Okahandja is related to Coahuila, North Chile and Keen Mountain, and it is a member of group IIA. Okahandja apparently has had a complicated cosmic history involving slow cooling for the primary structure, followed by plastic deformation and Neumann band-producing shock events. Some of the internal cubic cleavage fissures and the cracks along phosphides must have been open microcavities for countless millions of years in space.

Okano, Hyogo Province, Honshu, Japan
35°5′N, 135°12′E

Hexahedrite, H. Single crystal larger than 10 cm. Neumann bands. HV 170±10.

Group IIA. 5.40% Ni, 0.42% Co, 0.23% P, 60 ppm Ga, 180 ppm Ge, 11 ppm Ir.

HISTORY

A mass of 4.74 kg was observed to fall on April 7, 1904, at 6:35 a.m. near the village of Okano. This is near Sasayama and 40 km north of Kobe. A noise resembling a distant cannon was heard there. A teacher who observed the fall from a point 30 km north of the impact reported:

> "On the northwestern sky, at an altitude of about 70°, there suddenly appeared a white-glowing mass. From its tail I saw fused drops fall off. The light phenomenon lasted 1-2 seconds and then disappeared on the southeastern sky, but the white trail of smoke could be distinguished for another eight minutes. Some minutes after the disappearance (of the light) a loud noise like a thunderclap was heard, and this continued for about a minute."

The iron was located in a small forest by a farmer who saw it fall. It was recovered immediately from an 80 cm deep hole in clay. The mass was acquired by the Metallurgical Institute of Kyoto University where it was described by Jimbō (1906) who gave a map, and by Chikashige & Hiki (1912) and Hiki (1912) who reproduced figures of the exterior shape and discussed the metallography – somewhat biased, however, by their erroneous finding of only 4.4% Ni.

COLLECTIONS

Kyoto (3.5 kg), Harvard (383 g), London (302 g), New York (205 g), Washington (17 g).

DESCRIPTION

The mass is roughly lenticular in shape with the overall dimensions 18 x 12 x 7 cm. One surface is rather smooth and convex, while the other shows numerous angular regmaglypts, 2-3 cm in diameter, and a small beak. The fusion crust covers most of the surface as a thick crust measuring up to 1 mm. On the specimen in Washington it is very thin, however, about 25 μ, and consists of fused oxides only.

Under the fusion crust is a 2-3 mm wide heat-affected zone of α_2. In the outer 50%, where the rhabdites are melted and phosphorus has become partly dissolved in the metal, the microhardness is 180±5; in the inner part the α_2 hardness is only 155±5, indicating that phosphorus in solid solution contributes significantly to the hardness of the α_2 phase (Buchwald 1966: 18).

Okano is a normal hexahedrite, a single ferrite crystal larger than 10 cm. Neumann bands are well developed and reach from α_2 to α_2 zone, more or less uninterrupted. The microhardness of the matrix is 170±5. Subboundaries are present and are best seen near the troilite inclusions where they are decorated by 1-2 μ phosphides. No taenite is present.

Schreibersite occurs as 50-200 μ thick precipitates on the troilite. Rhabdites are very common. They range from 0.5 to 25 μ in size. Where they are finest, around the troilite-schreibersite inclusons, the matrix appears matte to the naked eye, and the Neumann bands are narrow – about 1 μ. The microhardness increases in these areas to 180±5. Where they are coarsest, their mutual distance is larger, the matrix appears bright, and the Neumann bands are broad. It is this variation in morphology that is responsible for the subdivision of an etched surface in irregular patches conspicuous to the naked eye. In addition to the rhabdite rods mentioned above a number of plate shaped rhabdites occur. They are typically 1-2 mm in two dimensions and as little as 5-15 μ in the third dimension. They are frequently offset by the Neumann bands.

Troilite is common as 1-10 mm nodules with about 15% daubreelite. The troilite is monocrystalline but shows numerous lenticular-acicular twins from plastic deformation. The daubreelite forms parallel lamellae ranging from 10 μ to 1 mm in width.

Okano is a normal hexahedrite which is structurally and chemically closely related to Braunau, which fell in 1847.

OKANO – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moss in Hey 1966	5.4											
Cobb 1967	5.25	0.42					138		59		10	
Wasson 1969	5.55								59.9	180	11	

Chikashige & Hiki (1912) reported 0.23% P.

Specimen in the U.S. National Museum in Washington:
17.5 g part slice (no. 1363, 3.5 x 3 x 0.2 cm)

Oktibbeha County, Mississippi, U.S.A.
About 33½°N, 89°W

A mass of 156 g was found about 1854 in an Indian tumulus. It was described and analyzed by Taylor (1857) and Cohen (1892) who found 59.7 and 62.0% Ni, respectively. This high nickel content has made the material suspect in the eyes of many authors. Wülfing (1897: 265), Cohen (1905: 135), Farrington (1915: 9) and Buddhue (1938) thus assumed that the small mass was a pseudo-meteorite. To make things still worse, half of the original 156 g mass was cut off and forged and is now lost (Taylor 1857). It may be feared that the unforged half was also artificially reheated and thereby more or less altered.

Perry (1944: plate 34) showed four photomicrographs which indicated the presence of meteoritic minerals; a reexamination by Reed (1972a) also strongly suggests that Oktibbeha County is a meteorite, albeit a very extraordinary one which has no relatives at all. With about 60% nickel, it is about twice as nickel-rich as the nearest irons, such as Santa Catharina (36% Ni), Tishomingo (32.5% Ni), Twin City (30.0% Ni) and Lime Creek (28% Ni). See, however, the new find, Dermbach, with about 42% Ni.

Unfortunately, it is not known from where the Indians got the material. Was it an entire individual monolith, or a fragment detached from a larger mass? If it were an entire monolith, heat-affected rim zones from the atmospheric flight might perhaps still be identified. Or perhaps the artificial reheating altered the structure too much for any conclusions to be drawn.

COLLECTIONS

Philadelphia (25 g), New York (14.8 g), Harvard (6 g), London (less than a gram). The 1.9 g Washington sample is apparently lost.

Ollague. See Imilac in the Supplement.

Opava, Silesia, Czechoslovakia
49°58′N, 17°54′E

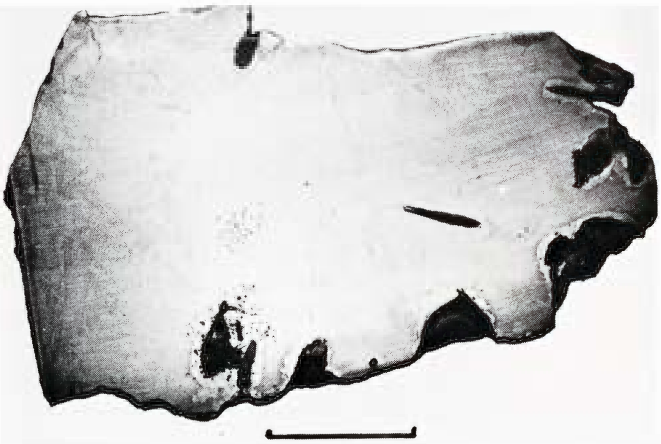

Figure 1327. Opava (Prague no. 322 of 68 g). A little known hexahedrite. The white zones along the rim and around troilite inclusions are artificial and represent metal that was protected by wax during deep-etching. Scale bar 2 cm.

Four pieces of 7.8, 5.8, 1.0 and 0.1 kg were found in 1925, 80 cm below the surface in a loess deposit on the Kylesovsky Hill. The material has been described as a hexahedrite by Drahny (1926) and Rost (1955) with 5.6% Ni. The main masses are in Praha Polytechnic, Dejvice; 611 g is in Prague National Museum (Hey 1966: 359).

Orange River, South Africa
29°40′S, 22°45′E

Medium octahedrite, Om. Bandwidth 1.20±0.15 mm. ε-structure. HV 310±20.

Group IIIAB. 8.54% Ni, 0.50% Co, 0.26% P, 21 ppm Ga, 44 ppm Ge, 0.12 ppm Ir.

HISTORY

Little is known of the origin of this 150 kg meteorite. Shepard (1856) described it and presented two good sketches of the exterior. He stated that he had purchased the mass in 1855 after it had been brought to London by the master of a Scottish ship. The meteorite had evidently been discovered shortly before that time by a farmer of the Orange River district. No further information was published, except for uncommented notes by Brezina (1886: 264) and Ward (1904a: 19) that the meteorite had been found at Garib or Gariep. This is the old name for Orange River, but it was also the name of a mission station located near the junction of Orange River and Brak River, near the present Prieska; see, e.g., Colton's General Atlas, 1866: 116. Furthermore, Gariep Station is at the border of the old Griqualand district, a name which has been used as a synonym for the meteorite in some publications. The coordinates given above are those of Prieska, since it is felt that there is a certain probability that this was the place of find; at this late date, however, it is difficult to reach a definitive conclusion.

COLLECTIONS

Amherst (146 kg), London (828 g), Tempe (567 g), Chicago (283 g), Washington (110 g), New York (91 g), Calcutta (66 g), Leningrad (49 g), Vienna (47 g), Budapest (43 g), Harvard (32 g), Göttingen (30 g), Berlin (28 g), Vatican (26 g), Paris (22 g), Yale (18 g).

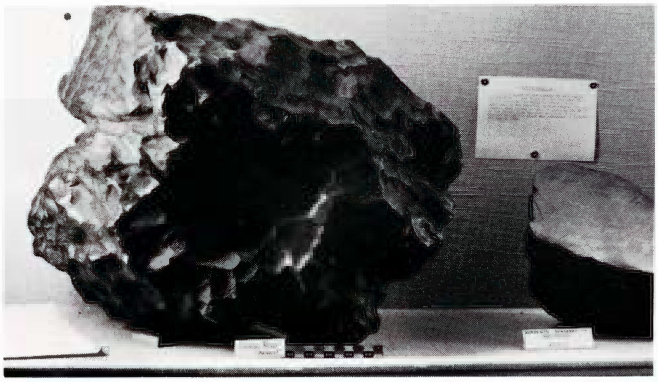

Figure 1328. Orange River (Amherst). The 146 kg main mass. To the right, a significant portion of the Ruff's Mountain meteorite. Ruler is 10 cm.

Reeds (1937: 607), and Hey (1966: 359) state "Repository of main mass unknown." However, for over one hundred years it has been in the Amherst Collection where it was deposited by Shepard (1872a).

DESCRIPTION

The mass is an almost square box with the overall dimensions of 38 x 31 x 25 cm. At one place an 18 x 10 cm cut shows where a few kilograms have been removed. The surface is rather evenly covered with beautiful regmaglypts, each 2-4 cm across and rather shallow. Locally, the pits coalesce to form subparallel grooves – each 5 x 2 or 4 x 3 cm across – radiating from a saucer-shaped depression, 15 cm in diameter and a few centimeters deep. The edges between the angular regmaglypts are smooth, although generally sharper than those found on, e.g., Cabin Creek, Glorieta Mountain, and Oakley. The fusion crust is preserved over many square decimeters as a paper-thin layer; it is blackish with a red-brown tint, due to slight rusting. Fine striae and warts are visible in numerous places; and in two places there are small, cylindrical holes, 8 and 15 mm in diameter, respectively. The holes, which are the same in depth, indicate where troilite partly melted out during the atmospheric passage. Orange River is certainly one of our best preserved large iron meteorite finds.

Etched sections reveal a medium Widmanstätten structure of straight, long, ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.20±0.15 mm. The lamella width increases to about 2.0 mm when central schreibersite bodies are present. The kamacite displays an acicular, shock-hardened ϵ-structure with a microhardness of 310±20.

Taenite and plessite cover about 40% by area, both as comb and net plessite and as the specific type so common in Narraburra and certain other high phosphorus group IIIB meteorites. These fields are conspicuous in having marked, concave taenite islands, each 10-20 μ wide and being rather homogeneous. Locally, only a few millimeters away from these pointed, concave taenite blebs are whole fields where the taenite is well spheroidized to 2-10 μ grains. It is not easy to visualize a process that simultaneously forms spheroidized and extremely pointed taenite blebs with concave edges. However, with steep Ni- and C-gradients such structures may be expected.

Schreibersite is common centrally in the larger kamacite lamellae as elongated bodies, typically 1.5 x 0.4 mm in size. It is further common as 10-100 μ wide grain boundary precipitates and as 1-50 μ blebs inside the plessite fields, substituting for taenite of the same general size. An interesting aspect is the location of the numerous short and 5-20 μ thick schreibersite bodies right at the interphase between taenite and kamacite and showing a transition stage to the well-developed island chains seen in, e.g., Apoala and Narraburra, meteorites related to Orange River. Rhabdites are common in the kamacite lamellae as 2-10 μ thick, tetragonal prisms.

Troilite occurs as nodules, 1-12 mm in diameter, but appears to be rather sparse. Euhedral daubreelite crystals, 10-50 μ in diameter, are present locally in the α-phase.

The fusion crust is composed of magnetite and wüstite but is somewhat weathered. It varies in thickness; on the specimen in the U.S. National Museum it is 20-100 μ thick and displays many inclusions of 2-25 μ metallic spherules. The oxidic fusion crust is underlain by a metallic fusion crust ranging from 5 to 100 μ in thickness and composed of 2-10 μ cellular dendrites. Under the fusion crust is a

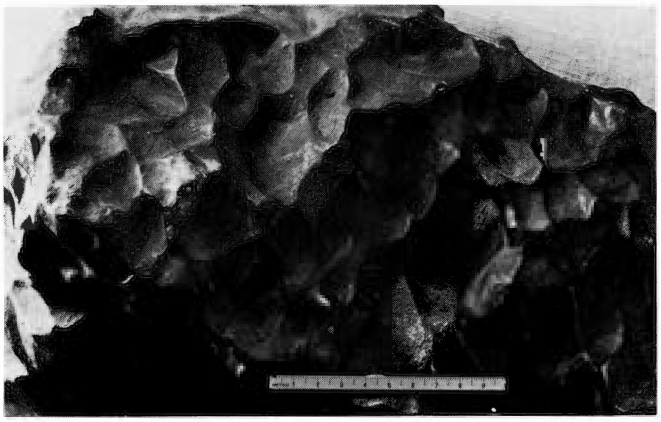

Figure 1329. Orange River (Amherst). Detail of the well-preserved regmaglypts. Ruler is 10 cm.

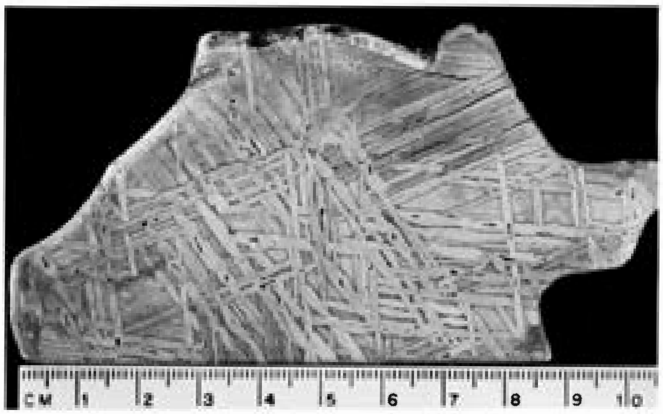

Figure 1330. Orange River (Tempe no. 322.1). Medium octahedrite transitional between group IIIA and IIIB. The heat-affected α_2 zone runs continuously along the rim. Schreibersite crystals (black) are situated centrally in many kamacite lamellae. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

ORANGE RIVER – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	8.62	0.50	0.26	100	60		145					
Scott et al. 1973	8.46								21.2	43.7	0.12	

heat-affected zone of α_2, 2 mm thick. In the exterior half of this, the phosphides are micromelted and frequently connected along the grain boundaries by 1-2 μ wide veinlets of phosphide melts. The α_2 zone ranges in microhardness from 210, where most phosphorus has gone into solid solution, to 180 at the inner boundary against the ϵ-structure, where the $\epsilon \rightarrow \gamma \rightarrow \alpha_2$ transformation has taken place within a few seconds, allowing no time for phosphorus diffusion (hardness curve type I).

Orange River is a shock-hardened medium octahedrite which is closely related to Aggie Creek, Campbellsville, Ilinskaya Stanitza and Luis Lopez. It provides a transition member between the low-phosphorus IIIA and the high-phosphorus IIIB irons.

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

99 g part slice (no. 79, 5 x 4 x 0.8 cm)
11 g part slice (no. 1103, 2.5 x 2 x 0.3 cm)

Oregon. See Klamath Falls

Oroville, California, U.S.A.

39°41'N, 121°38'W; 100 m

Medium octahedrite, Om. Bandwidth 0.85 mm±0.15 mm. Deformed Neumann bands. HV 275±20.

Group IIIB. 8.8±0.4% Ni and 0.4±0.1% P, 20.3 ppm Ga, 40.7 ppm Ge, 0.053 ppm Ir.

HISTORY

A mass of 54 pounds (24.5 kg) was plowed up in 1893 by C.E. Bloomfield 10 miles north of Oroville, Butte County (Butler 1964). The meteorite was almost immediately purchased by the California Academy of Science and kept in the Academy Building in San Francisco. During the fire that followed the great earthquake in 1906 the building was completely ruined. A few fossils and meteorites could, however, be recovered from the rubble, but since the labels had been destroyed some confusion existed as to the identity of the various specimens. Linsley (1934) suspected that an alleged Canyon Diablo specimen in the Ferry Building was, in fact, the missing mass of Oroville, and Butler (1964) proved it to be so. Butler stated that one side of the mass looked much blacker than the other, presumably due to the direct contact with burning timbers. The main mass has apparently not been cut and examined after the fire; all larger sections so far distributed to collections were cut before the meteorite was reheated in the fire.

The first brief and incomplete notes on Oroville are found in Bement (1894) and Brezina (1896: 358). Ward, who had borrowed the mass in order to cut a number of slices about 1898, described it briefly (1900: 21; 1901a: 6) and gave a photomacrograph (1904a: plate 3). Other photographs are given by Butler (1964; 1966). Bauer (1963) examined the $^3He/^4He$ ratio and found Oroville to have a value of 0.297, higher than for any other iron he examined. He estimated the cosmic ray exposure age to be 600 million years.

COLLECTIONS

San Francisco (20.8 kg), Washington (401 g), London (373 g), Chicago (315 g), New York (282 g), Budapest (129 g), Vienna (119 g), Paris (76 g), Berlin (23 g), Bonn (16 g), Stockholm (13 g), Strasbourg (12 g), Vatican (11 g).

DESCRIPTION

The approximate dimensions of the lenticular mass were 25 x 20 x 10 cm before cutting. At one end several parallel slices have been cut, leaving an elliptical cut, 15 x 5 cm in size. Some of the sections distributed by Ward around 1900 still carry the name Oroville, characteristically etched in. Such specimens also display a 2-3 mm wide, glossy rim zone, indicating where the metal was wax-covered during the etching procedure.

This method, in common use from about 1880 to 1940, is unfortunate since it conveys the false impression of a heat-affected rim zone and, in fact, has often been misinterpreted thus by later investigators.

Oroville is corroded but does, in places, have remnants of a heat-affected α_2 zone left. On one specimen (no. 3352) it attains a maximum thickness of 0.5 mm, but 1.5-2 mm must have been removed by weathering. The microhardness of the α_2 structure is 195±10. From the minimum of about 190 the hardness increases inwards and levels off at about 275±20 in a depth of 5 mm (hardness curve type 1).

Etched sections display a medium Widmanstätten structure of somewhat swollen and undulating ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.85±0.15 mm. The kamacite has subboundaries with a few 1 μ phosphide precipitates. It also shows a mixture of deformed Neumann bands and lenticular deformation bands, indicating a thorough plastic cold working. The corresponding microhardness is 275±20, as mentioned above. Taenite and plessite cover about 40% by area; comb and net plessite

OROVILLE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	8.36								20.3	40.7	0.053	

The nickel determination appears low for the structure.

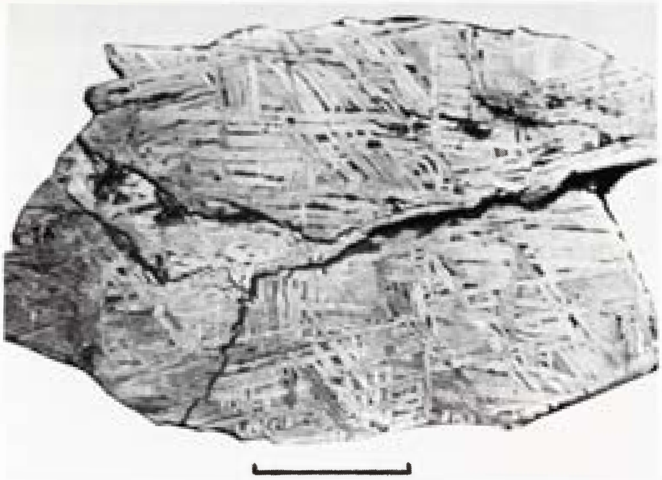

Figure 1331. Oroville (Vienna no. H444, of 119 g). A medium octahedrite of group IIIB. Fissured and weathered. Deep-etched. Scale bar 20 mm.

fields with concave taenite blebs, 5-25 μ across, are particularly common. Also common is annealed martensite and duplex $\alpha + \gamma$ fields with individual γ beads as small as 0.5-2 μ. The various martensite types form transition zones between the taenite rims and the duplex interiors, as usual. A typical, brown-etching, almost unresolvable martensite-duplex interior has a microhardness of 310, and the taenite rims are harder still, 400±25.

Schreibersite is common as Brezina lamellae that reach sizes of at least 20 x 5 x 1 mm. They are enveloped in 1.5-3 mm wide rims of swathing kamacite. They are monocrystalline but violently distorted and brecciated in places. Shear displacements of 0.5-1 mm are present in many sections. The adjacent kamacite then exhibits a significant plastic flow, leading to hardnesses in excess of 300. Schreibersite is further present as 10-50 μ wide grain boundary precipitates and as small, angular blebs inside the plessite. The numerous 5-20 μ thick schreibersite bodies are conspicuous; they are located as beads on a string only 5-30 μ in front of the taenite and plessite fields. Similar morphologies are met with in Bald Eagle, Apoala, Narraburra Creek and other irons of groups IIIA and IIIB – and only in these.

Troilite is not present as a major component in the slices available. It does, however, occur in minute blebs, and as grain boundary fillings. It often penetrates the larger, brecciated schreibersite crystals in 2-5 μ wide veinlets, and it is possible that a number of the corroded cracks in the meteorite were also originally filled with troilite. The troilite is now mostly converted to pentlandite and "limonite," apparently because the mass, when it arrived on the surface of the earth, had already been filled with fissures along which ground water had easy access.

Oroville is a heavily deformed, medium octahedrite which is closely related to Bald Eagle, Apoala and other group IIIB meteorites. Its intense deformation is probably due to a preatmospheric collision which brecciated the minerals and created numerous fissures in the metal. The microcracked meteorite was easily attacked by terrestrial weathering, and, therefore, we find limonitic veins to many centimeters depth below the surface, while the heat-affected α_2 zone may still be rather well-preserved.

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

262 g slice (no. 864, 13 x 6 x 0.6 cm, Butler 1964: 5 and figure 3.)
139 g slice (no. 3352, 8.5 x 5 x 0.6 cm)

Oscuro Mountains, New Mexico, U.S.A.

33°39'N, 106°3'W; 1600 m

Coarse octahedrite, Og. Bandwidth 1.75±0.25 mm. Recrystallized. HV 170±10.

Group I judging from the structure. About 7.0% Ni, 0.27% P, 0.15% C.

HISTORY

Three masses of 1.47, 1.23 and 0.7 kg, respectively, were found close together in 1895 by Philippe Montoya, a Mexican sheepherder. The pieces were found on the south side of a limestone-gypsum hill in the Oscuro Mountains, Socorro County; they were lying on the surface and only separated by one or two meters (Hills 1897). Hills noted that the small mass had been heated in a forge, while the larger were undamaged. He gave two photographs of the exterior shape and one of the structure, printed directly from an etched slice. The meteorite was cut and distributed around 1898-1902, mainly through Ward's Natural Science Establishment. Ward deep-etched the specimens with the name of the meteorite as was usual in that period.

Although the meteorite is called Oscuro Mountains it was not found in this range proper, but 15-20 miles farther east. From the original report by Hills and a comparison with modern maps in 1:62,500 scale, it appears that the place is 10 miles directly west of Carrizozo, with the coordinates given above. Nearby place names are Long Canyon and Sixshooter Canyon.

Figure 1332. Oscuro Mountains (New York no. 71). A full slice showing a coarse Widmanstätten pattern with recrystallized kamacite and decomposed cohenite. Deep-etched. Scale bar 20 mm. (Perry 1950: Volume 7.)

COLLECTIONS

Chicago (751 g), London (494 g), New York (252 g), Washington (102 g), Ann Arbor (102 g), Prague (86 g), Vienna (77 g), Tübingen (60 g found mislabeled "Siratik" in the collection), Harvard (57 g), Ottawa (23 g), Berlin (18 g), Helsinki (18 g), Vatican (13 g).

DESCRIPTION

The two larger masses had the overall dimensions of 12 x 7 x 5 cm each and totaled 2.7 kg in weight. They were, according to Hills, complete individuals with regmaglypts and some weathered fusion crust. The smallest specimen, however, had been damaged by hammering and was fractured.

These observations were confirmed in the present study. Typical slices of the undamaged larger specimens are, e.g., preserved in Ann Arbor, Prague, and Tübingen. They show regmaglypts, 15-20 mm in diameter, and remnants of a heat-affected α_2 zone which is about 1 mm thick and apparently is present under all surfaces. The microhardness of the α_2 phase is 185±10. In a few places even remnants of the fusion crust were observed as 300 μ thick, laminated dendritic metal overlain by a 50-100 μ thick oxidic fusion crust. Therefore, the meteorite must have split early in the atmosphere, but the fragments (three or more) must have continued close together and landed within a few feet, if we are to believe the finder. It is, I think, not impossible – but rare – to find fully crusted specimens so close together.

Etched specimens reveal an altered, coarse Widmanstätten structure of straight, stubby ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 1.75±0.25 mm. Some grain growth has eliminated the kamacite lamellae locally and created large, equiaxial grains, 5-15 mm in size. All the kamacite is well recrystallized to lobed, irregular grains that range from 100 to 500 μ in diameter. This recrystallization is due to an independent reheating which took place after the lamellae formation and the formation of the large kamacite grains, just mentioned. The recrystallized grains show narrow and sharp Neumann bands which, presumably, were formed when the meteorite broke up in the atmosphere. The microhardness is 170±10. The kamacite is more fully recrystallized than in Dungannon, a meteorite which appears to be closely related to Oscuro Mountains.

Taenite and plessite cover about 5% by area. They were originally of the normal group I types, comb plessite and pearlitic plessitic, but are now extremely altered to granulated structures resembling those found in Maria Elena and Reed City. They are decomposed to intimate mixtures of taenite and kamacite, with unequilibrated taenite covering from 50 to 90% by area, while the kamacite forms angular windows, 1-5 μ across. Due to selective corrosion the kamacite component is frequently converted to limonitic products. The hardness of the decomposed taenite ranges from 180 to 200, depending on the relative amount of the two phases. The taenite is considerably more decomposed than it is in Dungannon; but in the center of some of the larger fields, primary pearlitic plessite with 0.5-1 μ taenite lamellae may still be seen.

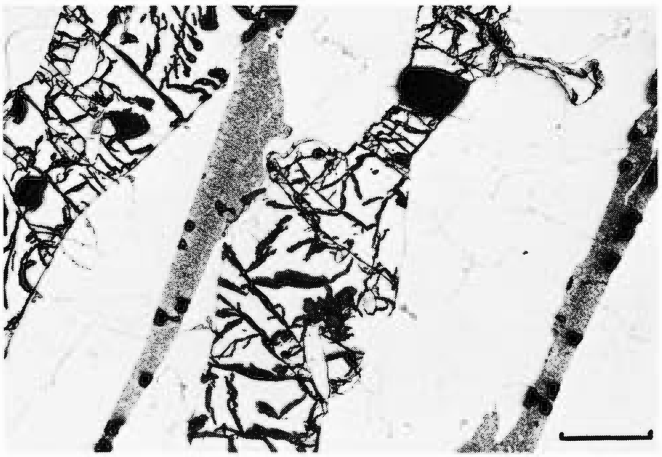

Figure 1333. Oscuro Mountains. Detail of Figure 1332. Two decomposed cohenite crystals with lamellar graphite and two decomposed plessite fields. Recrystallized kamacite in between. Lightly etched. Scale bar 400 μ. (Perry 1950: Volume 7.)

Figure 1334. Oscuro Mountains. Detail of Figure 1332. Cohenite, originally intergrown with kamacite, taenite, schreibersite and daubreelite, is decomposed to lamellar graphite and granular ferrite. Etched. Scale bar 150 μ. (Perry 1950: Volume 7.)

OSCURO MOUNTAINS – SELECTED CHEMICAL ANALYSES

The nickel percentage appears too high. Judging from the structure it may be 7.0±0.4%. By point counting of the graphite, I arrived at 0.15% C as a lower estimate for the bulk carbon content.

	percentage			ppm							
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hills 1897	7.66	0.57	0.27	700								

Schreibersite is common as skeleton crystals, for example, 2 x 0.4 mm in size. Cohenite was once present around them as 100-400 μ wide rims. Schreibersite is also common as 20-150 μ wide grain boundary precipitates and as 5-25 μ blebs inside the taenite. Rhabdites, 5-15 μ across, occur in the kamacite lamellae. All phosphides located in the kamacite phase are severely altered due to reheating. They are enveloped in 5-25 μ wide zones of kamacite and taenite of almost the same morphology as in the plessite-taenite areas. The taenite component constitutes about 80%, the kamacite, 20% in the form of small, angular windows.

It is important to note that such phosphides as were completely enveloped in cohenite – and thus had no direct contact with the kamacite – did not develop the characteristic two-phase rim zones. Therefore, the zones, rather than being simple decomposition products of schreibersite, appear to be narrow reaction zones between schreibersite and kamacite – probably registering an attempt to reach equilibrium compositions corresponding to a temperature of about 500° C. Before equilibrium was attained, the meteorite cooled again; and the peculiar structures were frozen in. They are not present in Dungannon. In the kamacite there are numerous tiny rhabdites, less than 1 μ thick; and 1-2 μ thick phosphide bodies are present in the recrystallized grain boundaries. These phosphides appear to have precipitated after the secondary reheating.

The numerous former cohenite bodies are conspicuous. They were situated in the kamacite lamellae as 3 x 0.4 mm rounded, elongated crystals; and they incorporated the usual small blebs of taenite, kamacite and schreibersite. They are now completely decomposed to graphite and ferrite. The graphite forms plumose masses ranging from 5 to 50 μ in width and reaching lengths up to 500 μ and more. Very often a thin limonite vein forms the midrib of the graphite feathers. It is suspected that this was the position of early cracks in the cohenite from which the decomposition propagated. It would then be natural if the crack itself never healed and was available for circulating water during the terrestrial exposure, thus becoming the seat of some iron oxide veins. The ferrite from the decomposition forms 5-50 μ recrystallized units; it is extremely soft, 106±3, indicating that the nickel and phosphorus contents are very low. The original kamacite windows of the cohenite still show a hardness equal to the bulk kamacite of the lamellae; there are also other indications that no significant nickel and phosphorus diffusion took place. Only the decomposition $Fe_3C \rightarrow 3 Fe + C$ took place, in situ, suggesting a rather low temperature – below 500° C.

The cohenite decomposition resembles that seen in Dungannon. It appears to have been completed – at least in all sections I have seen. In this respect Dungannon and Oscuro Mountains represent end-members in a series in which Odessa, e.g., has cohenite which is not decomposed, and Wichita County has partly decomposed cohenite. The series apparently indicates increasing intensities of cosmic reheating of almost the same primary material.

Troilite is present as 10-15 mm nodules with schreibersite and (decomposed) cohenite rims.

The specimen in the U.S. National Museum (No. 214) apparently comes from the third, reheated fragment. It has been beaten and squeezed somewhat in a vice, and it shows tempering colors. The structure was, however, found to be only little altered; but the lower microhardness of 150±10 showed that annealing or recovery had taken place during the heating. Narrow, lace-like reaction zones are present between the terrestrial oxides and the matrix. It is estimated that the specimen was reheated artificially to 600° or 650° C for a short time.

Oscuro Mountains is a remarkable meteorite. While its primary structure, no doubt, was that of Odessa and similar

Figure 1335. Oscuro Mountains. Detail of Figure 1332. Below, two altered taenite lamellae. Above these, a schreibersite crystal (white) surrounded by fine blebs of taenite. Etched. Scale bar 150 μ. (Perry 1950: Volume 7.)

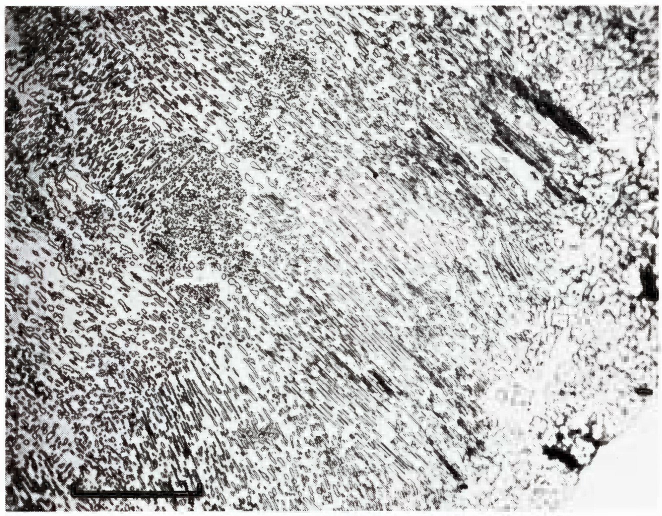

Figure 1336. Oscuro Mountains. Details of Figure 1332. An altered plessite field. The interior is pearlitic or spheroidized. The previously continuous taenite rim (right) is decomposed into a number of irregular amoeba-like particles. Etched. Scale bar 40 μ. (Perry 1950: Volume 7.)

irons of group I, a cosmic reheating has superimposed a secondary, anomalous structure. The kamacite has recrystallized; the cohenite decomposed to graphite in situ; the schreibersite reacted with the kamacite along a narrow interphase zone; and the plessite-taenite decomposed to a characteristic mosaic structure. The troilite is probably altered, too, but no good sections were available for examination. Only short range diffusion took place, suggesting a low temperature annealing, probably around 400-500° C over an extended time. Oscuro Mountains is structurally closely related to Dungannon but represents an even more intense reheating, as estimated from the taenite morphology and the schreibersite reaction zones.

Specimen in the U.S. National Museum in Washington:
102 g fragment (no. 214, 4 x 3 x 2 cm) Slightly damaged.

Osseo, Ontario, Canada

47°38'N, 80°5'W; 300 m

Coarse octahedrite, Og. Bandwidth 2.8±0.8 mm. Cold-worked Neumann bands. HV 225 - 350.

Group I. 6.56% Ni, 0.45% Co, 0.16% P, 91 ppm Ga, 450 ppm Ge, 5.4 ppm Ir.

HISTORY

A mass of 46.3 kg was found in June 1931 near the village of Osseo in Ontario. The locality is 2 km west-northwest of Cane and has the coordinates given above. The coordinates quoted in Hey (1966: 362) are misleading. The meteorite was purchased by the U.S. National Museum in 1935 and was described with photographs of the exterior and of an etched slice by Marble (1938). Hintenberger et al. (1967) and Schultz & Hintenberger (1967) determined the amounts and ratios of the noble gases, while Voshage (1967) by the $^{40}K/^{41}K$ method found a cosmic ray exposure age of 490±55 million years. Jaeger & Lipschutz (1967b) estimated the kamacite to be shocked below 130 k bar.

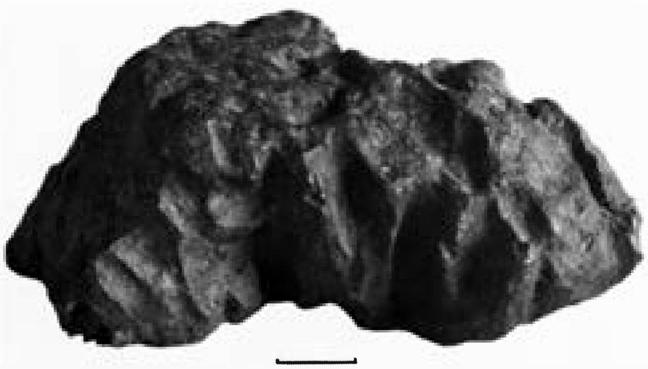

Figure 1337. Osseo (U.S.N.M. no. 925). The main mass displays coarse regmaglypts and is only slightly weathered. Scale bar approximately 5 cm. S.I. neg. 32056E.

COLLECTIONS

Washington (37.8 kg), Ottawa (2,100 g), Moscow (1,315 g), University of Edmonton, Alberta (896 g), Denver (775 g), Ann Arbor (762 g), Calcutta (505 g), Canberra (292 g), Tempe (204 g), London (197 g), Chicago (166 g), Los Angeles (142 g).

DESCRIPTION

The mass has roughly the shape of a deeply sculptured rectangular box with the average dimensions of 38 x 18 x 17 cm. A close examination of the weathered surface reveals that the original fusion crust is preserved in numerous places on all sides of the mass. The many pits and grooves are, therefore, due to flight sculpturing and not to terrestrial weathering. The normal regmaglypts are 15-25 mm in diameter and up to 20 mm deep. Locally, there are larger elongated grooves, e.g., 9 x 2.5 cm in aperture and 2 cm deep, and 7 x 2.5 cm in aperture and 3 cm deep. They correspond somewhat to the finger-shaped grooves on Glorieta Mountain and may have the same explanation, i.e., the dislodging during flight of finger-shaped fragments that became separated along mineral-filled Widmanstätten boundaries. A few cylindrical or hemispherical pits, 4-8 mm in diameter and 5-10 mm deep, indicate where troilite was removed by ablation.

Sections perpendicular to the surface confirm that only a minor part of the surface has been removed by corrosion. The fusion crust is 0.5-1 mm thick, and, locally, it fills cavities massively to a depth of 20 mm. Whirlpools are common, e.g., as basins 10 mm in diameter and irregularly penetrating to a depth of 10 mm. The fused metal is solidified to dendritic-cellular aggregates that frequently are arranged in concentric shells. The cells are 10-200 μ across and the armspacing of the dendrites 3-10 μ. The microhardness is high, 375±25. Under the fusion crust is a 2-3 mm wide α_2 zone with a hardness of 180±10.

Etched sections reveal a coarse Widmanstätten structure of straight, irregular ($\frac{L}{W} \sim 5$) kamacite lamellae with a width of 2.8±0.8 mm. Significant late grain growth has eliminated quite a few of the lamella boundaries and created many almost equiaxial kamacite grains, ranging from 5 to 20 mm in diameter. The narrowest kamacite bands are normally found in association with cohenite

OSSEO – SELECTED CHEMICAL ANALYSES

References	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957		0.47				17	125		82	313		
Moore et al. 1969	6.68	0.42	0.16	90	25		165					
Wasson 1970a	6.44								91.7	450	5.4	

crystals. The kamacite shows various degrees of cold working. The Neumann bands may be straight or severely distorted and folded. Some grains exhibit a hatched structure, while others are filled with broad lenticular deformation bands. Long narrow shear zones, within which the kamacite structure is wholly destroyed, extend for centimeters across the sections. In accordance with optical appearance, the microhardness ranges from 225 in Neumann band regions to 350 in severely cold-worked shear zones (hardness curve type IV). Some recrystallization has taken place in the 500-700° C zone immediately below the α_2 rim zone, due to the brief atmospheric reheating.

Taenite and plessite cover 2-3% by area, mostly as comb plessite and acicular plessite. The taenite ribbons are tarnished bluish-black and have hardnesses up to 455, probably due to severe work-hardening. The interior of many taenite ribbons is decomposed to acicular martensite of high nickel and carbon content.

Schreibersite is common as 1-5 mm skeleton crystals, enveloped in 3-10 mm wide swathing kamacite. It is further present as 25-250 μ grain boundary precipitates. Rhabdites are common as 3-20 μ thick prisms. All the phosphides are shear-displaced and brecciated to various extents; the flow lines in the adjacent kamacite reveal the differential movements between the hard brittle phosphides and the ductile metal. The deformation is clearly preatmospheric in origin.

Cohenite forms clusters of oriented 2 x 0.5 mm crystals and also rims around the troilite-schreibersite nodules. It has the usual small inclusions of schreibersite, taenite and kamacite, and its hardness is normal, 1125±25. No decomposition to graphite was observed.

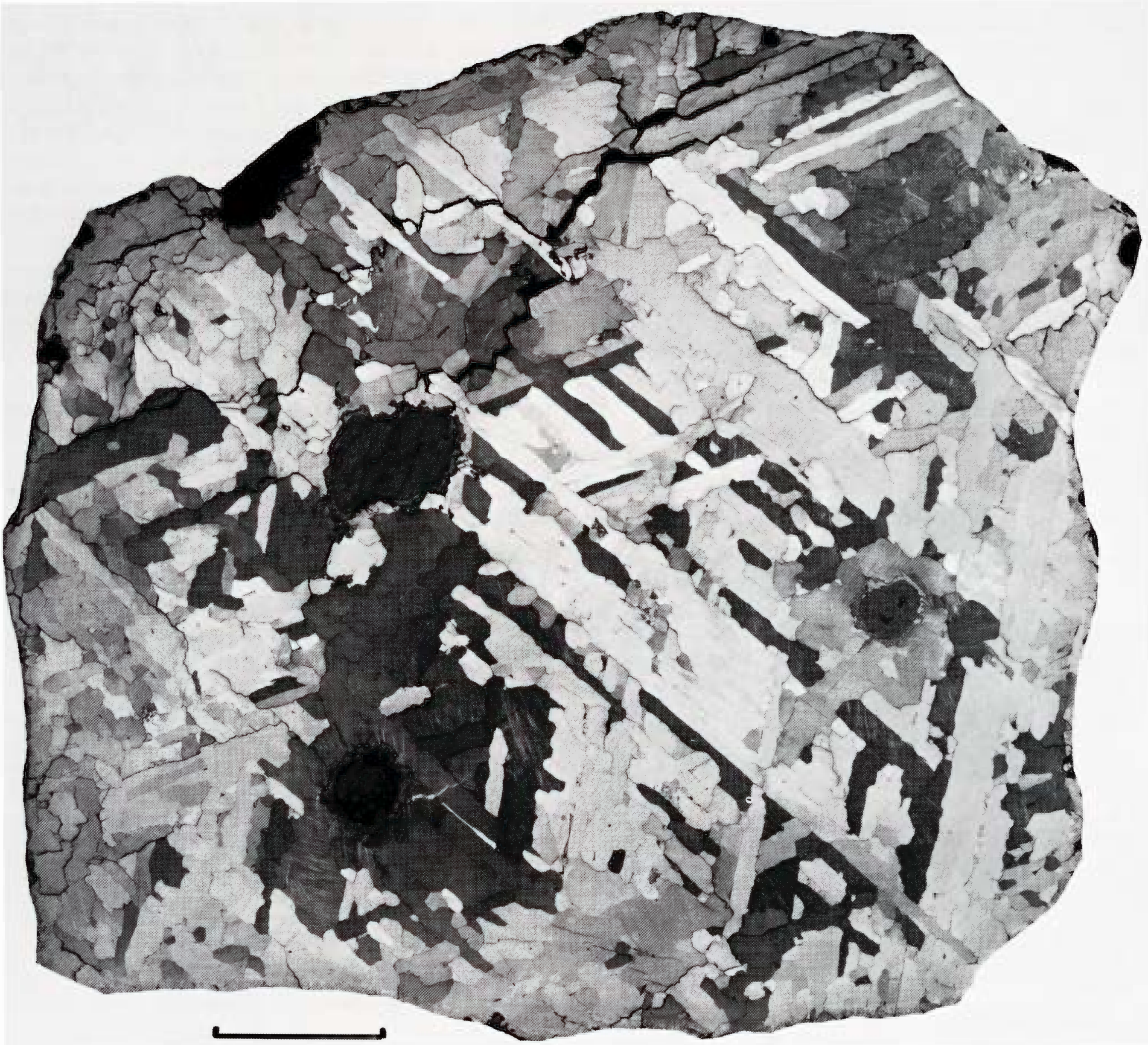

Figure 1338. Osseo (U.S.N.M. no. 925). A coarse octahedrite of group I. Three troilite-graphite nodules with schreibersite-cohenite rims. Deep-etched. Scale bar 30 mm. S.I. neg. 1641B.

Troilite occurs as scattered nodules, 5-30 mm in diameter. The nodules have served as nucleation sites for successive rims of schreibersite and cohenite that together form ragged 1-2 mm wide rims. Some of the troilite nodules contain a little graphite.

The meteorite displays corroded veinlets to the very center of the available slices. This is surprising at first, considering the relatively mild weathering of the surface. It appears, however, that the primary reason for the deep attack is a host of microcracks which were already present when the meteorite arrived on the Earth. The cracks follow Widmanstätten boundaries, the brittle minerals and even – to a minor extent – the cubic cleavage planes of the kamacite lamellae. The schreibersite has been crushed and brecciated and only loosely fills the open cracks. It is now partly recemented by terrestrial limonite. The fissuring appears to be preatmospheric and probably dates back to the general cold working which is observed all over the mass.

Osseo is a typical coarse octahedrite ot group I. It is related to Campo del Cielo, Seeläsgen, Sarepta and Cosby's Creek, but its surface and fusion crust are in a better state of preservation than on most of these.

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

37.6 kg main mass (no. 925, 27 x 18 x 17 cm)
175 g corner (no. 925, 7 x 3.5 x 2.5 cm)

Otasawian, Ontario, Canada

Approximately 50°10′N, 84°30′W

A mass of about 9 kg was briefly mentioned by Baldanza & Pialli (1969), without details of the date and locality of find. Otasawian, a river in Ontario, is one of the numerous tributaries of the Albany River from the southwest. From the descriptions and photomicrographs presented, it appears that the meteorite is a coarse octahedrite, possibly blonging to the resolved chemical group I, and closely related to Mayerthorpe and Canyon Diablo. See also the Supplement.

Otchinjau, Angola

Approximately 16°30′S, 14°E

Fine octahedrite, Of. Bandwidth 0.29±0.04 mm. ε-structure. HV 270±20.

Group IVA. 7.85% Ni, 0.05% P, 2.1 ppm Ga, 0.12 ppm Ge, 2.6 ppm Ir.

HISTORY

A mass of 30 kg was found in 1919 by J. d'Almeida, according to letters in the British Museum from 1950 (Prior

Figure 1339. Otchinjau (Brit. Mus. no. 1953, 61). A 1,450 g sample showing the structure of a fine octahedrite of group IVA. Deep-etched. Scale bar approximately 3 cm. Brit. Mus. neg. 8387.

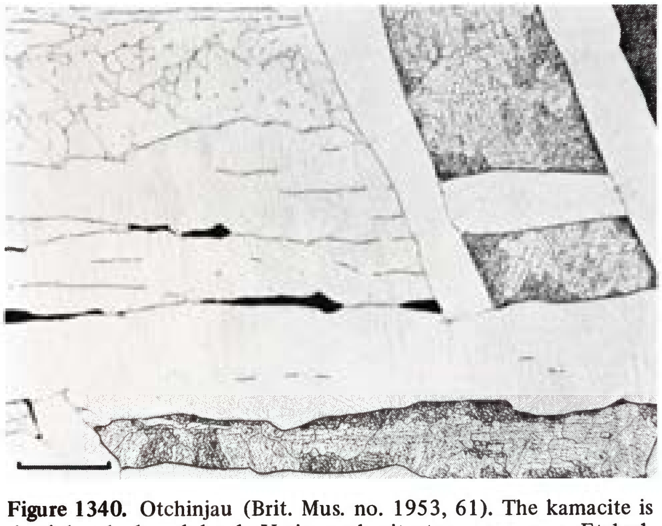

Figure 1340. Otchinjau (Brit. Mus. no. 1953, 61). The kamacite is shock-hatched and hard. Various plessite types are seen. Etched. Scale bar 400 μ.

OTCHINJAU – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Bothwell in Aires-Barros 1964	7.74	0.45	0.069									
Moss in Aires-Barros 1964	8.00	0.44	0.04		0	133	127		2	<1		
Smales et al. 1967						162	144	<1	2.12	0.12		
Schaudy et al. 1972	7.82								2.13	0.117	2.6	
Crocket 1972											2.1	5.8

1953; Hey 1966: 362). A full description and ten photographs appeared later (Aires-Barros & Gomes 1964). The meteorite had been found in the southern part of Angola, close to Otchinjau, but the coordinates could not be given with greater precision than quoted above. When the mass was transferred to the Geological Service of Angola, its weight was 29.6 kg. In 1950 and 1962 small fragments were detached for the collections in London and Lisbon.

COLLECTIONS

Luanda, Serviços de Geologia e Minas (about 27 kg), London (1,417 g & 47 g), Lisbon (about 1 kg).

DESCRIPTION

The 29.6 kg meteorite is an angular lens with the average dimensions of 32 x 22 x 15 cm, according to Aires-Barros & Gomes (1964). It is well-preserved and covered with regmaglypts which range from 1.5 to 3 cm in size and normally are less than 1 cm deep. In numerous places the fusion crust is preserved, although somewhat weathered.

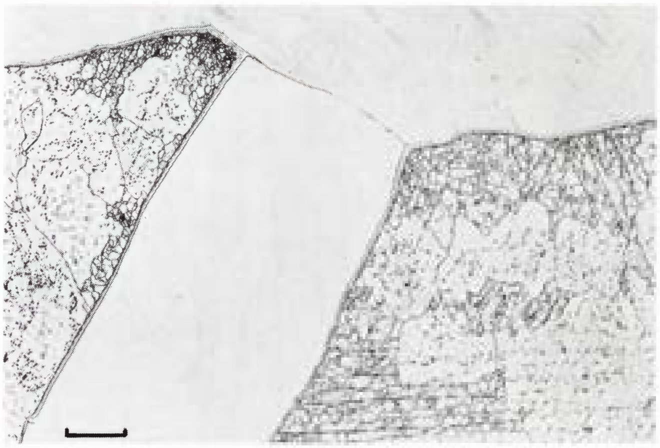

Figure 1341. Otchinjau (Brit. Mus. no. 1953, 61). Two fields of cellular plessite. The finely disseminated particles are taenite. Phosphides are absent. Etched. Scale bar 100 μ.

The sample examined in this study is a 74 g endpiece, off No. 1953, 61 in the British Museum. The polished and etched section exhibits a fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 40$) kamacite lamellae with a width of 0.29±0.04 mm. The kamacite is of the cross-hatched ϵ-variety due to shock above 130 k bar. The hardness is correspondingly high, 270±20.

Taenite and plessite cover 50-60% by area. Open-meshed comb and net plessite are abundant, but dark-etching small fields of unresolvable $\alpha + \gamma$ mixtures are also common. Cellular plessite and finger plessite of the types so characteristic for Gibeon are present in significant amounts. A full plessite field will exhibit a tarnished taenite rim followed by a martensitic-bainitic transition zone. Further inwards unresolvable duplex $\alpha + \gamma$ mixtures are to be found, and finally, easily resolvable $\alpha + \gamma$.

Schreibersite and rhabdite were not detected, in accordance with the low bulk phosphorus value reported in the wet chemical analyses.

Troilite occurs as rounded nodules up to 15 mm in size. The troilite is monocrystalline but, due to shock somewhat fissured and rich in regions with multiple twinning. The troilite contains several daubreelite lamellae arranged parallel to its basis plane (0001). Daubreelite also occurs in the kamacite as euhedric or rounded crystals, ranging in size from 5 to 50 μ. The low bulk phosphorus content of the meteorite has prevented any precipitation of phosphides upon the troilite-daubreelite aggregates.

The sample exhibits several interior fissures which mainly follow the Widmanstätten grain boundaries. They reach lengths of several centimeters at a width of a few microns. They are slightly corroded due to exposure to terrestrial ground water so they have not been formed by chiseling. It appears that the internal cracks are contemporary with the event that formed the shock-hardened ϵ-structure, and thus probably many million years old. The specimen does show chisel marks in places, but these are of no consequence. The meteorite has not been artificially reheated.

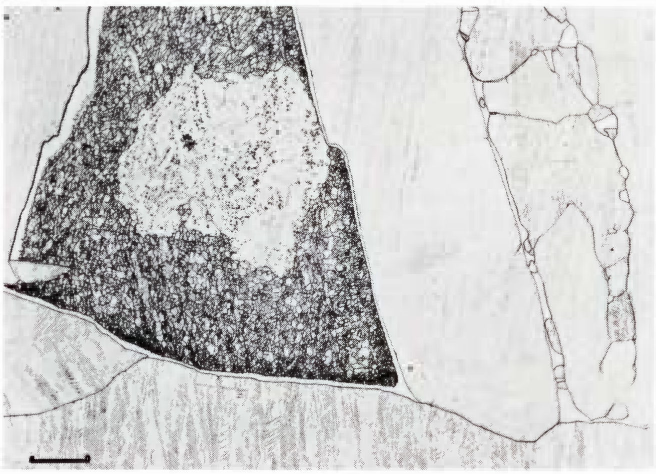

Figure 1342. Otchinjau (Brit. Mus. no. 1953, 61). A dense finger-plessite field to the left and an open-meshed net plessite field to the right. Shock-hatched kamacite. Etched. Scale bar 100 μ.

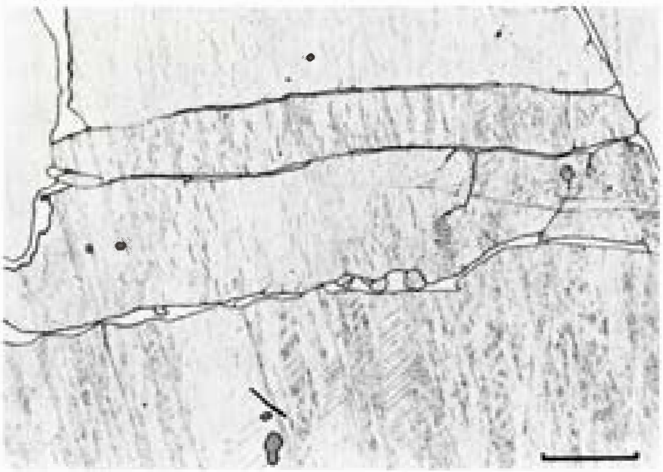

Figure 1343. Otchinjau (Brit. Mus. no. 1953, 61). Open-meshed plessite that is almost resorbed. Shock-hatched kamacite with several daubreelite particles (dark). Etched. Scale bar 100 μ.

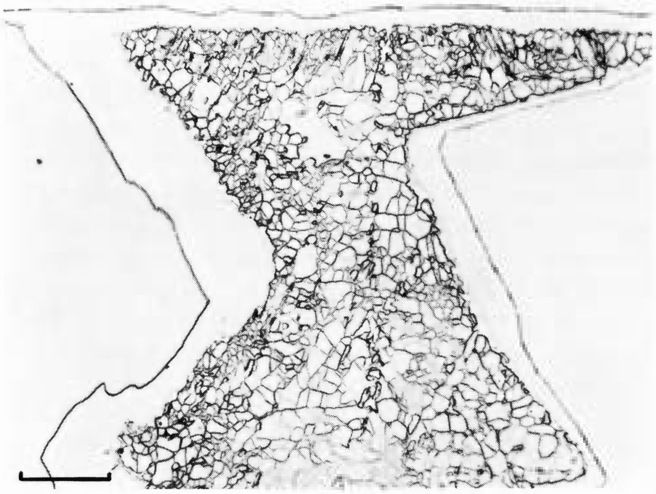

Figure 1344. Otchinjau (Brit. Mus. no. 1953, 61). A plessite field cut almost parallel to $(111)_\gamma$. The taenite rim appears very wide. The interior is duplex $\alpha + \gamma$ without phosphides. Etched. Scale bar 40 μ.

The heat-affected α_2 zone is preserved as a 1-2 mm thick rim along the edge. The α_2 crystallites are small, 5-25 μ, because they formed from a preexisting shock-hardened ϵ-structure. There is a hardness gradient from 270±20 in the interior to 190±15 in the heat-affected α_2 zone (hardness curve type I).

Otchinjau is a shock-hardened, unannealed fine octahedrite belonging to the resolved chemical group IVA. It is closely related to Gibeon, the huge shower which occurred almost a thousand kilometers south of the reported locality of Otchinjau. A significant difference between Otchinjau and known Gibeon specimens is the ϵ-structure of the former. Otchinjau also appears to be a fall of a more recent date than Gibeon. Although the detailed chemical composition and the macrostructure of the two tally very well, the shock structure, the state of corrosion and the distance between the sites indicate that Otchinjau is an independent fall.

Owens Valley, California, U.S.A.

Approximately 37°28′N, 118°0′W; 1800 m

Medium octahedrite, Om. Bandwidth 1.15±0.15 mm. Recrystallized. HV 167±10.

Group IIIB. 8.60% Ni, 0.51% Co, about 0.25% P, 21.5 ppm Ga, 45.9 ppm Ge, 0.15 ppm Ir.

HISTORY

A mass of 193.2 kg was found by a sheepherder in 1913, some 22 miles northeast of Big Pine, Owens Valley, in Inyo County. It passed immediately into the hands of Lincoln Ellsworth, the Arctic explorer, who in 1922 donated the whole mass to the U.S. National Museum. Merrill (1922d) cut an end from it and described it with excellent figures of the exterior and of etched slices. Nininger (1933: figure 17) and Nininger & Nininger (1950: plate 5) reproduced photographs of the exterior and of another, etched section. The meteorite is erroneously listed as a coarse octahedrite in Hey's catalog (1966: 365).

COLLECTIONS

Washington (157.7 kg main mass), New York (32.63 kg endpiece), Tempe (430 g), London (277 g), Paris (50 g).

DESCRIPTION

The elongated mass has the average dimensions 65 x 35 x 27 cm and weighs 193.2 kg. It is boldly sculptured, displaying several large bowl-shaped pits and numerous smaller pits. The largest pits are 18 x 10 cm across and 9 cm deep; 15 x 10 cm across and 4 cm deep; and 13 x 13 cm across and 3 cm deep. The smaller pits are 15-100 mm in diameter and 5-10 mm deep. Common to all these bowls and pits are the sharp ridges that separate them. They are covered with terrestrial oxides, 0.1-1 mm thick; and no fusion crust is visible. It appears that the original regmaglypts are significantly modified by long exposure to weathering.

A minor part of the surface, 20 x 20 cm in area, appears to have survived the corrosion relatively intact. The original regmaglypts here form low depressions, 25-35 mm in diameter and 5-10 mm deep. They are separated by rounded ridges. In four places there are small, hemispherical holes, 12-17 mm in diameter – presumably left after troilite that ablated away. The fusion crust is, I believe,

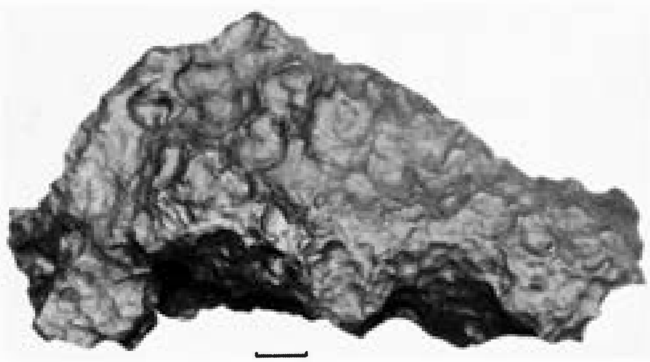

Figure 1345. Owens Valley (U.S.N.M. no. 623). The 193 kg mass is boldly sculptured and exhibits numerous large pits and bowls. The original regmaglypts are modified by long exposure to terrestrial corrosion. Scale bar approximately 5 cm. S.I. neg. 30675A.

OWENS VALLEY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	8.67	0.51	0.21	85	40							
Scott et al. 1973	8.53								21.5	45.9	0.15	

preserved in these holes, while the remainder of this part of the surface is faintly checkered, reflecting the octahedral structure below. No cut through this part has been made, but it seems to me that it represents a far less corroded part of the meteorite, possibly the result of its projecting a few centimeters above the soil level.

Etched sections show a medium Widmanstätten structure of straight, slightly swollen ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.15±0.15 mm. The hatched, shock-hardened ϵ-structure was once present throughout the kamacite phase; a late, cosmic annealing has, however, recrystallized the kamacite and precipitated densely spaced beads of γ all over the kamacite. The recrystallized grains are lobed and irregular except near the schreibersite crystals where they are perfectly equiaxial. The grain size ranges from 10 to 200 μ in the lamellae and from 5 to 30 μ in the plessite fields. The γ-precipitates are generally 0.5 μ across and often trace the outlines of the former ϵ-structure. The microhardness of the recrystallized kamacite is 167±10 except in the relatively nickel-poor kamacite grains adjacent to schreibersite where it drops to 145.

Taenite and plessite cover about 40% by area, partly as comb and net plessite, partly as black taenite. High magnification reveals the black taenite to be a fine-grained (0.5-1 μ) mixture of alpha and gamma phase, the microhardness being 240±10. The martensitic transition zones, otherwise so common in group III are annealed and decomposed. The taenite displays a faint grid of almost submicroscopic particles, precipitated in a few directions only. The taenite has frayed edges, having been dissolved on a microscale. The taenite hardness is 200±10 – which is remarkably low – and indicates that the taenite is well-annealed.

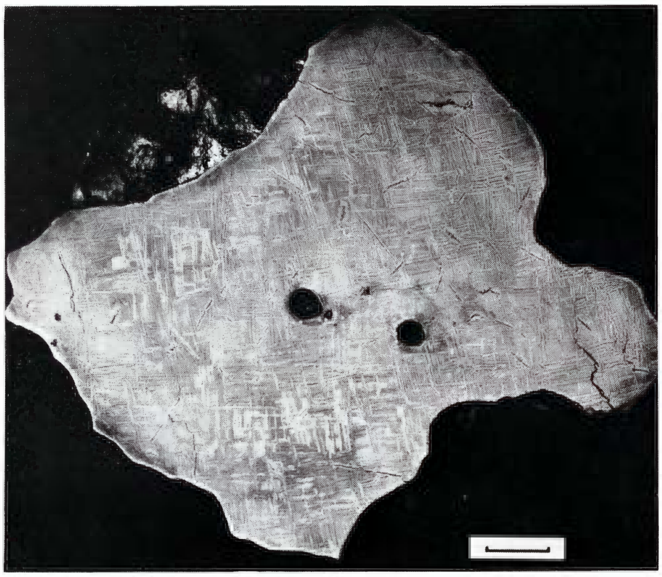

Figure 1346. Owens Valley (U.S.N.M. no. 623). A medium octahedrite which is transitional between group IIIA and IIIB, judging from the structure. The streaks are schreibersite skeleton crystals. Two troilite nodules with schreibersite and kamacite rims are in center. Deep-etched. Scale bar approximately 3 cm. S.I. neg. 30768A.

Schreibersite is present as 0.3-0.5 mm wide and 5-10 mm long lamellae; they are monocrystalline but brecciated and enveloped in 0.6-1.5 mm wide rims of swathing kamacite. They appear to be Brezina lamellae, precipitated in the dodecahedral planes of the parent taenite; but the sections were too small to solve the question. Schreibersite is also common as 0.2-0.5 mm wide skeleton crystals situated centrally in the kamacite lamellae, as 20-50 μ wide grain boundary veins, as 10-20 μ wide blebs forming an "island arc" outside taenite and plessite, and as 2-25 μ blebs inside the comb plessite fields. The bulk phosphorus content is estimated to be 0.25-0.30%, somewhat higher than indicated in the analysis.

The larger schreibersite crystals are frequently sheared and the shear zones are filled with 1-20 μ wide troilite veinlets. The troilite is microcrystalline (about 1 μ grainsize) and partially converted to pentlandite by terrestrial weathering. It was probably squeezed into the shear zones from the larger reservoirs during a violent shock.

Troilite occurs, in addition, as 2-15 mm rounded nodules, the microstructure of which could not be examined. It is expected that they are microcrystalline shock-melted aggregates. A few Reichenbach lamellae, typically 25 mm long and 0.01 mm wide and consisting of troilite with precipitated schreibersite flags, are also present.

The overall impression of the etched sections is that of a structure which was plastically deformed while still hot. Thereby the large schreibersite crystals were sheared and brecciated, and troilite was squeezed into open fissures in the schreibersite and the metal. The metallic matrix, however, later developed a normal, undistorted Widmanstätten structure in which more phosphides precipitated.

The local, severe corrosion is mainly concentrated around the fissures – partially filled with troilite – of the schreibersite and the metal.

Owens Valley has a primary structure corresponding to Aggie Creek, Baquedano and Cleveland. Its secondary structure of recrystallized kamacite with finely dispersed taenite particles resembles particularly Plymouth and Withrow. Chemically, it belongs to those meteorites that are transitional between group IIIA and group IIIB.

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

157.7 kg main mass with 30 x 20 cm cut face (no. 623, 57 x 35 x 27 cm)

Ozren, Bosnia, Yugoslavia

44°36′45″N, 18°20′5″E; 500 m

Coarse octahedrite, Og. Bandwidth 2.0±0.5 mm. Neumann bands. HV 180±5.

Group I judging from the structure. 6.9% Ni, about 0.2% P, 0.26% C.

HISTORY

A mass of about 3.9 kg was found in 1952 among the samples of ores piled up outside the asbestos mine Bosansko Petrovo Selo in Bosnia. It was classified as a coarsest octahedrite by Ramović (1956; 1965) who described it with a macrograph and numerous photomicrographs. He also gave a map sketch.

COLLECTIONS

Sarajevo (2.98 kg), Washington (17 g), London (14 g), Belgrade (12 g), Zagreb (12 g), Ljubljana, Moscow.

DESCRIPTION

According to Ramović (1956), the 3.9 kg mass had been split into two fragments of 3.6 and 0.3 kg by the finder. The restored mass, which was very weathered, showed regmaglypts and measured approximately 10 x 10 x 8 cm.

The small piece in the U.S. National Museum shows that Ozren has a coarse Widmanstätten structure with straight, short ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.0±0.5 mm. Locally, grain growth has created irregular kamacite grains, 10-15 mm across. The subboundaries are decorated with 1 μ rhabdites. Neumann bands are common, and these also appear to be decorated along both sides with particles – probably phosphides – less than 0.5 μ across. The microhardness of the kamacite is 180±5.

Taenite and plessite cover 2-3% by area as up to 1 x 2 mm comb plessite fields and as wedges with acicular or martensitic interiors. The yellow taenite rim zone frequently merges inwards with a tarnished zone; then follows carbon and nickel-rich, highly contrasting martensite platelets; and then a martensitic or duplex $\alpha + \gamma$ structure of a lower nickel and carbon content. The microhardness of the martensitic structures ranges from 330 to 425. Although the specimen was examined for pearlitic and spheroidized plessite fields, these were not detected and they may be totally absent in Ozren.

Schreibersite is common as angular skeleton crystals, e.g., 3 x 1 or 1 x 0.3 mm in size. It is also common as 30-100 μ wide grain boundary precipitates and as 5-25 μ thick blebs in the plessite interiors. Rhabdites are common, both as 5-20 μ thick prisms and as a much finer generation, less than 2 μ across. The phosphides are brecciated and often displaced 3-10 μ by shear. The bulk phosphorus content is estimated to be about 0.2%, not 0.08% as indicated in the analysis above.

Troilite, daubreelite, silicates and cohenite are not present in the U.S. National Museum specimen but are expected to be present in other, larger, sections. The three first mentioned minerals were, in fact, noted by Ramović (1956; 1965) who, among other things, reported a 15 mm troilite nodule enveloped by a 1 mm thick schreibersite rim.

Ozren is significantly weathered. The fusion crust and the heat-affected α_2 zone are lost, and it is questionable whether the surface cavities are regmaglypts. They are more likely corrosion pits superimposed upon the original flight sculpture. The corrosion penetrates along grain boundaries deep into the interior, and limonitic veinlets, 0.1-0.2 mm wide, are common. The nickel-poor vicinity of the rhabdites and the taenite is selectively attacked, and the microscopic alpha phase of the plessite fields is dissolved before the nickel-rich gamma phase. The Neumann bands are also corroded. It appears, however, that it is not the Neumann bands that are primarily responsible for this attack but the fine precipitates along them that have established a chemical potential by segregation of nickel and phosphorus.

From the limited material available for this study, it is concluded that Ozren is a coarse octahedrite that must belong to group I. It appears to be related to Cosby's Creek, Canyon Diablo, Magura and Yardymly.

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

17 g part slice (no. 1784, 2.5 x 2 x 0.5 cm)

OZREN – SELECTED CHEMICAL ANALYSES

The cobalt and phosphorus values appear low and need reexamination. Ramović (1956) also published an analysis of a troilite inclusion: 63.32% Fe, 36.04% S, 0.51% Ni, 0.04% Co; specific gravity: 4.66.

	percentage			ppm							
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Ramović 1965	6.90	0.32	0.08	2600								

Palinshih, Inner Mongolia, China

43°29'N, 118°37'E

A mass of 18 kg was allegedly observed to fall in July 1914 near Palinshih. It appears to be an octahedrite (Meteoritical Bulletin, No. 12, 1959. Here also additional references).

Palisades Park, Texas, U.S.A.

35°6'N, 101°52'W

A mass of 120 g was found in 1935 near Palisades Park, Randall County (Nininger & Nininger 1950: 81). It is a coarse octahedrite, of which 26 g is in Tempe and 27 g in London (Hey 1966: 367). An examination of the Tempe sample (November 1972) indicated that the mass is a transported Canyon Diablo slug which was exposed to impact-reheating to stage VI.

Paloduro, Texas, U.S.A.

34°14'N, 101°13'W

A mass of 3 kg was found in 1935 near Paloduro, Armstrong County (A.D. Nininger 1937). According to Barnes (1939a: 598), the main mass of 2,826 g, apparently an octahedrite, is in Texas Observers Collection, Fort Worth, but the material is undescribed.

Pan de Azucar, Atacama, Chile

Approximately 26°S, 70°W

Coarse octahedrite, Og. Bandwidth 2.2±0.5 mm. Neumann bands. HV 180±5.

Group I. About 6.8% Ni, 0.18% P, 82 ppm Ga, 308 ppm Ge, 2.0 ppm Ir.

Carrizalillo is probably a fragment of the Pan de Azucar shower.

HISTORY

A mass of about 20.3 kg was found in 1887 in the Atacama Desert. The locality was reported to be 67 miles from the small port of Pan de Azucar (Fletcher 1908).

The complete mass was purchased by the British Museum, from which a few small sections have been distributed. Smales et al. (1967), who determined the trace elements, found Pan de Azucar similar to Youndegin and five other, typical group I irons. As discussed below (page 961), the Pan de Azucar fall comprises another mass, previously known as Carrizalillo.

COLLECTIONS

London (19.28 kg main mass and 91 g slice), Chicago (210 g), Washington (101 g), Calcutta (92 g).

DESCRIPTION

The main mass in London is undescribed. The slice in the U.S. National Museum shows, however, that it must be in quite good shape, since regmaglypts, 2-3 cm in diameter, are present; and the fusion crust is preserved in protected places, albeit somewhat rusty. The etched section confirms that the iron has suffered very little from weathering. The heat-affected α_2 zone is found as a 1-2.5 mm wide rim under most of the surfaces, and micromelted phosphides are present in the exterior 0.5-1 mm of the zone, indicating that, at the most, 0.5 mm has been removed by corrosion. The rhabdites are frequently connected with 1 μ wide veinlets of phosphide melts. The microhardness of the α_2 zone is 200±10.

Pan de Azucar is a coarse octahedrite which shows straight, but swollen ($\frac{L}{W} \sim 10$), kamacite lamellae with a width of 2.2±0.5 mm. Local grain growth, which has eliminated the straight Widmanstätten boundaries, is responsible for the swollen, irregular appearance of the lamellae, and in places it has created polyhedric grains, 5-10 mm across. The kamacite has subboundaries, decorated with 0.5-2 μ rhabdites; and Neumann bands are very common. The microhardness of the kamacite is 180±5.

Taenite and plessite cover 2-3% by area. The fields are, as usual, situated in the lamella boundaries but, due to the α-grain growth, may also be completely embedded in a kamacite grain of uniform orientation. Comb plessite and acicular plessite are the most common forms, and tarnished taenite (HV 370±30) occurs everywhere. Spheroidized and pearlitic plessite were not observed but may be present in other cohenite-rich sections. The acicular plessite has a grid of characteristic pointed kamacite platelets, each 5-10 μ thick. As usual, the tarnished taenite loses its bluish-gray tint in the heat-affected α_2 zone. It is here bordered by 10-20 μ wide bainite-martensite rims, presumably because carbon redistributed itself by the brief atmospheric reheating.

Schreibersite is common as 20-80 μ wide grain boundary precipitates and as 5-25 μ blebs inside the plessite fields, but no large crystals were observed on 80 cm². Rhabdites are very common, ranging from 1-30 μ in size, with the majority being prisms about 10 μ thick. The bulk phosphorus content is estimated to be 0.15-0.20%.

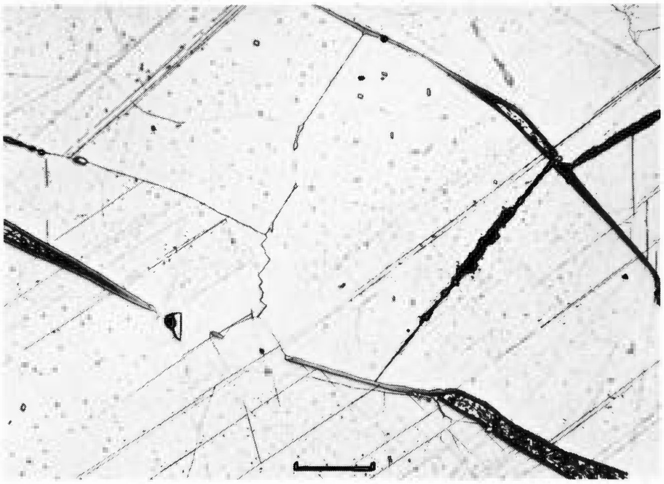

Figure 1347. Pan de Azucar. The Carrizalillo specimen (Oslo). A coarse octahedrite of group I. Taenite and plessite bands appear dark. Two fissures that follow cubic cleavage planes of the kamacite are at the right. Grain boundaries, subboundaries, rhabdites and Neumann bands are prominent, as usual, in group I. Etched. Scale bar 500 μ.

PAN DE AZUCAR – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Smales et al. 1967						13.0	172	15.1	82	308		
Wasson, 1971, pers. comm.	6.84								82.1	308	2.0	
Crocket 1972											2.8	8.9