Merceditas, Atacama, Chile Approximately 26°23'S, 70°10'W

Medium octahedrite, Om. Bandwidth 1.00 ± 0.15 mm. ϵ and Neumann bands. HV 270±25.

Group IIIA. 7.92% Ni, 0.48% Co, 0.13% P, 18.8 ppm Ga, 39.7 ppm Ge, 3.4 ppm Ir.

HISTORY

A mass of 43.4 kg was found before 1884 near the mining camp of Merceditas, located 10 or 12 leagues (about 50 km, if Chilean leagues) east of Chañaral, in the province of Atacama. The corresponding coordinates are given above. For a while it was kept in a grocery store, partially covered with onions, and later deposited in a music store in Valparaiso, where Ward discovered it in 1889. He purchased and sliced it, and a preliminary description with a photograph of the exterior was given by Howell (1890). Brezina (1896: 280), in describing the Vienna specimens, noted particularly the hazelnut-to-walnut-sized troilite nodules, which frequently contained islands of metallic matrix, showing Widmanstätten structure. Cohen (1900b: 379) reviewed the literature, and added some observations and an analysis, which was somewhat low in nickel (7.33%). Ward (1904a: plate 2) gave a photomacrograph, and Mason (1962a: 138) presented another photomacrograph, which, among other things, showed the prominent troilite inclusions.

Jaeger & Lipschutz (1967b) found that the matrix was shocked to between 130 and 400 k bar. Signer & Nier (1962) assumed from their noble gas measurements that the preatmospheric mass had weighed about 2,000 kg, and found a cosmic ray exposure age of 600 ± 150 million years. Their estimate of the weight of the preatmospheric mass is hard to believe in view of the fact that so little has been recovered. Bauer (1963) estimated the exposure age to be 580 million years. Further determinations of the noble gases were presented by Lipschutz et al. (1965) and by Schultz & Hintenberger (1967). Voshage (1967) found by the 40 K/ 41 K method an exposure age of 600 ± 80 million years.

COLLECTIONS

New York (11.4 kg), Vienna (7.8 kg), Budapest (2,124 g), London (1,917 g), Harvard (1,589 g), Chicago (1,029 g), Oslo (914 g), Dorpat (881 g), Calcutta (831 g), Washington (724 g), Sarajevo (710 g), Ottawa (291 g), Tempe (254 g), Rome (237 g), Paris (220 g), Berlin (177 g),

Bonn (153 g), Dresden (147 g), Prague (139 g), Bally (115 g), Stockholm (108 g), Sydney (93 g), Copenhagen (76 g), Leningrad (64 g) and numerous other collections. Merceditas is one of the best distributed small iron meteorites. Some are still labeled El Chanaralino, since this was the name attached to the meteorite by Howell (1890) and Ward (1892) and often etched into the slices.

DESCRIPTION

The overall dimensions are approximately 33 x 22 x 15 cm, and the mass is angular with numerous regmaglypts on the uncorroded side and with pockmarks on the corroded side. The regmaglypts are 2-4 cm in diameter and occasionally clustered in larger, shallow depressions. Sections through the surface prove that the regmaglypts are from atmospheric ablation, since a 1-3 mm wide heataffected α_2 zone is still preserved. Micromelted phosphides are present in the exterior part. The 1000° C isotherm may be plotted by following the border between melted and unmelted phosphides. This isotherm has a smoother shape than the present pitted surface, and from its position, it is possible to extrapolate to the original location of the surface before corrosion started. It appears that only about 0.2-0.8 mm has weathered away from the less corroded side.

The more corroded side has lost considerably more material. The surface is pock-marked by small craters, about 5-10 mm across, which are locally arranged in



Figure 1143. Merceditas (Vienna no. G1825). A shocked medium octahedrite of group IIIA. Fusion crust to the right, and a large troilite nodule with a metallic island to the left. Deep-etched. Scale bar 20 mm.

		MERCE	DITAS -	JELECT	sp cher	ICAL A	ALIDE	5				
	р	ercentage	e					ppm				
References	Ni	Co	Р	С	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson & Kimberlin												
1967	7.93								18.8	39.7	3.4	
Lewis & Moore 1971	7.90	0.48	0.13	40								

MERCEDITAS – SELECTED CHEMICAL ANALYSES

subparallel rows, 10-15 mm apart. It has been said (Howell 1890; Cohen 1900b) that the phenomenon is conditioned either by the distribution of sulfides or by the octahedral arrangement of the lamellae. However, since the phenomenon — in different forms — is found on both sulfide-free and sulfide-rich irons, and on both hexahedrites (Filomena) and ataxites (Iquique), it is more likely that it is primarily conditioned by the Chilean climate alone, and thus develops irrespective of the structure of the meteorites.

While corrosion has removed perhaps 0.2-5 mm of the surfaces, it only slightly penetrates the mass and then only along a few grain boundaries. As the meteorite is slow to corrode, it is also slow to etch in Nital.

The etched sections display a medium Widmanstätten structure with little contrast between the kamacite and taenite areas. The kamacite lamellae are bundled, long $(\frac{1}{W} \sim 25)$ and with a width of 1.00±0.15 mm. They have well-marked subgrain boundaries, decorated with a few, less than 1 μ thick, phosphides. Due to a beginning grain growth the edges of the lamellae are no longer straight, since invasion of adjacent kamacite and comb plessite has begun. Areas in which Neumann bands are prominent alternate with areas of an indistinctly hatched character, which presumably indicates a shock intensity just above 130 k bar. The Neumann band-rich areas dominate, however. The hardness curve through the heat-affected zone to the unaltered interior is of type I, with exterior values of 205±10, a transitional zone of 165±10 and interior values of 270±25.

Taenite and plessite cover about 40% by area, mostly as open-meshed comb plessite that repeats the bulk Widmanstätten structure. The framing taenite is often discontinuous and regularly becomes brownish-bluish upon etching, presumably due to submicroscopic decomposition to $\alpha + \gamma$. The taenite of the high-nickel fields is continuous and grades via a martensitic zone into duplex $\alpha + \gamma$ mixtures of varying finenesses, some of them poorly resolvable under the microscope (black taenite).

Schreibersite occurs sparsely in the grain boundaries as $10-30 \mu$ wide veinlets. It is also found inside the plessite fields in irregular shapes $1-50 \mu$ across. Rhabdites were not observed.

No large troilite nodules are present in the specimens in the U.S. National Museum, but specimens in Vienna (e.g., Nos. G 1825, F 9005) contain nodules up to 30 mm in diameter which frequently have 2-12 mm inclusions of iron. Some of these are, in fact, fingers intruding from the surrounding iron phase but cut in a way which makes them appear to be islands. Others are true islands, 2-5 mm in diameter, with Widmanstätten structure.

Troilite is also present as 1-10 mm angular or rounded, monocrystalline inclusions, some of them with parallel bars of daubreelite. Since the overall phosphorus content of Merceditas is low (0.13% P) only discontinuous, thin schreibersite crystals have precipitated upon the troilite. Some troilite nodules have 1 mm thick rims of swathing kamacite, some none at all. In some sections the troilite appears as 30 x 2 mm plates, which are apparently oriented parallel to the dodecahedron and, therefore, are a rather coarse variety of the Reichenbach lamellae.

Fine, hard inclusions, typically $20 \times 1 \mu$ across are frequent in the α -phase. They are oriented in three, or maybe four, directions with respect to the kamacite and are identical to the carlsbergite precipitates noted in Cape York, Costilla Peak and many other irons. Although reported (Meunier 1893a), graphite is not present, and neither is it expected in a medium octahedrite of this type.

Merceditas is a shock-hardened medium octahedrite, which shows little, if any, signs of cosmic annealing. Structurally and chemically it is closely related to Casas Grandes, Kyancutta, and Thule. It is not a paired fall with other Chilean octahedrites, but it is related to Juncal.

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

206 g part slice (no. 313, 9 x 6 x 0.5 cm)

152 g part slice (no. 1500, 6.5 x 5 x 0.8 cm)

127 g part slice (no. 1608, 8 x 7 x 0.4 cm)

173 g chiseled fragment (no. 2911, 7 x 3 x 3 cm)

54 g small part slices (nos. 2909, 2910, 3340)

Mertzon, Texas, U.S.A. 31°21′N, 100°45′W; 600 m

Polycrystalline medium octahedrite, Om. Bandwidth 0.80±0.10 mm. Neumann bands. HV 185±10.

Anomalous group I. 9.3% Ni, about 0.25% P, 1.4% S, 68 ppm Ga, 293 ppm Ge, 2.4 ppm Ir.

HISTOR Y

Two small masses of 2.38 kg and 1.34 kg were found near Mertzon in 1936 by G.F. Sides, a prospector. The pieces were exposed on the surface, only 3 m apart; the erosion had cut the soil away from them in the hilly, limestone country. The locality is eight miles northeast of Mertzon, in Irion County (Annual Report of the U.S. National Museum for 1947: 43: Letter of October 24th, 1949 from S.H. Perry to E.P. Henderson). The masses were

MERTZON -	SELECTED	CHEMICAL	ANALYSES
-----------	----------	----------	----------

	р	ercentage	•					ppm				
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson & Perry												
1954	9.61											
Wasson 1970a	8.98								68.0	293	2.4	

donated to the U.S. National Museum by Perry and were briefly mentioned by Henderson & Perry (1954) who reported a density of 7.88 and classified Mertzon as a medium octahedrite.

COLLECTIONS

Washington (3.3 kg), Chicago (202 g).

DESCRIPTION

The larger fragment measured $10 \times 9 \times 6$ cm and weighed 2,382 g; the smaller fragment measured $9 \times 9 \times 4$ cm and weighed 1,337 g. Both masses are covered with 0.5-1 mm thick crusts of terrestrial corrosion products, and the fusion crust and most of the heat-affected zones have disappeared. At one end of the smaller mass, a recent fracture indicates where the finder broke off a fragment of about $6 \times 2 \times 2$ cm. On the surface of the two masses there are at least 25 small pits, ranging from 1 to 10 mm in diameter and 1-10 mm deep. They are the cavities left from troilite which melted by ablation in the atmosphere.

Etched sections show the meteorite to be polycrystalline. The parent mass was composed of austenite grains, ranging from 3 to 6 cm in diameter. The grain boundaries are rich in troilite and are characterized by 1 mm wide ribbons of kamacite. The grain boundaries may be followed on the surface of the meteorite because the associated troilite melted out and left a 1 mm wide groove which, later, was further deepened by corrosion. The two fragments appear to have become completely separated when the meteorite hit the ground.

Each individual austenite grain has decomposed to a medium Widmanstätten structure of straight, short $(\frac{L}{W} \sim 10)$ kamacite lamellae with a width of 0.80±0.10 mm. The kamacite has faintly visible Neumann bands and numerous subboundaries decorated with 1-2 μ phosphides. Some of the boundaries have moved 10-20 μ after the



Figure 1144. Mertzon (U.S.N.M. no. 1435). A full section showing the polycrystalline taenite aggregate, with swathing kamacite along grain boundaries and around silicate and schreibersite inclusions. See also Figure 77. Deep-etched. Scale bar 20 mm. S.I. neg. 37663A.

precipitation took place. The microhardness of the kamacite (100 g Vickers) was found to be 185 ± 10 .

Taenite and plessite cover about 15% by area. Comb and net plessite are not present. Most is in the form of narrow wedges, the interiors of which are martensitic. A particularly well-developed field will consist of an exterior brown-stained taenite layer, followed by a carbon- and nickel-rich acicular martensite. Then follows a martensite low in nickel-carbon, which is in the form of platelets parallel to the bulk Widmanstätten structure; and eventually in the interior, there may be a duplex $\alpha + \gamma$ structure of 1-2 μ wide units.

Schreibersite is present as 1-2 mm wide layers around some of the troilite crystals and as scattered skeleton crystals, typically 7 x 0.5 mm in size. It is monocrystalline. Schreibersite is further common as 20-100 μ wide grain boundary precipitates. Rhabdites are ubiquitous as a dense cloud of 0.5-2 μ thick prisms in the matrix. The bulk phosphorus content is estimated to be 0.25%.

Troilite is the dominant mineral, occurring in irregular nodules which range from 5μ to 12 mm across. It is unusual to meet such a population where all sizes are more or less equally represented in numbers. Point counting of sections, totaling 80 cm², yielded a bulk troilite content of 6.5% by area, corresponding to about 1.4% S in the meteorite. Some of the troilite is enveloped in schreibersite and most have nucleated 0.5-1 mm thick rims of swathing kamacite. Daubreelite constitutes about 10% of the nodules. The troilite is shock-melted and solidified to fine, polycrystalline aggregates in which tiny blebs of metal and daubreelite are dispersed, particularly near the borders to metal and original daubreelite bars, respectively. Troilite melts have been injected about one millimeter out into the metallic matrix and into some $10-20 \mu$ wide fissures in the adjacent schreibersite. In one place, a 200 μ strongly anisotropic silicate inclusion was observed. Heavily fractured, it was located in the troilite, but it was not identified.

Mertzon is structurally unusual by being polycrystalline and having a thorough dispersion of troilite nodules through the mass. It is different from group IIIB irons of the same nickel content and bandwidth, both in detailed plessite morphology and in the kamacite hardness, which is significantly lower in Mertzon than in IIIB irons. Mertzon is more closely related to the group I irons, although cohenite, graphite and pearlitic plessite were not observed in the available sections. Carbon however, is, present on a significant level as indicated by the martensite morphology.

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

- 1,480 g main mass, No. 1 (no. 1435, 8 x 8 x 6 cm)
 - 296 g endpiece, No. 1 (no. 1435, 8 x 6 x 1.5 cm)
- 201 g part slice, No. 1 (no. 1435, 8 x 4 x 0.6 cm)
- 1,215 g main mass, No. 2 (no. 1435, 8 x 9 x 4 cm)
 - 50 g endpiece, No. 2 (no. 1435, 4 x 4 x 1 cm)
 - 77 g fragments and mounted specimens

Mesa Verde

Mesa Verde, Colorado, U.S.A. 37°9'N, 108°29'W

Polycrystalline, medium octahedrite, Om, Bandwidth 0.60±0.10 mm. Neumann bands. HV 175±10.

Group I. 10.56% Ni, about 0.2% P, 53 ppm Ga, 142 ppm Ge, 1.8 ppm Ir.

HISTORY

A mass of 3.52 kg was found in 1922 by archeologists, who were restoring the Sun Shrine at the north end of Pipe Shrine House in Mesa Verde National Park. It was brought to the U.S. National Museum and was breifly described with a few photographs by Merrill (1923c). As far as could be learned the iron had been regarded with little interest by the cliff dwellers, since it was found together with miscellaneous rock fragments of no particular value. Doctor Fewkes, Director of the Bureau of American Ethnology, estimated that the iron had been collected and placed in the house at its time of construction, i.e., in the Thirteenth Century, the date commonly assigned to these ruins.

COLLECTION

Washington (Main mass of 3.38 kg and fragments).

DESCRIPTION

The irregular mass has the overall dimensions of 16 x 10 x 7 cm. Contrary to what Merrill stated, the iron is very well preserved. Fusion crusts cover most of the specimen as 0.1 mm thick skins. They are somewhat corroded in situ and thereby altered to reddish-brown deposits. Their presence do, however, indicate that the numerous angular and hemispherical pits, 10-40 mm in diameter and 10-30 mm deep, are mainly the result of atmospheric ablation and are not due to corrosion. Under the fusion crust is a 1.5-3 mm thick, heat-affected α_2 zone. In the exterior 50% the phosphides are micromelted, and the graphite flakes are partially dissolved. Upon cooling, the carbon-rich austenite transformed to martensitic nests, 10-50 μ in diameter, similar to those seen in, e.g., Arispe and Morrill. The intricate sculpture of the small mass, comparable to a bunch of grapes where numerous grapes have been picked in an irregular way, stands in sharp contrast to the smooth exterior of other small irons, such as Bushman Land, Boogaldi, Charlotte and Avče.

Etched sections show that the parent mass was a polycrystalline aggregate of 2-4 cm austenite grains. Each of these has developed a medium octahedrite structure of straight, long ($\sqrt[6]{w} \sim 15$) kamacite lamellae with a width of 0.60±0.10 mm. The interstices between the primary lamellae are mostly filled with 0.3-0.6 mm wide repetition lamellae, that occur in bundles and substitute for the normal comb and net plessite. The kamacite has Neumann bands, and subboundaries decorated with 1μ rhabdites are common. The kamacite has a hardness of 175±10; it decreases to a minimum of 160 at the transition to the heat-altered α_2 zone, which has a hardness of 205±20 (hardness curve type II). Taenite and plessite cover about 50% by area. Most taenite wedges have martensitic interiors, either with blunt platelets parallel to the {111} directions, or with pointed, spindle-shaped needles arranged in numerous directions. This last type is associated with higher than 25% nickel and considerable quantities of carbon. The taenite frames become bluish and brownish upon etching, except in the heat-affected zone. This is an indication of carbon in solid solution. Some plessite fields are duplex, mostly with 1-5 μ wide acicular kamacite plates dispersed in a finegrained matrix.

Schreibersite occurs as 3 x 1.5 mm brecciated, but monocrystalline units, enveloped in 0.5 mm swathing kamacite. Further, as 20-80 μ wide grain boundary precipitates and as $100-200 \mu$ thick rims around some troilite nodules. Rhabdites are common as $0.5-1 \mu$ thick prisms. Some schreibersite crystals have grown around 100 μ blebs of troilite. The troilite is shock-melted and has injected fine veinlets through the brecciated schreibersite.

Troilite is present as 1-10 mm nodules, partially enveloped in schreibersite. The troilite is divided into 200-500 μ passive blocks separated by wide zones of recrystallized grains, 2-10 μ in size. Locally a 50 μ daubreelite bleb may be found. Several of the smaller pits on the surface were

Figure 1145. Mesa Verde (U.S.N.M. no. 645). The 3.4 kg main mass is well-preserved with only slightly weathered fusion crusts. Scale bar approximately 3 cm.

IESA	VERDE -	- SELECTED	CHEMICAL	ANALYSES

p	ercentage	•					ppm				
Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
10.56								53.0	142	1.8	
	P Ni 10.56	Ni Co	Ni Co P 10.56	Ni Co P C	Ni Co P C S	Ni Co P C S Cr 10.56	Ni Co P C S Cr Cu 10.56	percentage ppm Ni Co P C S Cr Cu Zn 10.56	percentage ppm Ni Co P C S Cr Cu Zn Ga 10.56 53.0	percentage ppm Ni Co P C S Cr Cu Zn Ga Ge 10.56 53.0 142	percentageppmNiCoPCSCrCuZnGaGeIr10.5653.01421.8





Figure 1146. Mesa Verda (U.S.N.M. no. 1663). A small endpiece showing a twin boundary T-T and several troilite-graphite nodules. Heat-affected α_2 zone is present along most of the periphery. Deep-etched. Scale bar 6 mm.

formed in the atmosphere by partial or complete burning out of troilite.

Graphite is common as 2-500 μ units. Most of them are bordered by straight lines and many could be accepted as imperfect cliftonite crystals, 25-50 μ across. The graphite also often occurs in formations of oriented, acicular platelets, each, e.g., 2 x 10 μ in size. The graphite must have precipitated in the kamacite before most of the schreibersite, since it is often found completely embedded in 100-500 μ schreibersite crystals.

Mesa Verde is not a "medium octahedrite of ordinary type" (Merrill 1923c), but rather a very unusual one, related to Colfax and Four Corners. The structure is, in fact, closely akin to that of Four Corners, except that Four Corners, in addition, contains various silicates. Since only two small sections of Mesa Verde have been made this mass may contain silicates, too. Specimens in the U.S. National Museum in Washington:

3,380 g main mass (no. 645, 16 x 10 x 7 cm) 59 g part slice (no. 1663, 4.5 x 3 x 0.5 cm)

Michigan, see Toluca (Michigan fragment)

Milly Milly, Murchison District, Western Australia 26°7'S, 116°40'E

Medium octahedrite, Om. Bandwidth 1.00 ±0.15 mm. Deformed Neumann bands. HV 195-250.

Group IIIA. 7.64% Ni, 0.20% P, 19.5 ppm Ga, 38 ppm Ge, 2.8 ppm Ir.

HISTORY

A mass of 26.5 kg was found by an aborigine, D. Mulcahy, in 1921 three miles from the Milly Milly sheep

percentage					ppm									
References	Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt		
Simpson 1938	7.84	0.77	0.20	200	100									
De Laeter 1972									19.9					
Rosman 1972	7.46							1.96		35				
Scott et al. 1973	7.62								19.1	38.6	2.8			

MILLY MILLY - SELECTED CHEMICAL ANALYSES

The cobalt determination is probably 50% too high, and the phosphorus determination also appears a little high.

station homestead. It was presented to the Western Australian Museum in the same year and briefly mentioned in the Annual Report of the Geological Survey of Western Australia (for 1921: 53). A description, with analysis, and two photographs were presented by Simpson (1938), and additional information and a photograph of the exterior were given by McCall & de Laeter (1965: 38 and plate 3).

COLLECTIONS

Perth (24.5 kg main mass), Washington (283 g), New York (230 g).

DESCRIPTION

According to Simpson, the mass has the overall dimensions of 25 x 23 x 10 cm. It presents deep and broad pits, typically 3-5 cm in diameter, on both sides. The mass is covered with a 0.5-2 mm thick, shaly oxide crust, as a result of considerable terrestrial weathering. Sections normal to the surface show that the fusion crust and the heat-affected α_2 zone are lost and indicate that at least part of the sculpturing is rather due to corrosion than to ablation in the atmosphere. Also the sizes of the pits appear too large for regmaglypts.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{1}{W} \sim 20$) kamacite lamellae with a width of 1.00 ± 0.15 mm. The kamacite has numerous subboundaries, decorated with 1μ phosphides. It is also loaded with Neumann bands, and, locally, there are shear zones with numerous, lenticular deformation bands. The Neumann bands are often distorted, and the schreibersite and troilite inclusions are sheared and brecciated, proving that considerable plastic flow once took place. That the mass is cosmically cold-worked is supported by the hardness of the kamacite that ranges from 195 to 250, with most values falling around 210.

Taenite and plessite cover about one-third by area. Comb and net plessite fields are common, often forming large fields, 6 x 2 mm in size. The framing taenite is frequently discontinuous. Other fields with more nickel display a taenite rim followed by a martensitic zone which inwards merges with a duplex $\alpha + \gamma$ structure where the individual taenite grains are about 1-2 μ across.

Schreibersite is common as $20-80 \mu$ grain boundary precipitates and as $5-50 \mu$ irregular blebs in the openmeshed plessite fields. Many of the schreibersite crystals have apparently grown around $5-20 \mu$ daubreelite grains which are rather evenly dispersed in the kamacite. Rhabdites are common as sharp prisms, $1-2 \mu$ in cross section. In the kamacite there are some hard platelets of carlsbergite, typically $10 \ge 1 \mu$ in size.

Troilite occurs as lenticular and rhombic bodies, 0.5-5 mm in size, at least. The troilite is monocrystalline and contains about 15% daubreelite in 5-50 μ wide, parallel bars. The aggregates are, however, heavily sheared and display zones of crushing. In several places 5-10 mm long, narrow fissures extend from the troilite. These fissures are partly filled with angular troilite and daubreelite debris, although the width of the fissures may be as small as 20μ . Corrosion has had easy play along these, preatmospheric, fissures.

Milly Milly is a medium octahedrite which has suffered some plastic deformation in Cosmos similar to that seen in, e.g., Drum Mountains. It is related to Dimitrovgrad, Kyancutta and Cape York. Chemically, it is a member of group IIIA.

Specimen in the U.S. National Museum in Washington: 284 g part slice (7 x 5 x 1.3 cm)

Minnesota (iron), U.S.A.

A fragment of six grams from an unknown locality in Minnesota was recorded by Nininger & Nininger (1950: 72). The specimen is in Tempe and appears to be a fragment of a medium octahedrite, possibly one which is already well known.

Misteca, Oaxaca, Mexico

Approximately 17°5'N, 96°41'W

Coarse octahedrite, Og. Bandwidth 1.35 ± 0.30 mm α_2 matrix. HV 175±15.

Group I. 8.28% Ni, 0.3% P, 67.8 ppm Ga, 233 ppm Ge, 1.5 ppm Ir. The whole mass has been reheated artificially to about 1000° C.

HISTORY

There is a great confusion as to how many different meteorites were originally located in the state of Oaxaca. During the nineteenth century various specimens reached European and American collections and were incorporated under the names "Oaxaca 1804," "Misteca 1804," "Oaxaca 1843," "Teposcolula 1804," "Yanhuitlan 1804," "Misteca 1834" and perhaps more combinations. At times specimens



Figure 1147. Misteca (Vienna no. D8376). A $13 \times 8 \times 0.5$ cm full slice with a hole, possibly from fused troilite. There is no oriented sheen because the meteorite has been artificially reheated above 900° C. Deep-etched. Scale bar 20 mm.

of Toluca, Charcas, Descubridora and Adargas were traded as rather unspecified Mexican meteorites, so one was never quite certain what was really authentic Misteca material (see, e.g., Brezina 1896: 268, 273, 275, 299). As this study shows, the state of Oaxaca has furnished three different iron meteorites, Misteca (Og), Yanhuitlan (Of) and Apoala (Om), brought to scientific knowledge in that order.

The first mentioning of Misteca as a locality for meteoric iron was by Rio (1804: 57), but no specific information was given. The somewhat later references to Misteca by Partsch (1843: 134) and Bergemann (1847: 246) almost certainly refer to the much larger Yanhuitlan mass. Castillo (1889) thus informs us that the fragments which Bergemann analyzed in 1857 as Misteca were sent by Castillo to Germany and came from the truncated end of the 421 kg Yanhuitlan mass.

The following, hitherto overlooked note concerning material preserved in Stockholm would seem to give important information as to the original size and history of the Misteca mass:

"No. 86. Found 1804. Misteca in Oaxaca. One larger and three smaller fragments (total 104 g). The larger bought from Gregory, the others gift from professor Wilander. Original label to the smaller fragments: 'Von einer etwa 25 Pfund schweren angeblichen Meteoreisenmasse, die in der Nähe von Oaxaca in Mexico gefunden sein soll, und etwa 1826 von dem vormaligen Bergsecretair von Uslar, damals Director einer englisch-amerikanischen Bergwerksgesellschaft in Oaxaca, nach Deutschland geschickt ist' "(Nordenskiöld 1870a: 45; Lindström 1884: 217).

An approximate weight of 25 pounds or 10-11 kg is in harmony with the dimensions of preserved full slices, which indicate an original, irregularly rounded mass approximately $15 \times 15 \times 10$ cm. The mass appears to have been cut in parallel slices at an early date, probably around 1850. Whether a place called Misteca exists — or existed — is uncertain. The name could not be found on any of the available maps. It appears likely that Misteca is a corruption of Mixtepec, a name which is associated with several small villages about 30 km southwest of Oaxaca, e.g., Magdalena Mixtepec and Asuncion Mixtepec. For want of better information, however, the coordinates given above are those of the town Oaxaca.

Descriptions and analyses of what appear to be authentic Misteca material were presented by Rose (1864a: 55, 62; Cohen 1892: 151; Meunier 1884: 121 and figure 4; 1893a: 52; Brezina 1896: 275). Brezina (1896: plate 9, figures 17 and 18) presented photomacrographs of Vienna specimens of which at least Figure 18 (No. A533), and possibly Figure 17, also show authentic Misteca material. Fletcher (1890a: 172), nevertheless, erroneously maintained that Misteca and Yanhuitlan were identical meteorites. His opinion carried some weight and is probably the main reason that Ward's Establishment, when cutting and etching authentic Yanhuitlan material a decade later, etched the name "Misteca" into all their sections. These became widely distributed and may still be seen in many collections. Thus was the Yanhuitlan specimen in the Tempe Collection still etched and labeled "Misteca" until 1968, and the same is still true of Yanhuitlan specimens in other collections, e.g., the 330 g sample in Tübingen (9112082). In a recent paper by Jain & Lipschutz (1968) the structure of Misteca (Chicago No. 956) was interpreted as a result of some cosmic shocking and reheating. That another explanation is more plausible will be discussed below.

The Karawinsky specimen, mentioned by Partsch (1843: 134), was small, about 8 g, and was for a long time the only specimen in Vienna. It may, however, be a fragment chiseled off the Yanhuitlan mass. In 1856 and following years (Brezina 1885: 241, 262) specimens of authentic Misteca were acquired for the Vienna Collection, probably from Burkart in Bonn, from whom Rose (1864a: 55) also obtained material of similar sizes. In 1863 the British Museum obtained 152 g (No. 35173) from Vienna (Brezina 1885: 244; Hey: personal communication)



Figure 1148. Misteca (Brit. Mus. no. 35173). Artifically reheated to about 1000° C. Fused schreibersite (above the scale bar), resorbed rhabdites, diffuse comb plessite and unequilibrated α_2 . Etched. Scale bar 500 μ .



Figure 1149. Misteca (Brit. Mus. no. 35173). Fused schreibersite (S), diffuse taenite (T) and resorbed rhabdites in unequilibrated α_2 matrix. Etched. Scale bar 200 μ .

830 Misteca

and 163 g (No. 35187) from Berlin (Hey: personal communication), so all this material appears to be authentic. In the following list is summarized what the present author, after having checked numerous specimens, believes to be authentic Misteca material.

COLLECTIONS

Vienna (nos. A533, D8376 and others, about 2 kg), Berlin (1,231 g), Chicago (no. 32, 82 g; no. 956, 62 g; no. 1013, 266 g, the last one erroneously labeled Adargas), Harvard (no. 41a, 430 g; no. 41b, 57 g), Washington (344 g), London (no. 35173, 152 g; no. 35187, 163 g), Amherst (105 g), La Plata (97 g), Stockholm (no. 84:0183, 92 g), Paris (87 g), Tempe (no. 764, 78 g, erroneously labeled Adargas), Prague (no. 104, 26 g, erroneously labeled Adargas), Tübingen (no. 9112083, 36 g); There is, no doubt, more authentic material present in collections. It is hoped that the descriptions and analyses given in the following paragraphs will help in identifying the authentic Misteca specimens.

DESCRIPTION

In order to reinvestigate material which was genuine Misteca and so to speak redefine the meteorite, a specimen of British Museum No. 35173 was lent to me by Dr. M.H. Hey. Other specimens were kindly lent me by Dr. Olsen, Chicago and Mr. Roy Clarke, Washington. Numerous specimens were examined briefly upon visits to various museums.

Most specimens are in the form of 0.3-0.8 cm thick plates which reach a maximum size of about 15 x 15 cm, and thereby indicate the original dimensions. It is an important characteristic that most plates are slightly curved, because they were cut with a wire saw (in the workshops of Krantz, Bonn ?), of which marks may still be found on the backside of many polished specimens. The specimens frequently display hammer and chisel marks, and the oxidized crust is of the type associated with high temperature working. The structure is somewhat opened along the Widmanstätten lamellae and many sections show empty holes and fissures. A 2-3 mm wide rim zone of swathing kamacite around some of the cavities prove that at least these were formerly the site of schreibersite and troilite inclusions, (e.g., on U.S.N.M. no. 2926). The mass is corroded, and the surface is somewhat rough due to separation of the individual octahedral lamellae by terrestrial oxidation products. No fusion crust or heat-affected α_2 zone is preserved.

Etched sections display an indistinct Widmanstätten structure of short $(\frac{L}{W} \sim 12)$ kamacite lamellae with a width of 1.35±0.30 mm. Local grain growth has created almost equiaxial grains, 10-15 mm across. There is no oriented sheen because all kamacite has been transformed to a polycrystalline array of servated α_2 grains, 40-100 μ in diameter. No trace of Neumann bands is present. The hardness is 175±15, typical of the relatively rapidly cooled α_2 grains. The taenite ribbons, normally very hard, have, by the artificial reheating, been annealed to hardnesses about 160. The plessite fields cover about 20% by area, mostly in form of comb plessite, but pearlitic and spheroidized forms were also found, although altered and with diffuse borders due to artificial reheating. That the reheating is by man and not cosmic, is proven by the fact that the corrosion products have reacted at high temperature with the meteoritic minerals to produce fine-grained, eutectic Fe-S-O structures. The presence of high temperature intercrystalline oxidation products along the surface also indicate an artificial reheating. The only written evidence that corroborates this conclusion is an old (1850?) German label, attached to the Amherst specimen, which states that the mass was artificially reheated. Even without this proof all morphological and structural features clearly indicate a maltreatment.



Figure 1150. Misteca (Brit. Mus. no. 35173). Resorbed rhabdites in a still not homogenized matrix, transformed to unequilibrated α_2 . Etched. Scale bar 100 μ .

MISTECA - SELECTED CHEMICAL ANALYSES

Manteuffel's analysis was performed upon a Vienna specimen, Wasson's upon British Museum No. 35173, which, as discussed above, also was a Vienna specimen originally, and presumably part of the same mass. Analytical work by Lovering et al. (1957) led to results that indicate that they had received mislabeled material.

	р	ercentag	e					ppm				
References	Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Manteuffel in Cohen			-									
1892	8.25	0.68	0.32	200			100					
Wasson 1970a	8.27								67.8	233	1.6	

Schreibersite was originally present as 20×2 , 25×3 or 7×0.5 mm skeleton crystals, surrounded by 1-2 mm swathing kamacite. They are now melted and solidified to fine-grained eutectics. Rhabdites were ubiquitous as $5-10 \mu$ prisms, but they are now almost resorbed in the matrix.

There are indications that troilite-graphite-schreibersite nodules were originally present, since some of the cavities are surrounded by a heavily carburized zone which is transformed to carbon-rich martensitic and bainitic structures. It is assumed here that the sulfide and phosphide inclusions melted and partly seeped out during the artificial reheating, which is the reason for the many empty holes.

It appears, that Misteca, structurally, was a close relative to Bischtübe, Balfour Downs and Toluca. This conclusion is in harmony with the analytical results of Wasson, which independently place Misteca close to these meteorites and to others of group I. The structure indicates that reheating was carried to about 1000° C, and that the temperature was kept on the order of one hour, possibly by a blacksmith who attempted to divide the mass before it was acquired by a collector and brought to Germany.

It is interesting that Reichenbach (1862a: 155) had already observed the mottled kamacite in Misteca and rightly attributed it to artificial reheating.

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

19 g part slice (no. 1083, Shepard Collection no. 12) 180 g part slice (no. 2925, 10 x 6.5 x 0.4 cm) 145 g slice (no. 2926, 10 x 8 x 0.4 cm)



Figure 1151. Misteca (Brit. Mus. no. 35173). A former troilite nodule, that upon artificial reheating reacted with kamacite, limonite and oxygen from the air, to produce complex ternary Fe-S-O eutectics. The γ -iron dendrites transformed upon cooling to unequilibrated α_2 . Etched. Scale bar 20 μ .

N



Figure 1152. Misteca (Brit. Mus. no. 35173). An artificially created ternary eutectic of iron, sulfur and oxygen. Compare the artificial structures of Bitburg, Figures 350-354. Etched. Scale bar 20 μ ,

Moctezuma, Sonora, Mexico 29°48'N, 109°40'W

Medium octahedrite, Om. Bandwidth 1.3 ± 0.2 mm. Distorted Neumann bands. HV 161 ±10 .

Group I. 7.98% Ni, about 0.25% P, 67 ppm Ga, 237 ppm Ge, 2.4 ppm Ir.

HISTORY

According to Ward (1904a: 17) a mass of 1.7 kg had been found near Moctezuma in 1899 and had been acquired by the School of Mines in Mexico City. Haro (1931: 78) reported that the meteorite had been discovered in the Sierra de La Madera, 12 km northeast of Moctezuma. Nininger & Nininger (1950: 73) briefly mentioned the material in the Nininger Collection.

COLLECTIONS

Tempe (362 g), Chicago (357 g), London (170 g), Institute of Geology, Mexico City (9 g). It has been assumed that the main mass is still in Mexico, but that is not the case. It appears that it has been exchanged and distributed. A 900 g hammered and chiseled endpiece in the Faculty of Engineering, (Rock Collection, New School of Engineering, Mexico City) is erroneously labeled Moctezuma. It is, in fact, a typical Chupaderos sample, detached from one of the three large masses in the same faculty, but still located at the old site, in Tacuba No. 5, in central Mexico City.

IOCTEZUMA – SELE	CTED CHEM	ICAL AN	VALYSES
------------------	-----------	---------	---------

	p	ercentage	e					ppm				
Reference	Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1971,												
pers. comm.	7.98								67.2	237	2.4	

DESCRIPTION

The following applies to the authentic slices in Tempe and Chicago. The 362 g Tempe sample is a full section, $11 \times 8 \times 0.9$ cm, through the mass. It is corroded; no fusion crust and no heat-affected α_2 zones were detected.

Etched sections display a medium to coarse Widmanstätten structure of straight, long $(\frac{L}{W} \sim 25)$ kamacite lamellae with a width of 1.3 ± 0.2 mm. The kamacite is rich in Neumann bands that locally are bent and distorted due to cosmic deformation. The kamacite is of a surprisingly low hardness, 161 ± 10 , considering composition and structure. It appears that it is moderately annealed, perhaps by artificial reheating to about 400° C.

Schreibersite forms cuneiform or star-shaped crystals up to 10 x 1 mm in size and 1 mm wide rims around troilite. The schreibersite has nucleated 2-3 mm wide rims of swathing kamacite. Schreibersite also occurs as 10-100 μ wide grain boundary veinlets and as 5-50 μ blebs inside some plessite fields substituting for γ -particles of similar size. Rhabdites are abundant as 1-10 μ tetragonal prisms. All phosphides are brecciated and somewhat shear-displaced due to cosmic deformation. The bulk phosphorus content is estimated to be 0.25±0.05%.

Troilite is present, e.g., as a 15 mm nodule, but it could not be examined in detail. Cohenite occurs as 0.1-0.4 mm wide rims on several of the large schreibersite crystals. No decomposition to graphite and kamacite has begun. A few 50-100 μ chromite crystals were observed in the kamacite.

The mineralogy and morphology indicate that Moctezuma is related to the coarse inclusion-rich octahedrites, of which Canyon Diablo is a typical member. In its detailed structure Moctezuma is very closely related to Toluca. It is a normal member of the resolved chemical group I. Moctezuma is distinctly different from Arispe, Carbo and Cumpas, three other iron meteorites from the State of Sonora. It may have been slightly reheated to 400° C by the discoverer.

Monahans, Texas, U.S.A. 31°29'N, 102°53'W; 300 m

Plessitic octahedrite, Opl. Scattered α -needles $50\pm 20 \mu$ wide. Neumann bands. HV 195±10.

Anomalous. 10.75% Ni, 0.56% Co, 0.09% P, 8.9 ppm Ga, 127 ppm Ge, 13 ppm Ir.

HISTORY

A mass of 29.5 kg (65 pounds) was discovered in 1938 by M.P. White of Monahans, Ward County. It was found 30 cm below the surface in the sandy hills 11 km southsoutheast of Monahans, and it was betrayed by the scattered brown patches and scales on the surface sand. When acquired by Nininger it only weighed 27.9 kg due to loss of part of the oxidized crust. It was described with photomacrographs by Nininger (1939a), and more information and a photograph of the whole mass were given later by Nininger & Nininger (1950: 73, 114; plate 17). Buddhue (1939b) examined the oxide crust and found it depleted in nickel. The presence of lawrencite was suspected but not proven; the source of most of the chlorine present is, no doubt, terrestrial ground water. Perry (1944) gave four photomicrographs. Wood (1964) and Reed (1965b) examined the composition of the kamacite and the taenite. Reed (1969) gave corrected data for the kamacite; he found 6.9% Ni and 0.036% P in solid solution in the fine α -plates. Thode et al. (1961) examined the sulfur isotopes. Herr et al. (1961) determined the rhenium and osmium concentrations. Bauer (1963) determined the ³He and ⁴He concentrations and estimated the exposure age to be 40 x 10⁶ years, while Voshage (1967), finding too small concentrations of ⁴¹K and ⁴⁰K for his method, accepted Bauer's estimate.



Figure 1153. Moctezuma (Tempe no. 78a). A small meteorite of group I which is very closely related to Toluca. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)



Figure 1154. Monahans (Copenhagen no. 1966, 141). A plessitic octahedrite, or an ataxite. The dark streak is a chromite lamella, similar to, but larger than, that of Figure 1156. Etched. Scale bar 3 mm.

COLLECTIONS

London (5.95 kg), Tempe (5.28 kg), Washington (893 g), Chicago (844 g), Harvard (811 g), Amherst (651 g), Fort Worth (577 g), Los Angeles (369 g), New York (333 g), Ann Arbor (118 g), Canberra (37 g), Copenhagen 14 g).

DESCRIPTION

The average dimensions of the mass were $23 \times 21 \times 15$ cm. It was penetrated by a deep, wedge-shaped fissure which almost divided the mass in halves. The fissure was filled with oxides, and the exterior of the mass was covered with 5-15 mm thick, often laminated oxides. The mass was split in two by inserting a wedge in the fissure and breaking the remaining metallic junction of 3 cm^2 (Nininger 1939a). Many specimens in collections have one, almost straight, corroded side, which is the fissure wall. The fusion crust and the heat-affected rim zone are removed by the violent corrosion. Below the heavy oxide crust the corrosion selectively attacks the α -phase, but generally penetrates less than a millimeter into the meteorite.

Etched sections display an ataxitic structure, interrupted only by scattered large and small troilite inclusions. The few kamacite needles occur with a frequency of about 10 per cm² and range from 15-100 μ in width. Their length-width ratio is about 20, and they are divided in subgrains. They are normally inclusion-free. The matrix is a duplex mixture of alpha and gamma in various developments. Easily resolvable areas with 5-10 μ taenite grains in a veined kamacite dominate the matrix, but patches of black-etching, unresolvable "plessite" fields, only 10-40 μ across, occur everywhere. The orientation appears to be uniform throughout, indicating a single parent austenite crystal. Surprisingly enough the kamacite matrix is coarse enough and coherent enough to allow the development of Neumann bands. They are present locally, in bundles, and appear to have formed adjacent to the fissure when the meteorite almost split in the atmosphere. The microhardness of the kamacite spindles and of the duplex matrix is almost identical, 195±10.

Schreibersite is only present as microscopic crystals, the largest observed being $50 \times 200 \mu$ in size. It is common throughout the duplex matrix as $5-30 \mu$ thick blebs which are easily overlooked because they resemble taenite somewhat in size and shape. No kamacite precipitation of any significance has occurred around the schreibersite bodies which, therefore, are presumably the result of coprecipitating α and phosphides.

Troilite occurs as a few 10-15 mm nodules that are divided in elongated, undulating cells, $50-100 \mu$ wide, of different extinction. Along shear zones the troilite is recrystallized to $5-10 \mu$ units. Troilite is further common (about one grain per 2 cm²) as angular crystals, 0.1-2 mm in size. Also these were originally monocrystalline, but



Figure 1155. Monahans. Detail of Figure 1154. Kamacite spindles in a duplex $\alpha + \gamma$ matrix of varying density. Etched. Scale bar 200 μ .



Figure 1156. Monahans. Detail of Figure 1154. A fine chromite lamella which has nucleated a kamacite rim along its upper left part but otherwise is still in contact with taenite. Etched. Scale bar 200 μ . See also Figure 190.

	pe	ercentage	e					ppm				
References	Ni	Со	Р	С	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hawley in Nininger												
1939a	10.88	0.63	0.09		470	210	6900					
Cobb 1967	11.9	0.54					295		6		12	
Jarosewich 1968,												
pers. comm.	10.75	0.52	0.09									
Moore et al. 1969	10.74		0.09	90	25		325					
Wasson 1969	10.60								8.9	127	14	

MONAHANS – SELECTED CHEMICAL ANALYSES



Figure 1157. Monahans. The lower part of the chromite lamella in Figure 1156. It is in direct contact with taenite. Farther out, kamacite (K) and, to the right, duplex martensitic plessite with kamacite spindles. Etched. Oil immersion. Scale bar 20 μ .



Figure 1158. Monahans. Detail of Figure 1154. A very narrow chromite lamella (dark, wide at the bottom, narrow at top) has nucleated a wide rim of troilite. Subsequently schreibersite (S) and kamacite (K) formed, but some taenite (T) remained in contact with the troilite. Etched. Scale bar 30μ .

have, presumably due to deformation, become subdivided into cells with undulatory extinction. Some troilite nodules have nucleated a 100-300 μ wide rim of swathing kamacite. Chromite crystals are common as straight plates and bars, typically 1,000 x 15 μ or 500 x 100 μ in size. They are euhedral and frequently form the nuclei around which troilite crystals have grown. If not surrounded by troilite, they may have nucleated a rim of schreibersite or of kamacite.

Monahans is structurally different from most other meteorites. It is, e.g., unrelated to the significant group IVB, which comprises Hoba, Kokomo and others. Monahans is also chemically anomalous, as indicated by the trace elements. The closest relative is Dorofeevka with which Monahans has many structural and chemical features in common.

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

867 g slice (no. 1303, 15 x 7.5 x 1.2 cm) 26 g laminated shale (no. 1407, 6 x 2 x 0.8 cm)

Monument Rock

No doubt fragments of the inclusion-poor variety of Canyon Diablo. Twenty-five g fragments are in Tempe. See also page 381.

Moonbi, County Inglis, New South Wales 30°55'S, 151°17'E; 1,500 m

Medium octahedrite, Om. Bandwidth 0.55±0.10 mm. Artificial α_2 . HV 200±15.

Anomalous. 7.89% Ni, 0.43% Co, 0.22% P, 6.8 ppm Ga, 0.82 ppm Ge, 1.5 ppm Ir.

The whole mass was heated in a blacksmith's forge to 800°-900° C.

HISTORY

A mass of 13.2 kg (29 pounds) was found in 1892 by a Mr. Langston on the top of one of the granite ridges of the main Moonbi Range. The locality was near Tamworth, and the approximate coordinates and altitude are given above. The mass was heated in a blacksmith's forge prior to reaching the Department of Mines, Sydney, where it was briefly described by Mingaye (1893) and Card (1897a). Mingaye gave two photographs of the exterior. Cohen (1905: 308) reviewed the literature, and Brezina & Cohen (Atlas 1886-1906: plate 38) gave two photomicrographs of a chiseled, damaged piece. Lovering & Perry (1962) included Moonbi in their thermomagnetic analysis of meteor-

MOONBI -	SELECTED	CHEMICAL	ANA	LYSES
----------	----------	----------	-----	-------

				ppm								
References	Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957 Nichiporuk & Brown	7.99	0.43				350	201		6.0	< 1		
1965											1.4	9.2
Wasson 1966	7.79								6.8	0.81	1.5	
Smales et al. 1967						193	164	< 1	7.7	0.82		
Crocket 1972				_							1.2	

In addition, we have Mingaye's old value for phosphorus as 0.22% (1893), which is in harmony with the structure.

ites not realizing that it already once had been thermotreated by the blacksmith. Jaeger & Lipschutz (1967b) thought that the granulated kamacite indicated artificial reheating to below 650° C. As discussed below, the temperature was rather 850° C. Reed (1969) examined the kamacite phase and found 7.3% Ni and 0.14% P in solid solution, but the P value is high because of the artificial reheating. Schultz & Hintenberger (1967) determined the composition of the noble gases; the absolute amounts and the relative ratios were apparently not affected by the artificial reheating. Voshage (1967) estimated the exposure age to be between 440 and 900 million years.

COLLECTIONS

Sydney (5.85 kg main mass and 893 g slice), London (591 g), Washington (72 g), Vienna (2 g).

DESCRIPTION

The approximate dimensions of the rounded mass are 18 x 15 x 15 cm. It is weathered and covered with 0.1-1 mm thick, terrestrial oxides. Corrosion penetrates a few millimeters into the mass, particularly along phosphides. Fusion crust and heat-affected rim zones can not be distinguished. Because of the artificial reheating in the blacksmith's forge, the terrestrial iron hydroxides have reacted with the phosphides and created characteristic creamcolored rims, $2-5 \mu$ wide, around the phosphides. The oxides, furthermore, contain significant amounts of tiny metallic spherules, $0.5-2 \mu$ in diameter, evidently from high temperature decomposition reactions; the 25-50 μ along the oxidized fissures are frequently decomposed to intricate laceworks of metal and oxides.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.55±0.10 mm. The former subboundaries are



Figure 1159. Moonbi (U.S.N.M. no. 1457). An anomalous medium octahedrite which has been artificially reheated to about 900° C. Diffuse plessite and unequilibrated α_2 . On the right an unaltered, forked schreibersite crystal. Etched. Scale bar 400 μ . (Perry; 1950: volume 9.)

well marked by 0.5μ phosphide precipitates. The small phosphides are, however, almost redissolved, and the kamacite is converted to serrated α_2 units, 25-100 μ across, indicative of reheating above 800° C. Not all traces of the previous Neumann bands have been deleted by the reheating, because they were decorated with fine precipitates. The microhardness of the artificial α_2 structure is 200±15. Taenite and plessite cover about 50% by area, mostly as comb plessite and as spheroidized plessite. A significant part of the spheroidization must have been preatmospheric. On the other hand, the taenite and plessite clearly show diffusion effects from the artificial reheating. Carbon, which previously was concentrated in certain of the taenite fields, is now redistributed and locally gives rise to dark-etching α_2 .

Schreibersite occurs as 0.2-0.6 mm wide skeleton crystals centrally in some alpha lamellae. It is further common as $10-50 \mu$ wide grain boundary veinlets. It is monocrystalline but brecciated and frequently displaced by shear in successive steps up to 10μ wide. The terrestrial reheating has, as mentioned above, particularly attacked the crystals surrounded by limonite, while uncorroded phosphides are little affected.

Cohenite was reported by Card (1897) and Brezina & Cohen (Atlas 1886-1906), but this could not be confirmed.

Troilite was not observed, but daubreelite occurs in the kamacite as $10-100 \mu$ irregular blebs which often have served as nuclei for schreibersite precipitates.

Moonbi is structurally anomalous by combining a bandwidth of 0.55 mm with 7.9% Ni. It is also chemically anomalous in its Ga-Ge-Ir contents. It has, both structurally and chemically, a near relative in Saint Genevieve County. Its structure is somewhat obscured by the artificial reheating, which probably peaked between 800° and 900° C, judging from the absence of micromelted phosphides, yet the presence of α_2 and high temperature reaction zones between the "limonite", the metal and the phosphides.

Specimen in the U.S. National Museum in Washington: 72 g part slice (no. 1457, 4 x 2.5 x 1.5 cm)

Mooranoppin. See Youndegin

Moorumbunna, Anna Creek, South Australia 28°55′S, 136°15′E

Medium octahedrite, Om. Bandwidth 0.95±0.15 mm.

Group IIIAB. 8.90% Ni, 0.56% Co, 0.29% P, 22 ppm Ga, 44 ppm Ge, 0.26 ppm Ir.

HISTORY

A mass of 169 lbs 14 oz (i.e., 76.9 kg) was discovered by an aborigine in 1943 near Anna Creek Sheep Station's Moorumbunna Paddock. Only a small part of the meteorite projected above the level of the soil, but the abundantly pitted surface evidently attracted attention. The meteorite was presented to the University of Adelaide and was thoroughly described by Edwards (1946). Besides an analysis, he gave a map sketch, a figure of the exterior and six photomicrographs of etched sections.

COLLECTIONS

University of Adelaide (main mass).

DESCRIPTION

The following is based on a brief examination of a small deep-etched sample and on Edward's elaborate description (1946).

The mass measured $50 \times 31 \times 19$ cm; evidently these figures are the extreme values, since the mass only weighed 76.9 kg. The entire surface is covered by pits, 15-25 mm across, with rather sharp ridges in between. A Widmanstätten grid is etched out locally. No unambiguous regmaglypts, no fusion crust and no heat-affected α_2 zone could be detected, so it is estimated that the mass has lost more than 4 mm by corrosion on the average. Corrosion also penetrates grain boundaries, Reichenbach lamellae and brecciated schreibersite lamellae to a depth of at least 10 mm. Edwards recorded a 5 cm deep pit, which he also assumed to be due to weathering.

Etched sections reveal a medium Widmanstätten structure of swollen, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.95±0.15 mm. The Widmanstätten pattern appears very irregular, mainly because the numerous schreibersite and Reichenbach lamellae have nucleated their own independently oriented rims of swathing kamacite.

Taenite and plessite cover 25-30% by area as comb plessite, net plessite, dense felts with acicular α -platelets, martensitic fields and duplex, unresolvable $\alpha + \gamma$ mixtures ('black taenite').

Schreibersite is common as imperfect Brezina lamellae in the $\{110\}$ planes of the parent taenite crystal. They are typically 6 x 0.3 mm in size, but several of these may occur together as branching units, or they may be arranged in rows, all lined with 0.5-1.5 mm wide rims of swathing kamacite, of highly irregular outlines. Schreibersite further occurs as 20-60 μ wide grain boundary veinlets and as 5-50 μ blebs inside open-meshed plessite, substituting for

Edwards (1946) also reported 0.30% insolubles, and 0.07% Cl. On freshly cut surfaces minute drops of ferrous chloride were observed to ooze out, oxidize to ferric chloride and then to ferric oxide, deeply corroding the kamacite in the process. Edwards concluded that the

 γ -particles of equivalent sizes. The bulk phosphorus content is estimated to be 0.30±0.05% P.

Troilite was reported by Edwards as a $2 \times 2 \times 1$ cm nodule, composed of allotriomorphic troilite grains. The troilite had served as a nucleating substrate for a 0.5 mm wide schreibersite rim.

Reichenbach lamellae occur with a frequency of about one per 10 cm². They are up to 30 mm long and less than 100 μ wide, apparently composed of a central troilite lamellae upon which minute flags and beads of schreibersite have precipitated. Irregular asymmetric rims of kamacite have grown around the aggregates, that clearly interrupt the Widmanstätten structure and thus antedate it.

Moorumbunna is a weathered medium octahedrite, related to Lenarto, View Hill, Ilinskaya Stanitsa, Cleveland and El Capitan.

Morasko, Poznan, Poland 52°29'N, 16°55'E

Coarse octahedrite, Og. Bandwidth 2.5±0.5 mm. Neumann bands. Group I judging from the structure. 6.70% Ni, 0.53% Co, 0.18% P.

HISTORY

A mass of 77.5 kg was discovered in November 1914 by a German soldier, Dr. Cobliner, who was engaged in fortification works near Morasko. The mass was recovered from a depth of about 50 cm and was an entire monolith with regmaglypts. It came to Berlin, but after the first World War it was retrieved for the Poznan collection, and is now diminished by cutting to 61 kg. Three additional masses, of 4.2, 3.5 and 3.5 kg were later found in the vicinity, and all were pictured and briefly described by Pokrzywnicki (1956).

In the 1950s focus centered upon some small 'craters' both west and east of Morasko. They were fully described, with a map, cross sectional drawings, etc., by Pokrzywnicki (1964: 49) who also reported the discovery of several new masses weighing respectively 78, 75, 6.38, 4.18 and 3 kg. In addition, seven specimens totaling 28 kg, five specimens totaling 8 kg, and several smaller specimens totaling 4 kg were discovered. Thus a total of almost 300 kg has now been recovered. Analyses and numerous photomicrographs

MOORUMBUNNA - SELECTED CHEMICAL ANALYSES

cosmic mineral lawrencite was the cause. Considering the weathered state of the meteorite, it appears much more likely that the chlorine comes from the terrestrial environment and has been introduced by ground water during the long exposure.

	p	percentage						ppm				
References	Ni	Со	Р	С	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Edwards 1946	8.82	0.56	0.29		200							
Scott et al. 1973	8.98								21.7	44	0.26	

were presented in the catalog of Polish meteorites (Pokrzywnicki 1964). The 78 kg specimen received a specific mention, with photographs, by Pokrzywnicki (1958).

Until further information becomes available the 'craters' are perhaps best thought of as large impact holes. Eight have been described by Pokrzywnicki (1964), Ranging in size from 60 m to 25 m, they appear to be situated within a narrow elliptical area with axes of 1.4 and 0.3 km and with the major axis extending in the direction W15°N. The fragments discovered so far have been found in the immediate vicinity of the impact holes but not actually in them.

COLLECTIONS

Warsaw, Polish Academy of Sciences (78 kg monolith, and 14 kg on various samples), Poznan, Institute of Palaeozoology of the Polish Academy of Sciences (61 kg cut monolith and 15.5 kg on various samples); Moscow (194 g), London (118 g).

DESCRIPTION

The two largest masses, each of about 78 kg, measure about 50 x 30 x 15 cm in three perpendicular directions. They are well-preserved with distinct regmaglypts, 2-5 cm across, and with smooth ridges in between. Fusion crusts may be detected in numerous places.

Etched sections display a coarse Widmanstätten structure of bulky short ($\frac{1}{W} \sim 10$) kamacite lamellae with a width of 2.5±0.5 mm. Local grain growth has led to almost equiaxial kamacite grains 10-15 mm across. Some specimens display Neumann bands, but others display reheated granulated structures.

Taenite and plessite cover 2-3% by area. Comb plessite, plessite with acicular α -platelets, poorly resolvable duplex taenite ('black taenite') and plessite with martensiticbainitic interiors are all present. Some of the plessite fields are faulted and shear-displaced; this presumably happened when the parent mass split in a large number of fragments in the atmosphere.

Schreibersite occurs as scattered cuneiform skeleton crystals of 1-2 mm size, surrounded by 1-3 mm wide rims of swathing kamacite. It is also common as 20-100 μ wide discontinuous grain boundary veinlets. Rhabdites occur as 5-15 μ thick tetragonal prisms.

Troilite was only observed on the surface where it outcropped as indistinct cavities, about 2 cm in diameter. Whether silicates and graphite were also present could not be determined on this occasion.

Cohenite is common in some sections, absent in others of 6 x 5 cm² area. Over an area of 4 x 3 cm², a total of 45 cohenite crystals, each typically 3 x 0.6 mm in size, was observed. They formed rounded bodies with reentrant angles and with 50-300 μ inclusions of kamacite, taenite and schreibersite. Cohenite crystals are figured by Pokrzywnicki (1964: plate 6, figures 3 and 6), although in the description they are believed to be schreibersite.

A polished section from a small (~ 200 g) Morasko specimen in the Paris National Museum showed severe reheating effects. The kamacite was transformed to granulated α_2 structures, and the cohenite was recrystallized. A narrow zone around the cohenite crystals was transformed to dark-etching bainite due to high carbon concentration from partially decomposed cohenite. It appears that at least one other minor mass (No. 12 of 75 g, Pokrzywnicki 1964) displays similar reheated structures. The presence of these structural types strongly suggests that Morasko was a crater-forming meteorite associated with significant shockalteration, similar to those known from, e.g., Canyon Diablo and Kaalijärv. The structure of the examined samples thus particularly correspond to the small shockannealed Canyon Diablo specimens of stages V and VI.

Morasko appears to be a typical inclusion-rich coarse octahedrite, related to Cranbourne, Seligman and Magura. It is probably a normal member of group I. It should be



Figure 1160. Morasko (Moscow sample). A 194 g slice showing the coarse octahedral structure, in this particular sample, with oriented sheen. Other fragments are matte due to α_2 transformation. Deep-etched. Scale bar 20 mm.

MORASKO – SELECTED CHEMICAL ANALYSES												
References	percentage							ppm				
	Ni	Co	Р	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Beyschlag in									_			
Pokrzywnicki 1956	6.65											
Rossola in												
Pokrzywnicki 1964	6.75	0.53	0.18	200	80		1 500					

The copper determination appears erroneously high.

838 Morasko – Morito

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.

> Morden, New South Wales 30°30'S, 142°20'E

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.

Morito, Chihuahua, Mexico 27°3'N, 105°26'W; 1,600 m

Medium octahedrite, Om. Bandwidth 1.05±0.15 mm. ϵ -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



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.

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