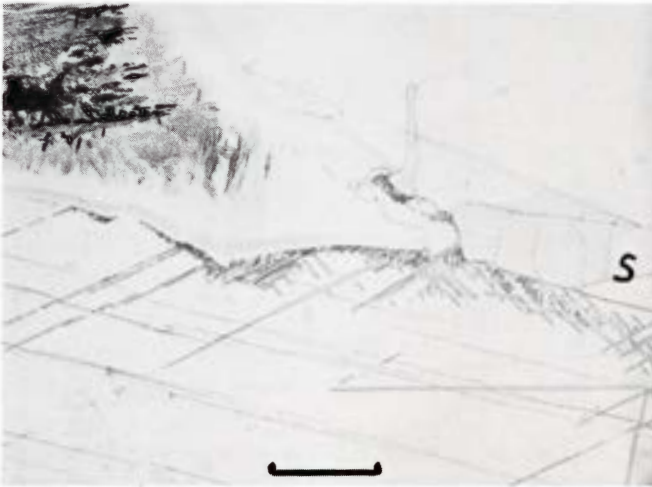


Figure 1190. Mount Ouray (Harvard no. 462A). A plessite field with cloudy taenite rims and martensitic transition zones. Schreibersite (S) and dense clusters of Neumann bands. Etched. Scale bar 100 μ .

of Mount Ouray, in Chaffee County. It was donated in 1905 to Harvard University where it was described by Palache (1926a).

COLLECTIONS

Harvard (626 g main mass), London (146 g), Washington (84 g), Denver (about 60 g). New York (53 g). This last specimen (A.M.N.H. no. 33) has, since Farrington's days, been mislabeled Ute Pass but was, in the present study, found to be identical in every respect to authentic Mount Ouray specimens, a conclusion which was confirmed by Dr. Manson after a check of his archives in the American Museum. The specimen had been cut from the main mass and was acquired from the dealer S.A. Chase in 1896 (sic!) long before the remaining mass came to Harvard.

DESCRIPTION

The meteorite is a well rounded sphere with the overall dimensions of 7 x 7 x 6 cm. It was rather smooth originally but is now slightly roughened by terrestrial corrosion that has covered the mass by a 0.1-0.5 mm thick limonitic crust. Sections show, however, that the fusion crust is preserved locally in protected depressions. The fusion crust is composed of 50-100 μ thick dendritic oxides, underlain by several laminae – up to 0.8 mm thick – of cellular-dendritic metal. The cells are only 2-5 μ across and the

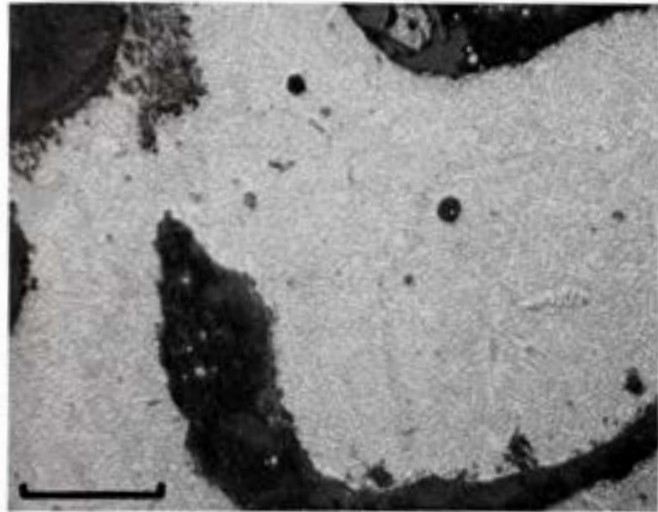


Figure 1191. Mount Ouray (Harvard no. 462A). Metallic fusion crust of cellular-dendritic material, rich in phosphides. Inclusions of fused globular iron oxides. Etched. Scale bar 50 μ .

MOUNT OURAY – SELECTED CHEMICAL ANALYSES

Palache (1926a) believed that lawrencite was present, since rust oozed up along the cracks upon a polished surface. This is, however, rather an indication that chloride-

bearing ground water had penetrated along the fissures during a prolonged terrestrial exposure.

Reference	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Wasson 1972, pers. comm.	10.13								71.4	84.3	15	

dendrite armspacing is about $1\ \mu$, indicative of a rapid solidification. In the fused metal are numerous, often hollow, spherules of dendritic oxides. They range in size from $3\text{--}50\ \mu$, and represent the trapped, immiscible oxide melts from the next but last stages of the entry through the atmosphere. Locally, the larger phosphides have melted to a depth of $2\text{--}3\ \text{mm}$ and have been removed – sucked out – leaving the cavity to be partially filled with another melt at a later stage.

The heat-affected α_2 zone is $3\text{--}4\ \text{mm}$ thick where it is best preserved. In places corrosion has removed $25\text{--}50\%$ of it. Micromelted phosphides are present in the exterior 50% of it.

Etched sections display a medium Widmanstätten pattern of straight, long ($W \sim 30$) kamacite lamellae with a width of $0.80 \pm 0.15\ \mu\text{m}$. The kamacite has subboundaries decorated with a few $1\text{--}5\ \mu$ phosphides. It shows a mixture of Neumann bands and hatched ϵ -structure with a microhardness of 265 ± 20 . A hardness trace across a full, $5\ \text{cm}$ wide, slice from rim to rim showed a symmetrical variation from 180 ± 15 in the rim zones, through a minimum of 145 to an interior level of 265 ± 20 (hardness curve type I). The interior level was reached $5\text{--}6\ \text{mm}$ below the surface and clearly shows that the interior was not reheated above $400^\circ\ \text{C}$ during the atmospheric passage. The hardness of about 265 ($100\ \text{g}$ Vickers) shows that the kamacite previously was appreciably hardened by shock-deformation, in harmony with the observed mixture of Neumann bands and ϵ -structure.

Taenite and plessite cover about 40% by area, both as comb and net plessite and as dense fields with duplex or martensitic interiors. A completely developed field has an exterior taenite rim ($\text{HV } 340 \pm 20$), spotted due to carbon in solid solution (except in the reheated rim zone, where the carbon has diffused away), followed by a martensitic zone ($\text{HV } 430 \pm 30$), which then merges into a duplex $\alpha + \gamma$ interior ($\text{HV } 300 \pm 40$). The martensite platelets are parallel

to the overall octahedral structure, as is the interior duplex structure. In the kamacite lamellae adjacent to martensitic and dark-etching duplex fields are numerous densely spaced slipplanes which have become decorated with almost submicroscopic particles, probably phosphides; compare Thule.

Schreibersite occurs as monocrystalline skeleton crystals and rosettes which frequently have precipitated around a $0.3\text{--}1\ \text{mm}$ nucleus of troilite. The schreibersite ranges from 0.5 to $10 \times 1\ \text{mm}$ in size and has a hardness of 925 ± 25 . It further occurs as $25\text{--}100\ \mu$ wide grain boundary precipitates and $5\text{--}20\ \mu$ irregular blebs inside the plessite. Rhabdites, $0.5\text{--}3\ \mu$ across, are present in varying amounts. The phosphides are brecciated and penetrated by terrestrial corrosion products. The bulk phosphorus content of Mount Ouray is estimated to be about 0.40% .

Troilite is present as $0.1\text{--}1\ \text{mm}$ nodules, sometimes angular. They are composed of numerous individuals, each $20\text{--}50\ \mu$ across. Daubreelite occupies about 15% by area as parallel, $5\text{--}100\ \mu$ wide lamellae. Both the enveloping schreibersite and the daubreelite are frequently severely brecciated; and $100\text{--}500\ \mu$ wide veins, filled with crushed fragments of phosphides and sulfides in a matrix of terrestrial oxides, extend several millimeters from the inclusions. It appears that the meteorite arrived with open, breccia-filled fissures which later were cemented by corrosion products. Corrosion penetrates the mass to the center along $2\text{--}500\ \mu$ wide, limonite-filled veins; and near the surface the α -phase of the plessite is selectively attacked.

Mount Ouray structurally resembles the phosphide-rich medium octahedrites, such as Carbo, Elbogen and Needles. Wasson (1969) interestingly finds that its Ga-Ge-Ir values are similar to these irons and includes Mount Ouray in the chemical group IID.

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

84 g slice (no. 777, $5 \times 4 \times 0.5\ \text{cm}$)

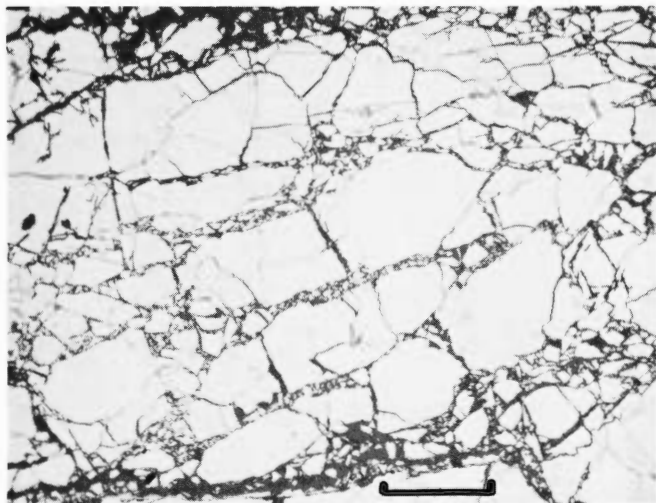


Figure 1192A. Mount Ouray (Harvard no. 462A). Schreibersite skeleton crystal which is brecciated but recemented by terrestrial limonite (black). Etched. Scale bar $100\ \mu$.

Mount Sir Charles. See Supplement

Mount Stirling. See Youndegin

Mount Tabby. See Duchesne

Mrirt Morocco

$33^\circ 8' \text{N}; 5^\circ 34' \text{W}$

A mass of $79.9\ \text{kg}$ was found in 1937 or 1938. It contains 8.08% Ni and is in the Museum of the Morocco Geological Survey (C. Gaudeloy & J. Lucas, Notes Service Geologique Maroc 1955: Volume 12: 162; Meteoritical Bulletin No. 40, 1967).

Mundrabilla, Nullarbor Plain, Western Australia
30°50'S, 127°30'E

Polycrystalline medium octahedrite with abundant troilite and graphite. Bandwidth 0.55 ± 0.10 mm. Neumann bands. HV 175 ± 10 .

Anomalous, judging from the structure. 7.8% Ni, 0.26% P, about 1% C, about 8% S, 66 ppm Ga, 208 ppm Ge, 0.84 ppm Ir.

Synonyms: Premier Downs and Loongana Station.

HISTORY

A mass of 112 g was discovered in 1911 by Mr. H. Kent, a member of the Transcontinental Railway Survey Party, on the part of the Nullarbor Plain known as Premier Downs. Shortly afterwards, Mr. Kent discovered another small mass, of 116 g, in the vicinity. Both meteorites were acquired by the Geological Survey Museum in Perth, where they were thoroughly described under the name Premier Downs by Simpson (1912) and Simpson & Bowley (1914). They were found to be complete individual masses of a peculiar knuckle-bone shape; the structure was that of a medium octahedrite with unusual concentrations of graphite.

A third mass, of 99 g, was reported later (Simpson 1938); since it was assumed to belong to the two first found, it was not further examined.

In 1965 McCall & De Laeter (38 and plate 14) reported a fourth mass, of 108 g, under the name Loongana Station (Hey 1966: 277). The finder reported it to be part of a very large mass, but no further particulars became available until Wilson & Cooney (1967) reported the discovery of two huge masses, estimated to weigh 4-6 tons and 10-12 tons, respectively. Unfortunately, these authors coined a new – and third – name for this fall, Mundrabilla, neglecting the fact that Simpson (1912; 1938) and Simpson & Bowley (1914) had already dealt with the occurrence very efficiently on the basis of the small samples available at a relatively early stage. Wilson & Cooney noted that the masses had



Figure 1192B. Mundrabilla. The 16 ton mass as exhibited in Perth. Note the soil line and the numerous centimeter-sized cavities in the surface.

previously been known to a rabbit trapper, presumably the Mr. Harrison mentioned by McCall & Cleverly (1970: table 1), but they were apparently not aware of other small masses having been found and described on several previous occasions. At about the same time two additional small samples, of 66.5 g and 178 g, were discovered by still other parties; see the table.

Wilson & Cooney (1967) described the circumstances of finding and the geological environment and gave photographs of the two large masses in situ. Ramdohr & El Goresy (1971) accepted “Mundrabilla” as a new meteorite

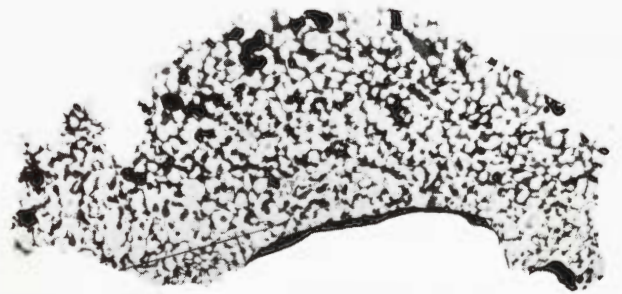


Figure 1192C. Mundrabilla (Heidelberg, Max-Planck-Institut für Kernphysik). From the 6.1 ton mass eight or nine slabs were cut in 1973-1974. They were each 4-5 cm thick and weighed 100-250 kg. The wire-cutting technique, first used by the author when dividing Cape York (see page 418), was also used here. The picture shows slab No. M 2, which has a maximum width of 130 cm. White is metal, black is troilite. The continuous black rim below are corrosion products, situated on the underside, as found. Courtesy Professor Paul Ramdohr.

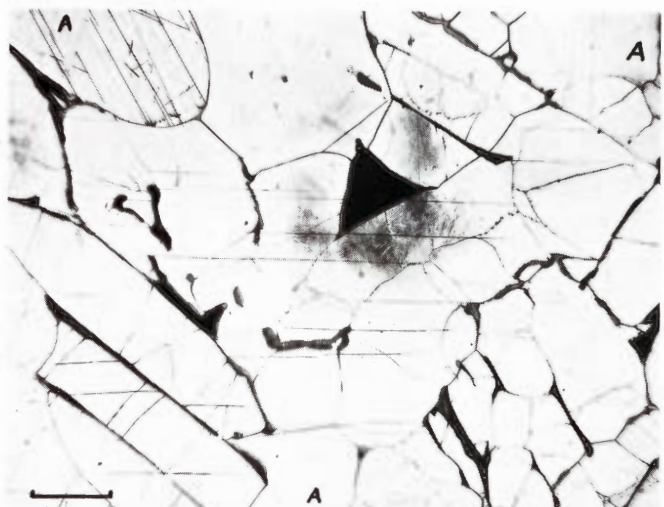


Figure 1192D. Mundrabilla (Los Angeles). Three precursor taenite grains once met near the center. Each of the three grains decomposed in a Widmanstätten pattern, mutually unrelated, and the grain boundaries were washed out by swathing kamacite. Etched. Scale bar 500 μ .

and presented an elaborate description with photomicrographs and electron probe analyses of the nonmetallic minerals.

In view of the fact that the knuckle-bone shaped small masses represent the material from the main masses very well, and considering that they were well described, with analyses, as early as 1912, it appears unfortunate that the name Premier Downs has been overruled by the name Mundrabilla. The latter was introduced without a literature survey or reference to earlier work on iron meteorites from that particular region. Moreover, the name Premier Downs would have been preferable because it conveys the idea that the individuals of this meteorite shower have been found, not at a particular site like Mundrabilla, but over a large area of the Nullarbor Plain, extending at least 70 km in an east-west direction. The large masses were discovered near the eastern extremity of this area which indicates that the body penetrated the atmosphere from a westerly direction and shed the small masses during flight. On the other hand, little field work has as yet been done, and all recovered specimens come from a zone within 10 km distance of the Trans-Australian railway.

The Nullarbor Plain is a porous limestone plateau of Miocene age with little or no drainage features. The annual rainfall is less than 250 mm, and there is no surface water. Slight depressions in the limestone are filled with clay-like soil; the two large masses were slightly buried in this soil and only 180 m apart. The front page color picture in

Sky & Telescope (February 1967) gives an excellent impression of the largest mass in situ and of the arid plain which is sparsely covered with low shrubs. Fragmentary iron shale was present under the masses and in a stellate pattern up to a distance of several hundred feet around the masses. Smaller fragments of iron and iron shale were reported to be distributed along an east to west band for at least a mile. No evidence of cratering was discovered (Wilson & Cooney 1967).

COLLECTIONS

Perth (16 t Mundrabilla mass; 103 g of Premier Downs); Copenhagen (3.5 kg), Perth, Government Chemical Laboratories (108 g Loongana Station). The 6.1 t mass is presently (1972) in the Max-Planck-Institut, Heidelberg, where preparations are underway for cutting it.

DESCRIPTION

The dimensions of the masses are unreported. From published photographs it is estimated that the large mass, weighing 15-16 t (Ramdohr & El Goresy 1971), measures 170 x 150 x 125 cm in three perpendicular directions, while the smaller 6.1 t mass measures 130 x 130 x 90 cm. Wilson & Cooney (1967) saw evidence of fragmentation on the larger mass in a sharp, angular, vertical face which matched in size and shape a similar sharp face on the smaller mass. This appears plausible since the two masses

Reported as	Found by	Date	Coordinates		Weight	References
			°S	°E		
Premier Downs	H. Kent	1911	30°57'	127°15'- 127°22'	112 g	{ Simpson 1912: analysis, figures McCall & De Laeter, 1965: plate 7 Simpson & Bowley 1914: analysis, figures Simpson 1938
Premier Downs II	H. Kent	1911			99 g	
Premier Downs III	A. Ewing	before 1918			108 g	
Loongana Station	Mr. Harrison ?	1962 ?	30°47'	127°33'	66.5 g	} McCall & De Laeter 1965: plate 14 McCall & Cleverly 1970: table 1
Loongana Station West	W.H. Butler	1967	30°57'	126°58'	178 g	
Mundrabilla	W.A. Crowle	1965	30°45'	127°30'	16 ton	} Wilson & Cooney 1967 McCall & Cleverly 1970: table 1 Ramdohr & El Goresy 1971: figures
Mundrabilla	Wilson & Cooney	1966	30°47'	127°33'	6 ton	
Mundrabilla	Wilson & Cooney	1966				

MUNDRABILLA - SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Simpson 1912	7.46	0.64	0.21	tr.	400							
Simpson & Bowley 1914	7.58	0.89	0.31	14100			1300					
De Laeter 1972; Rosman 1972	7.78							15.5	65.1	167		
Wasson 1972, pers. comm.	7.72								66.2	208	0.84	

were found at a distance of only 180 m from each other. They probably separated very late during the atmospheric flight.

The small fragments are typically of 100 g weight and of knuckle-bone shape, indicating that they are composed of two, three or four precursor taenite crystals, each 2-4 cm across. See, e.g., the figures presented by Simpson (1912) and McCall & De Laeter (1965).

Polished and etched sections are of a very unusual structure. The meteorite is composed of a very large number of precursor taenite crystals, each 2-5 cm across. The crystals are apparently randomly oriented and often separated by 0.5-5 mm wide troilite veins. Many grain boundaries are marked only by irregular 0.05-1 mm wide schreibersite-loaded boundaries. In a few cases indistinct straight austenite twin boundaries were noted. At the junction of many taenite crystals, the troilite-graphite aggregates may assume sausage or globular shapes and increase to 4 x 4, 15 x 8 or 10 x 5 mm in size. In many cases the troilite attains sizes of 20 x 30 mm.

Each original taenite crystal is decomposed in a Widmanstätten pattern. However, this is very indistinct. The kamacite lamellae are straight and they often occur in bundles ($\frac{1}{W} \sim 20$); the bandwidth may cautiously be estimated to be 0.55 ± 0.10 mm. Late kamacite grain growth has partly obscured previously straight octahedral boundaries and contributed to the indistinct appearance. Large kamacite areas are to be found along the high temperature $\gamma - \gamma$ boundaries. The α -phase evidently precipitated very early here during the primary cooling and grew to 0.7-2 mm wide rims of swathing kamacite.

The kamacite is very rich in dominating subboundaries which are decorated by numerous less than 1μ rhabdites. Neumann bands are common. They are narrow, 1μ , where they pass kamacite with densely spaced microrhabdites, but wide, about 5-10 μ , where they pass clear, precipitate-free kamacite. The Neumann bands — which are mechanical

twins — evidently postdated the precipitates and were severely hindered in their propagation (by dislocation movements) by the smaller precipitates. It is commonly believed (see, e.g., Ramdohr & El Goresy 1971) that Neumann bands are produced upon impact with the ground, but this is generally not the case. The Neumann bands of Mundrabilla are slightly annealed and, thereby, straightened and have locally disappeared. The annealing occurred in space and predated the impact. Thus, the majority of Neumann bands, here and elsewhere, were caused by preatmospheric shocks, often of ancient date.

The hardness of the kamacite is 175 ± 10 . It increases to at least 250 in near-surface parts which are visibly deformed due to the atmospheric breakup. In such parts the Neumann bands are twisted; there are lenticular deformation bands; and the included minerals, particularly the schreibersite crystals, are shear-displaced and rotated according to the prevailing strains.

Taenite and plessite cover 15-20% by area. An unusually large proportion occurs as open-meshed comb and net

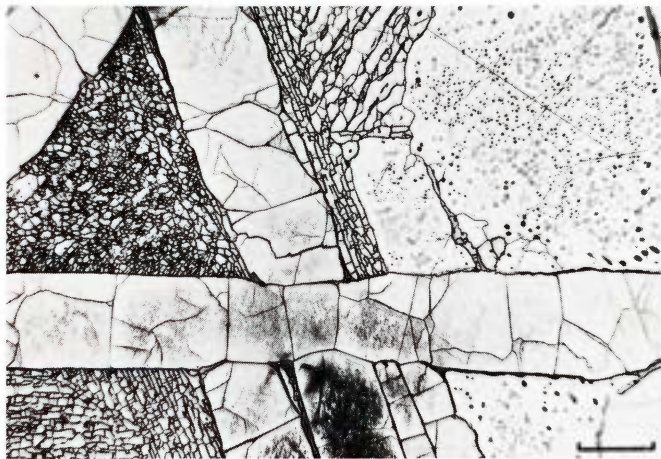


Figure 1192F. Mundrabilla (Copenhagen). A grain with distinct Widmanstätten structure. To the right, open-meshed plessite field with spheroidized taenite particles. Numerous subboundaries in the kamacite. Etched. Scale bar 500 μ .

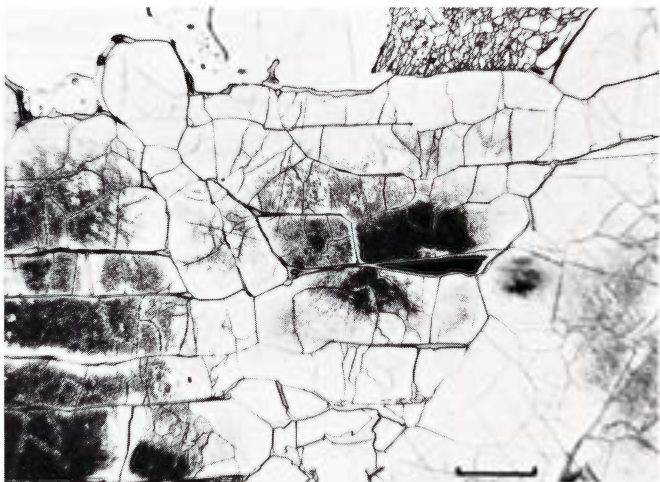


Figure 1192E. Mundrabilla (Copenhagen). Indistinct Widmanstätten structure within a precursor taenite grain. Black taenite surrounded by kamacite with decorated slipplanes. Schreibersite veinlets. Etched. Scale bar 500 μ .

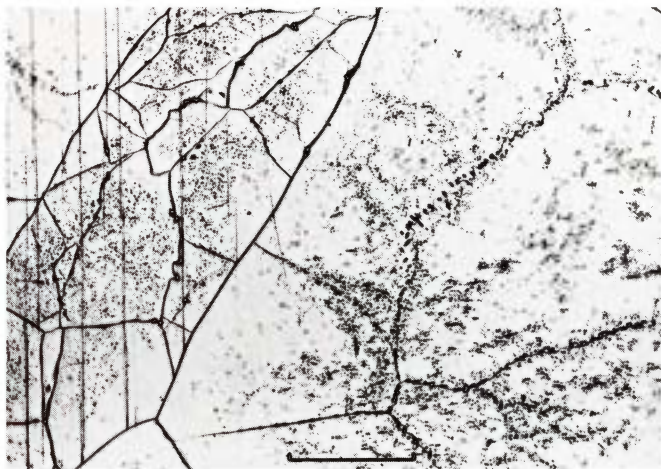


Figure 1192G. Mundrabilla (Copenhagen). Kamacite with decorated subboundaries. Indistinct vertical Neumann bands. Etched. Scale bar 200 μ .

plessite fields and as narrow taenite lamellae (HV 235±20). The taenite of many fields is spheroidized to 5-25 μ particles. Small wedges, 0.1-0.3 mm wide, displaying martensitic or dark-etching unresolvable $\alpha + \gamma$ interiors are also common. A typical field will exhibit a narrow, cloudy taenite border (HV 235±20), immediately followed by a light-etching martensitic transition zone (HV 290±20). Next follows dark-etching duplex structures (HV 260±20); and the interior may be easily resolvable $\alpha + \gamma$ structures with low hardnesses (HV 170±20). The dark-etching duplex wedges are often surrounded by kamacite lamellae with conspicuous slipplanes. In appearance they are similar to those of Thule, Trenton and others, and the explanation for them is the same, i.e., the kamacite was strained by the $\gamma \rightarrow \alpha_2$ transformation within the wedges, and the ensuing slipplanes later became decorated by less than 0.4 μ precipitates. The hardness is low, 168±5.

Schreibersite is common, as large $\gamma - \gamma$ grain boundary crystals, as 0.5-1.0 mm discontinuous rims on troilite, and as 10-60 μ wide $\alpha - \alpha$ grain boundary precipitates. It is also present as 5-50 μ vermicular bodies inside the open-meshed plessite fields, substituting for taenite of similar sizes. It further occurs in a peculiar development with graphite; see below. The schreibersite is monocrystalline, or composed of a few large crystals; it is slightly brecciated and shear-displaced by preatmospheric shocks. Terrestrial corrosion products penetrate the breccias and have recemented them incompletely. The hardness is rather low for schreibersite, 800±35. Rhabdites are rare, but microrhabdites, usually less than 0.5 μ across, occur in profusion in some kamacite grains.

Troilite occurs mainly in the $\gamma - \gamma$ grain boundaries as 2-10 mm veins and lenses, apparently always with a monocrystalline nucleus of rather pure troilite. The only other mineral here is daubreelite which is segregated as 1-100 μ wide platelets parallel to (0001) of the troilite. The rim zones are graphite-troilite aggregates in which accessory 10-100 μ grains of sphalerite and alabandite occur. The

outer rim may be 0.5 mm wide, almost pure graphite, developed as triangular or cliftonitic crystals. Similar 20-50 μ graphite crystals are also found in the kamacite immediately outside the troilite aggregates. Some chromite crystals also occur.

Smaller troilite nodules, 20-100 μ across, occur in the kamacite or associated with schreibersite or sphalerite. The nodules are usually composed of alternating 1-2 μ wide lamellae of troilite and daubreelite. Daubreelite also occurs in a pure form in kamacite, usually smaller than 60 μ across. The total troilite content is estimated to range from 25 to 35 volume percent, i.e., the bulk sulfur content is about 8%, the highest for any known large iron meteorite.

The sphalerite and alabandite occurrences were analyzed by Ramdohr & El Goresy (1971). Typical sphalerite contained 38.3% Zn, 28.2% Fe, 0.3% Mn and 34.3% S. Typical alabandite contained 59% Mn, 4% Fe, 0.46% Zn and 36.6% S. The daubreelite was found to contain 36% Cr, 19% Fe, 1.0% Mn, 0.01-1% Zn and 44% S.

These authors also detected a single rutile grain with the following preliminary microprobe analysis: 95% TiO₂, 1.1% Cr₂O₃, 2.9% NbO₂, 0.7% FeO, < 0.025% V₂O₃ and 0.028% MgO.

Finally, they reported the following average troilite composition: 63% Fe, 0.5% Cr, 0.3% Zn and 36.2% S.

Cohenite was reported by Simpson (1914), but this was apparently a misinterpretation of schreibersite.

Graphite is irregularly distributed. In some sections of several square centimeters it is entirely absent; in others it forms "cirrus-cloud-like" (Simpson & Bowley 1914) precipitates in the kamacite, covering areas of up to 15 x 20 mm. The individual graphite crystals are of widely varying size and shape, 5 μ - 1 mm, being spiky, needle-like, cliftonitic or lamellar. The graphite constitutes about 20% by area of these spongy intergrowths; 70% is granular kamacite (30-500 μ across); 4% is almost isotropic schreibersite and 1% is globular or lamellar taenite. There are no indications

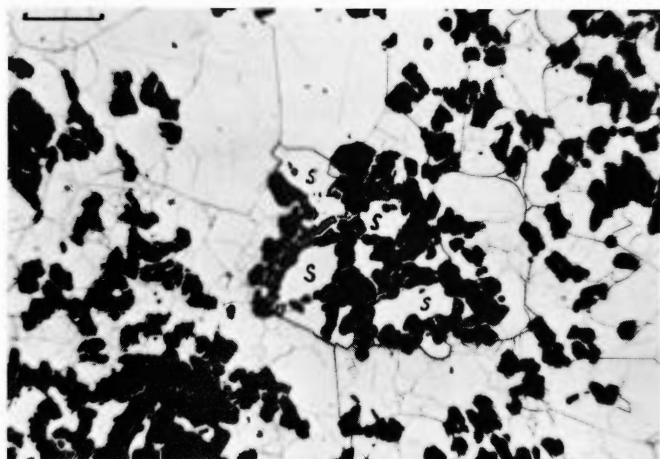


Figure 1192H. Mundrabilla (Copenhagen). Cluster of angular and rounded graphite crystals within schreibersite (S) and kamacite with subboundaries. Etched. Scale bar 500 μ .

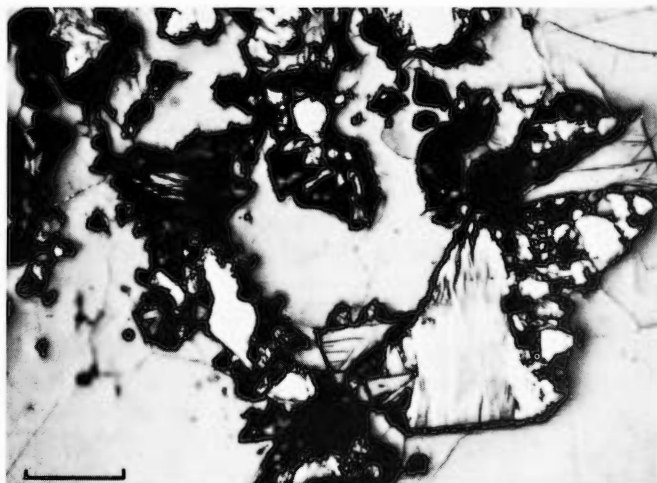


Figure 1192L. Mundrabilla (Copenhagen). Angular, acicular and triangular graphite crystals (black, gray and white) within kamacite. Etched. Crossed polars. Scale bar 100 μ .

that the graphite is substituting for a preexisting, now decomposed, carbide. It appears rather that the graphite has precipitated directly from the taenite at about the same time as the schreibersite, thereby creating the weird intergrowths, often visible to the naked eye as fan-shaped aggregates. The graphite morphology should be compared to that of Morrill, Waterville and Kendall County.

A major part of the graphite is developed as bundles of nearly parallel graphite crystals elongated along the *c*-axis. These crystal bundles form columnar units with triangular cross sections, the dimensions often being 1 x 0.1 x 0.05 mm. They show perfect cleavage parallel to (0001), perpendicularly to the long axes of the "three-edged files."

The meteorites of this fall are all corroded, and the fusion crusts have been lost. Occasionally 0.1-0.2 mm wide α_2 zones were disclosed, however. The small masses are partly covered by caliche incrustations. Limonitic laminated crusts up to several millimeters in thickness occur in many places, and the iron-shales in the vicinity also suggest a considerable terrestrial age. It is estimated that on the average 4 mm of the topside has been lost by weathering. The troilite displays pentlandite and chalcopyrite veining, the alabandite is under decomposition to pyrolusite, and the fissures are in general recemented by terrestrial limonite.

The masses, particularly the large ones, exhibit a very unusual exterior on the exposed topsides. The surfaces are knobby with numerous cavities, 1-3 cm across and 1-2 cm deep. The holes indicate missing troilite; whether it burned out in the atmosphere or weathered away during long terrestrial exposure, or, plausibly, a combination of both has produced the effects, is difficult to say. The curious result is a surface which truly indicates the polycrystalline nature of the whole mass, each exposed knob representing individual precursor taenite grains. A somewhat similar appearance is to be found in San Cristobal.

Mundrabilla is a very unusual meteorite which has no immediate relatives except perhaps Waterville. Its metallic and sulfidic phases indicate that it is lightly shocked and annealed. In its polycrystallinity, composition and primary structure it resembles Santa Rosa somewhat, but numerous differences are apparent. In its indistinct Widmanstätten structure it resembles Colomera; but silicates, so typical for Colomera, are apparently scarce in Mundrabilla.

Primary aggregates of inch-sized taenite crystals, separated by troilite melts, are apparently not at all rare but may occur within many groups of iron meteorites. Outstanding examples are N'Goureyima, San Cristobal, Barranca Blanca, Waterville, Soroti, Santa Catharina, Twin City, and Mundrabilla. There are, however, strong indications that these primitive structures mainly occur within the anomalous meteorites, and rarely within the resolved chemical groups II-IV. The polycrystalline metal-sulfide mixtures seem to indicate that the material was produced by compression and a homogenizing sintering from the components and that this initial process was followed by a high temperature grain growth process.

The present study was mainly performed on 250 g slices kindly placed at my disposal by Dr. J.T. Wasson before they were subjected to chemical analysis.

Mungindi, Queensland, Australia

28° 56'S, 148° 57'E; 200 m

Fine octahedrite, Of. Bandwidth 0.40±0.06 mm. Neumann bands, HV 220±15.

Group IIIC. 12.1% Ni, 0.56% Co, about 0.4% P, 19.7 ppm Ga, 22.1 ppm Ge, 0.47 ppm Ir.

HISTORY

Two masses of 28.1 and 23.1 kg were found in 1897 by Louis Troutman. They were lying partially exposed and close together about 5 km north-northeast of Mungindi, in Queensland. Several small pieces were detached before the masses were acquired for the Geological Museum in Sydney where they were briefly mentioned by Card (1897b). Ward (1898) cut and distributed two-thirds of the 28 kg mass and gave a photograph of the exterior and of an etched slice. Other slices were reproduced by Farrington (1903: plate 37), Ward (1904a: plate 2) and Brezina & Cohen (1886-1906: plate 31). A good photograph of the exterior of the 28 kg mass appears in Hodge-Smith (1939: plate 4); although the text states that it pictures the 23 kg mass, this presumably is an error which is clearly seen by comparison with Ward's figure (1898). Lovering & Parry (1962) examined the composition of the phases with the microprobe. Jaeger & Lipschutz (1967b) found the kamacite and the schreibersite to be typically unshocked crystals. Schultz &



Figure 1193. Mungindi (Prague no. 120). A fine octahedrite of group IIIC. Troilite nodules with schreibersite rims and well-preserved exterior surface. Deep-etched. Scale bar 20 mm.

Hintenberger (1967) determined the composition of the occluded, noble gases, while Voshage (1967) by the $^{40}\text{K}/^{41}\text{K}$ method found a cosmic ray exposure age of 820 ± 100 million years. Wasson & Schaudy (1971) included Mungindi in a new, resolved chemical group IHC.

COLLECTIONS

Sydney (10.18 kg of the 28 kg mass, and 9.42 kg of the 23 kg mass), New York (7,300 g), Chicago (2,010 g), Vatican (1,416 g), Vienna (736 g), Washington (573 g), Berlin (546 g), London (368 g), Leningrad (297 g), Prague (293 g), Paris (232 g), Canberra (226 g), Calcutta (122 g), Perth (120 g), Helsinki (116 g), St. Louis (76 g), Budapest (47 g), Copenhagen (44 g), Yale (37 g), Ottawa (34 g), Strasbourg (31 g), Harvard (31 g), Tempe (11 g).

DESCRIPTION

The 28 kg mass had the extreme dimensions of 39 x 24 x 17 cm (Ward 1898). It is irregular in shape and covered with numerous marked regmaglypts, 2-3 cm across and 0.5-1 cm deep. Local pits, 5-10 mm in aperture and 5-10 mm deep, indicate where troilite melted out during the atmospheric entry. Warty and striated fusion crusts of 0.1 mm thick oxides are preserved in a few places, but most of the surface is covered by terrestrial corrosion products. Sections perpendicular to the surface show that normally

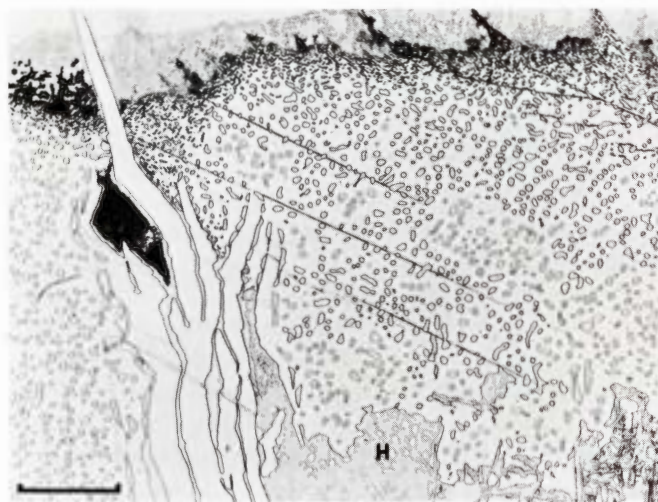


Figure 1194. Mungindi (U.S.N.M. no. 2944). Typical Mungindi-plessite with taenite edge (above) followed by a martensitic transition zone and spheroidized-acicular interior. Neumann bands penetrate the kamacite phase. Haxonite (H) below. Etched. Scale bar 100 μ .

only the innermost part of the heat-affected α_2 zone is preserved, while the rest is removed by corrosion. This is confirmed by hardness traces perpendicular to the surface. The microhardness of the kamacite starts at a minimum of about 175 and increases homogeneously to 220 ± 15 in the interior, which is reached 2-3 mm below the surface (hardness curve type I, where the α_2 part has been removed by corrosion). Corrosion penetrates a few millimeter into the mass along grain boundaries. Near the surface and near the fissures, the α -phase of the duplex plessite fields is selectively corroded.

It is not reported whether the two masses fit together along a cleavage plane or a fracture zone, or maybe along a former austenite grain boundary. Considering their proximity when found the breakup must have occurred during the very latest part of the flight.

Etched sections display a fine Widmanstätten structure of straight, very long ($l/w \sim 40$) kamacite lamellae with a width of 0.40 ± 0.06 mm. The value of 0.16 mm reported in Hey (1966: 326) must come from a non-representative section. The kamacite has subboundaries, decorated with 0.5-1 μ phosphides, and Neumann bands are common (HV 220 ± 15). Taenite and plessite cover about 40% by area and individual fields may reach sizes of 4 x 5 mm. Comb and net plessite are common, but duplex fields of $\alpha + \gamma$ — in a development that resembles the matrix of group IVB ataxites — are also common. Martensitic transition zones



Figure 1195. Mungindi (U.S.N.M. no. 2944). Detail of an acicular plessite field with haxonite precipitates (white). Scattered phosphides are also present. Compare Figure 1196. Etched. Scale bar 50 μ . See also Figures 144A and 144B.

MUNGINDI – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Lovering et al. 1957, No. 1	12.18	0.56				5.8	285		10	24		
Lovering et al. 1957, No. 2	12.36	0.56				3.7	230		13	23		
Wasson & Kimberlin 1967	11.7 ± 0.4								19.7	22.1	0.47	

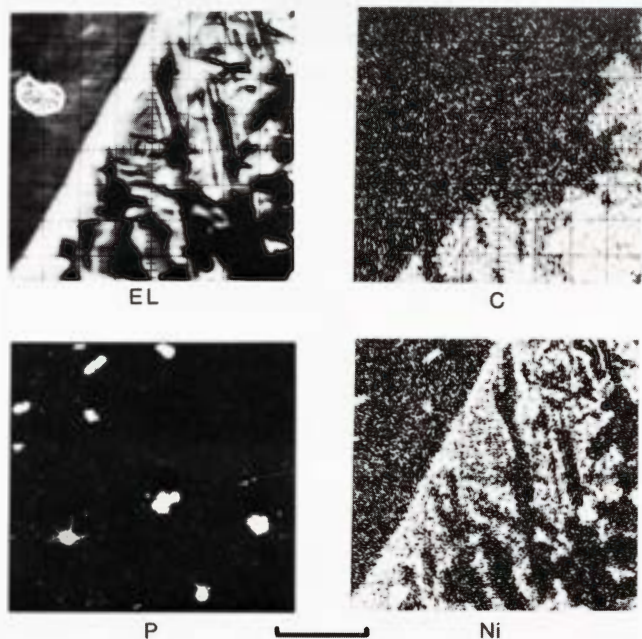


Figure 1196. Mungindi (U.S.N.M. no. 2944). X-ray scanning pictures of an acicular plessite field similar to Figure 1195. Phosphides are present in the kamacite lamella (left), in the plessite and in the haxonite. The extent of the haxonite is obvious from the CK α picture (above right), 15 KV. Scale bar 50 μ .

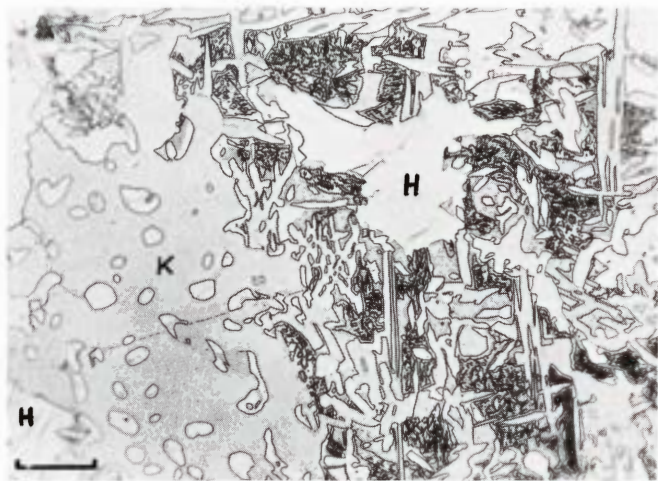


Figure 1197. Mungindi (U.S.N.M. no. 2944). Another view of haxonite precipitates (H) in a plessite field with spheroidized-acicular interior. K is kamacite. Etched. Scale bar 30 μ .

and martensitic interiors with individual martensite platelets parallel to the octahedral structure are very common. Fields with interior cavernous masses of haxonite are characteristic. The rosette-like carbide has tiny inclusions of kamacite, taenite and schreibersite, and may almost completely fill the plessite fields — in other words, attain sizes of 1-4 mm. Smaller blebs, 50-500 μ across, are also present. The plessite associated with carbide is mostly spheroidized to 2-5 μ taenite spherules. The microhardness (100 g) of the carbide is 950 \pm 60; it is somewhat harder but not as brittle



Figure 1198. Mungindi (U.S.N.M. no. 2944). A photograph with maximum contrast between kamacite (K), taenite (T) and haxonite (H). Etched. Scale bar 10 μ .

as the schreibersite in the same sections. In the kamacite lamellae are numerous 3 x 1 μ oriented, hard particles of the chromium nitride, carlsbergite.

Schreibersite dominates many sections as up to 40 x 10 x 2 mm plates, or 1-3 mm H- and Y-shaped skeleton crystals. It is also common as 100-300 μ thick crystals, centrally, in the kamacite lamellae. They are monocrystalline but often sheared and displaced several microns. Schreibersite further occurs as 10-40 μ grain boundary veinlets and as 2-10 μ blebs inside the plessite fields. Locally rhabdites occur as 0.5-1 μ prisms. The bulk phosphorus content is estimated to be about 0.40%.

Troilite is common as 2-15 mm nodules which always have a 0.5-1.5 mm thick, irregular rim of schreibersite. The aggregates are enveloped in 0.5-1.5 mm thick rims of swathing kamacite. Chromite crystals, 25-50 μ across, are also common as angular inclusions. We see here the normal sequence of precipitation. Chromite presumably started to form, whereupon troilite segregated upon it, probably still in liquid form. Upon further cooling the solidified troilite surface nucleated schreibersite from the P-supersaturated taenite matrix. The schreibersite formation depleted the taenite in nickel and phosphorus, and therefore kamacite first appeared around the schreibersite upon continued cooling. Eventually, the remaining taenite transformed, partially, by homogeneous nucleation and growth to the Widmanstätten structure as we now see it. At a very late stage carbide precipitated in some of the plessite fields.

Mungindi is a fine octahedrite with significant inclusions of schreibersite and carbide. It is structurally very closely related to Carlton and Edmonton (Kentucky), and also, chemically, it appears to form close ties to these irons.

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

462 g slice (no. 527, 21 x 7 x 0.4 cm)
111 g part slice (no. 2944, 5 x 4 x 0.7 cm)

Muonionalusta, Norrbotten, Sweden

67°48'N, 23°6'E; 250 m

Fine octahedrite, Of. Bandwidth 0.29±0.05 mm. ϵ -structure. HV 335±20.

Group IVA. 8.42% Ni, 0.05% P, 2.24 ppm Ga, 0.133 ppm Ge, 1.6 ppm Ir.

HISTORY

The history of this meteorite has recently been updated by Wickman (1963; 1964) who presents evidence in support of Muonionalusta having been a significant shower. That only three masses have been recovered from the area is ascribed to the low population density of 1 per km² and to the ground being covered by glaciofluvial sediments and by extensive bogs and swamps. Wickman's paper gives excellent photographs of the general area and of the exterior shape of Muonionalusta II and III.

Muonionalusta I was found in 1906 by the 10-year-old boy, Viktor Mattila, who tended cattle in the forest 3 km southwest of the village Kitkiöjärvi. The coordinates above are those of No.1 which is the westernmost of the individual masses. The locality is 140 km east of Kiruna and close to the Swedish-Finnish border. The mass weighed 7.53 kg and was lying on the surface. It went through several hands before it came to the Geological Institute of Uppsala, where it was described by Högbom (1908), with photographs of the exterior and a photomicrograph. Malmqvist (1948) concluded from an examination of the structure that the kamacite lamellae of Muonionalusta were not orientated parallel to the faces of an octahedron, but to the faces of a tetragonal pyramid of a specific character. The specimens which the present author has seen of Muonionalusta appear, however, to be normal octahedrites with angles between individual lamellae that can be interpreted by means of the Widmanstätten tables presented by Buchwald (1968b).

Muonionalusta II, of 15 kg, was found by Viktor Niemelä in 1946, while he was excavating gravel for the foundations of a house in the village of Kitkiöjoki. The mass was embedded in tightly packed gravel with boulders at a depth of 120-140 cm, and it was surrounded by a rusty zone. The specimen was purchased by the Swedish Museum of Natural History, Stockholm. The amount of helium isotopes was found to be very low, (Chackett et al. 1953), and also ⁴⁵Sc was low (Wänke 1960a). These results were taken by Wickman as an indication of a large preatmospheric mass, comparable, perhaps, to Cape York or Gibeon.

Chang & Wänke (1969) found a terrestrial age above 800,000 years by the ¹⁰Be/³⁶Cl method. Reed (1965b) examined the composition of the metallic phases with the microprobe.

Muonionalusta III, of 6.2 kg, was found in 1963 by Carl Henriksson during road construction 3.5 km east-northeast of Kitkiöjoki. It was picked up from among blocks that had been taken from a gravel pit, and it may have been situated about 2 m below the surface. A fourth mass, of about 5 kg (?), appears to have been found in the late nineteenth century in the village of Kitkiöjärvi, but it is now lost (Wickman 1964).

The shower appears to extend ESE-WNW and the maximum distance between recovered specimens is 10 km (see map in Wickman 1964). According to Wänke's age data it appears that the masses fell during the glaciation, and that the meteorites later became embedded in reworked till with gravel and other boulders. The extension and direction of the shower is, therefore, difficult to establish. This interpretation is supported by a recent discussion by Wickman (1970).

COLLECTIONS

Stockholm (main masses of No. II, 15 kg, and No. III, 6 kg), Uppsala (about 5 kg of No. I), Hamburg (448 g), Washington (418 g), Bonn (154 g), London (142 g), Budapest (131 g), New York (124 g), Paris (113 g), Helsinki (85 g), Chicago (84 g).

DESCRIPTION

The three masses are weathered, lenticular-to-angular specimens with no conspicuous grooves or cavities. Apparently they have corroded sufficiently under their long terrestrial sojourn to have lost the original fracture surfaces from the atmospheric breakup. Oxide crusts, 0.5-1 mm thick, cover most surfaces, and all fusion crusts and heat-affected α_2 zones have long since been removed. Locally, the surface is disintegrating into octahedral laminae, because a selective attack upon the α -phase, particularly the low-nickel part along the taenite, is progressing in the surface zones. The interior is, however, remarkably free from corrosion, considering the high age.

Etched sections display a fine Widmanstätten pattern of straight, long ($\frac{L}{W} \sim 40$) kamacite lamellae with a width of 0.29±0.05 mm. The kamacite appears to be an extremely densely hatched mixture of shocked ϵ and Neumann bands, in a variety that resembles the structures of, e.g., Grant and Kalkaska. The microhardness is 335±20,

MUONIONALUSTA – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Mauzelius in Högbom 1908	8.02	0.69	0.05			100	100					
Schaudy et al. 1972	8.42								2.24	0.133	1.6	

In the old analysis the sum of Ni and Co was almost correct, but the quantitative separation of Ni and Co was unsuccessful.

one of the hardest for the kamacite phase of any iron meteorite. The numerous subgrain boundaries of the kamacite are not decorated. Plessite covers about 40% by area, as comb and net plessite, as duplex $\alpha + \gamma$ fields, and as a little cellular plessite. The duplex fields are of varying fineness, many of them being unresolvable with a 40x objective; they are dark-etching because of their fineness and may be termed black taenite. Between the framing taenite and the duplex $\alpha + \gamma$ interiors are, as usual in the case of unannealed IVA meteorites, a fringe of martensitic structures. The microhardness ranges from 350 in taenite to 275 in the duplex interiors. These may thus be considerably softer than the kamacite, which is unusual.

Schreibersite is rare but does occur as 1-3 μ wide and 10-20 μ long grain boundary veinlets. Apparently the bulk analytical value of 0.05% P is the lower limit at which one may expect to find precipitated phosphides at the 8-9% Ni level.

Troilite occurs with a frequency of about one per 10 cm² in the shape of lenticular, rhombic or platy blebs, 0.5-2 mm across. They contain 5-10% daubreelite in form of distorted parallel laminae that may be anywhere between 1 and 100 μ wide. The troilite appears to be shock melted and resolidified to 10-50 μ anisotropic units, that often are elongated. Tiny fragments of the partly shattered daubreelite are embedded in the troilite. The melting must have been of extremely short duration, since the surrounding metal is only little attacked and since the daubreelite, after all, managed to maintain some sort of coherence.

Daubreelite is also present in the α -phase as isolated, rounded grains, 10-30 μ across.

Muonionalusta is a weathered, fine octahedrite, which is related to Charlotte and Altonah; it is chemically a typical group IVA iron. It is particularly interesting because of its high terrestrial age and association with reworked glacial deposits.

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

107 g part slice (No. I) (no. 424, 6 x 4.5 x 0.4 cm)
206 g part slice (No. I) (no. 2945, 9 x 6 x 0.6 cm)
105 g part slice (No. II) (no. 1871, 5 x 3 x 0.9 cm)

Murchison Downs, Western Australia

About 26°40'S, 119°E

A single piece of 33.5 g was found in 1925 on the Murchison Downs sheep station and described as a fine octahedrite. It is in the Museum of the Geological Survey of Western Australia, Perth. McCall & De Laeter (1965: 46 and plate 13) noted that "the specimen is similar to the small twisted irons commonly found near meteorite craters," perhaps suggesting that Murchison Downs is a transported Henbury or Boxhole slug.

Murfreesboro, Tennessee, U.S.A.

35°50'N, 86°25'W; 200 m

Medium octahedrite, Om. Bandwidth 0.95±0.10 mm. Neumann bands. HV 205±10.

Group IIIA – Anomalous. 7.91% Ni, about 0.15% P, 16.7 ppm Ga, 30.2 ppm Ge, 2.2 ppm Ir.

HISTORY

A mass of about 19 pounds (8.6 kg) was discovered by prospectors in 1847 a few miles from Murfreesboro, in Rutherford County. Only a small part had been chiseled off when it reached Troost, who briefly described it (1848). Several brief notes were published in the nineteenth century, references to which may be found in Wülfing (1897) and Farrington (1915). Brezina (1896: 276) gave a brief description and two photomicrographs. Berwerth (1914: 1080) believed that the mass had been reheated. This appears, however, not to be the case, at least not for the specimens in Harvard and Washington. Bauer (1963) determined the concentration of ³He and ⁴He and found proportions comparable to those in Merceditas and Oroville. He estimated the cosmic ray exposure age to be 670 million years.

COLLECTIONS

London (2,785 g), Harvard (2,197 g), Vienna (949 g), Paris (203 g), Washington (125 g), Philadelphia (116 g), Chicago (83 g), New York (74 g), Budapest (63 g), Stockholm (50 g), Ottawa (17 g), Berlin (15 g).

DESCRIPTION

The irregular oval mass is somewhat weathered and covered with 1-2 mm thick crusts of terrestrial oxides. Sections perpendicular to the surface disclose, however, that a 0.5-1 mm thick, heat-affected zone is preserved in many places which indicates that, at the most, 1-2 mm of the exterior surface has been lost by weathering. Veinlets of terrestrial oxides, 10-100 μ thick, penetrate some distance into the mass; the troilite is veined by pentlandite from corrosion, and there is some selective corrosion around the various phosphides, but otherwise the iron is reasonably well-preserved.

Etched sections display a medium octahedrite structure of straight, long ($l/w \sim 20$) kamacite lamellae with a width of 0.95±0.10 mm. The kamacite has subboundaries, decorated with 0.5-1 μ phosphides, and it has numerous Neumann bands. Locally, there are bundles of lenticular deformation bands. The microhardness of the interior is 205±10; it decreases to a minimum of 180±15 at the

MURFREESBORO – SELECTED CHEMICAL ANALYSES

Reference	percentage			ppm									
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt	
Scott et al. 1973	7.91								16.7	30.2	2.2		

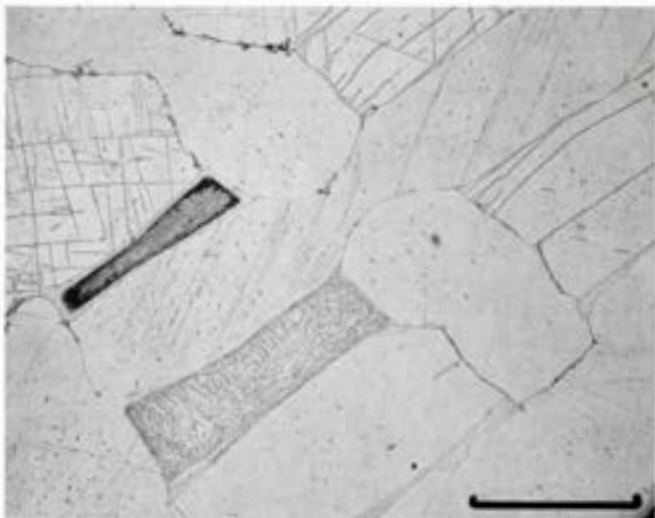


Figure 1199. Murfreesboro (Harvard no. 176F). Medium octahedrite of group IIIA. Kamacite with Neumann bands and normal variety in plessite types. Etched. Scale bar 1 mm.

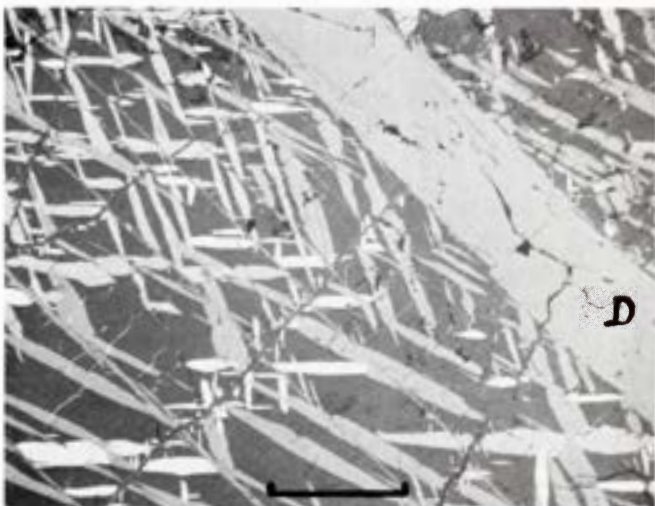


Figure 1200. Murfreesboro (Harvard no. 176F). Troilite with a wide daubreelite lamella (D) and several very narrow daubreelite lamellae parallel to the large one. The troilite shows multiple twinning. Polished. Crossed polars. Scale bar 200 μ .

transition to the heat-affected zone, then increases again to 220 ± 20 in the α_2 zone (hardness curve type I).

Taenite and plessite cover about 40% by area, mostly as open-meshed, comb and net plessite with discontinuous taenite frames. Duplex $\alpha + \gamma$ interiors and martensitic transition zones occur also.

MURNPEOWIE – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				
	Ni	Co	P					Zn	Ga	Ge	Ir	Pt
Hey in Spencer 1935	6.32	0.32			60		20			>70		700
Lovering et al. 1957	6.47	0.47				187	157		42	76		
Smales et al. 1967						198	160	< 1	35	93		
Wasson 1969, pers. comm.	6.31								41.8	85.4	1.8	

Schreibersite is present as 10-40 μ wide grain boundary precipitates and as 5-50 μ irregular blebs inside the plessite fields. Rhabdites, which range from 1-10 μ in cross section, are common. The bulk phosphorus content lies probably about 0.15%.

Troilite is present as scattered 1-10 mm nodules and lenticular bodies. Daubreelite constitutes 10-20% by area of the troilite bodies, mostly as 5-500 μ wide, parallel bars, which frequently protrude 5-10 μ outside the general outline of the nodules. The troilite is monocrystalline but contains numerous lenticular twins from plastic deformation. Local zones of crushing and brecciation are also present. Daubreelite is further present in the kamacitic matrix as 10-50 μ blebs.

In the kamacite are several oriented, hard platelets, about 20 x 1 μ in size, probably the same chromium nitride, carlsbergite, as observed in Costilla Peak and other irons.

Murfreesboro is a medium octahedrite closely related to, e.g., Cachiuyal and Casas Grandes. It somewhat resembles Harriman which was also found in Tennessee, about 170 km farther east, but the two irons are sufficiently different in structural details and in hardness to warrant their listing as two separate falls.

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

57 g part slice (no. 99, 2.5 x 2.5 x 0.7 cm, from J.L. Smith)

6 g part slice (no. 1091, 2.5 x 0.7 x 0.3 cm)

61 g part slice (no. 3344, 4 x 2.5 x 0.8 cm)

Murnpeowie, South Australia

Approximately 29°35'S, 139°54'E; less than 100 m

Anomalous. Recrystallized to 0.1-3 mm kamacite grains. Neumann bands. HV 185 \pm 9.

Anomalous. 6.37% Ni, 0.40% Co, 0.2% P, 40 ppm Ga, 85 ppm Ge, 1.8 ppm Ir.

HISTORY

A fine, well-preserved mass of 1,140 kg (2,520 pounds) was found in 1909 by A. Hamblin and others who were repairing some boundary fences on the Murnpeowie Sheep Run of the Beltana Pastoral Company. The locality is 16 miles northeast by east of Mount Hopeless and about five miles west of Lake Callabonna, corresponding to the coordinates given above. The mass was protruding significantly above the sandy plain which otherwise was devoid of stones. It took two men, with a wagon drawn by