Jenny's Creek, West Virginia, U.S.A.

37°54'N, 82°23'W; 180 m

Coarse octahedrite, Og. Bandwidth 2.2±0.4 mm. Neumann bands. HV 230±15.

Group I. 7.0% Ni, about 0.2% P, 84.6 ppm Ga, 320 ppm Ge, 2.3 ppm Ir.

HISTORY

Three oxidized fragments of about 1 kg, 10 kg and 587 g weight were found close together in 1883 and 1885 by Maston Christian in the creek bed of Jenny's Creek, a tributary to Tug Fork of Big Sandy River, in the extreme southern corner of Wayne County. The first two pieces were broken up and lost sight of, but the third was acquired by Kunz who described it with three figures of the exterior and of an etched slice (1886b). A brief description had already been given by Bailey (1885) who probably had obtained a 240 g fragment from one of the first found masses. Kunz believed that the meteorite had fallen about 1880 when trustworthy witnesses had seen a fireball disappear in the direction of Jenny's Creek, but this is out of the question considering the amount of heavy corrosion. Huntington (1894) believed that the mass originally was a part of Cosby's Creek which had been transported. This appears unlikely, since the original report of the find possesses all the marks of genuineness. Brezina (1896: 286) reported that the material in Vienna resembled Cosby's Creek and was slowly disintegrating into rubble. Farrington (1915) reviewed the literature.

COLLECTIONS

Vienna (587 g, from Kunz), New York (228 g, from Bailey), Chicago (131 g), London (79 g), Budapest (67 g), Harvard (32 g), Amherst (20 g), Bonn (17 g), Washington (14 g), Ottawa (11 g), Paris (10 g), Yale (6 g), Berlin (5 g). Minor, weathered fragments are in several other collections. The preserved weight appears to be about 1.3 kg.

DESCRIPTION

The three individuals found in the creek bed are probably fragments of a single mass that either burst when it struck the Earth or became separated through long-term corrosion. They are extremely ragged on the exterior faces, showing octahedral cleavage planes and heavy oxide crusts. No trace of fusion crust or heat-affected α_2 zone is preserved.

Etched sections display a coarse Widmanstätten structure of bulky, short ($\frac{L}{W} \sim 6$) kamacite lamellae with a width of 2.2±0.4 mm. Grain growth has progressed to a considerable extent, so that several almost equiaxial kamacite grains 8-10 mm in diameter may be found locally. The subgrain boundaries are prodigiously decorated with 0.5-2 μ rhabdites. Neumann bands are common, and the microhardness is 230±15. No plastic deformation is visible to account for this rather high hardness, compared to 170-180 for the kamacite of numerous other group I irons. However, slight cold-deformation will be detected by microhardness measurement before it can be seen in the microstructure.

Plessite covers 2-5% by area, mostly in form of comb plessite fields that are squeezed between the kamacite lamellae as typically 6 x 2 or 2 x 1 mm rhombohedral areas. The thicker taenite wedges are frequently decomposed to pearlitic (0.5-1 μ wide taenite lamellae) or spheroidized (2-5 μ spherules) aggregates. Locally a little acicular plessite occurs.

Schreibersite is present as 6 x 1.5 or 2 x 1 mm skeleton crystals and also as 50-150 μ grain boundary veinlets. It is monocrystalline but heavily brecciated, primarily due to terrestrial corrosion. Rhabdites are ubiquitous as 2-15 μ sharp prisms.

Remaining along the edge of U.S. National Museum specimen No. 46 is a 10 x 3 mm area that, although heavily corroded, is clearly a part of an original troilite-graphite nodule. The troilite is monocrystalline but interwoven by 2-10 μ wide pentlandite veinlets from corrosion, and it is bordered by a rim of 10 x 1 mm graphite in forms of sheaves with horsetail extinction. A few 60 μ cliftonite crystals are found in contact with the troilite. Locally, the graphite is intimately mixed with the troilite, which assumes shapes of 3-50 μ ragged, concave fragments embedded in sheaves of graphite. A trifle of 10-30 μ wide daubreelite lamellae, frequently brecciated, is present in the troilite.

The graphite-troilite nodule is surrounded by a broken rim of 0.4 mm schreibersite, followed by 0.4 mm cohenite with irregular pockets of troilite. The hardness of the cohenite is 1150±25. Cohenite is, no doubt, present as a significant mineral in other sections also, but its concentration may vary considerably from place to place as normally in the coarse octahedrites of group I.

Corrosion has, as mentioned, influenced the meteorite considerably. Troilite is partly converted to pentlandite, and 0.1-1 mm oxide veinlets in all grain boundaries facilitate greatly the mechanical separation of the mass in octahedral- to finger-shaped fragments. Selective corrosion is found around most near-surface rhabdites, and even ferritic subboundaries are attacked. The corrosion points to a high terrestrial age.

Jenny's Creek is a coarse octahedrite which structurally resembles Canyon Diablo, Cranbourne and Odessa and

JENNY'S CREEK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970a	7.0								84.6	320	2.3	

belongs to the chemical group I. It also resembles Cosby's Creek, wherefore various authors have suggested that they are paired falls. Since the distance between Cosby's Creek and Jenny's Creek is 260 km and both appear to be authentic localities it is improbable that Jenny's Creek can be part of the Cosby's Creek shower. Independent evidence to support this conclusion has recently been provided by Wasson (1970a) who found significant differences in the level of gallium and germanium.

Specimen in the U.S. National Museum in Washington:
14 g fragment (no. 46, 2 x 1.5 x 1 cm, from Kunz 1886)

Joel's Iron, Antofagasta, Chile
Approximately 23 1/2°S, 68 1/2°W

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Recrystallized. HV 155±5.

Group IIIAB. 8.60% Ni, 0.54% Co, 0.26% P, 22.6 ppm Ga, 43.6 ppm Ge, 0.26 ppm Ir.

Joel's Iron is an independent fall, different from other Chilean octahedrites.

HISTORY

This meteorite belongs to those the history of which is poorly elucidated. It was first mentioned in catalog entries from the British Museum as a native iron from Bolivia, e.g., in Story-Maskelyne (1877: 9): "No. 72. Found 1858. Atacama, Bolivia, South America. Weight 2 lbs. 14 oz. 299 grs." This corresponds to 1,323 g in the metric system. Under this name it was briefly discussed by Brezina (1885: 213-214, 234) who classified it as a medium octahedrite in his La Caille group.

Fletcher (1889: 263) stated that the 1,300 g mass had been found in some unspecified locality in the Desert of Atacama and had been presented to the British Museum in 1863 by Mr. Lewis Joel, the British Vice-Consul at Cobija. After this description had been published, the meteorite was called The Joel Iron (Fletcher 1889: 263) or Joel's Iron (Brezina 1896: 272, 277, 350; Wülfing 1897: 169; Hey 1966: 222).

Except for Fletcher's and Brezina's brief descriptions, virtually nothing is known about the mass. Brezina (1896: 350) gave the coordinate set 25°23'S, 70°2'W, while Hey (1966: 222) only stated "approximately 24°S, 69°W." Brezina's set is clearly incorrect, since it was based on the erroneous assumption that Joel's Iron was a paired fall with Cachiyual and, therefore, could be given Cachiyual's coordinates. Hey's set is better, since it takes into account the fact that the meteorite was acquired from the Antofagasta province which in 1858 was politically a part of Bolivia. Cobija, situated between Antofagasta and Tocopilla, was Bolivia's only harbor, but it was lost to Chile in 1883. It is now abandoned, but it was located only a few kilometers south of the present Gatico. It appears, then, that Joel's Iron originally came from the northernmost part of the Atacama Desert in the then Bolivian Antofagasta province. It is unfortunate that we cannot detect a precise location because it would help when discussing the possible relationship with other North Chilean octahedrites. However, as we shall see below, the unique combination of composition and microstructural characteristics clearly earmarks Joel's Iron as an iron unrelated to other Chilean irons. The locality of find, therefore, becomes less important and may, in the absence of anything better, here be adopted as the saltpeter mining district in the Desert of Atacama inland from Cobija.

COLLECTIONS

London (1,144 g main mass and 55 g slice), Chicago (43 g slice), Calcutta (18 g), Vienna (5 g), Paris (< 1 g).

DESCRIPTION

According to Fletcher (1889: 263), the mass is concavo-convex in form. "Although the meteorite is small, its surface has large deep cavities, one of them 40 mm in diameter, such as are shown by Ilimaë [Ilimaes (Iron)] : The large cavities are covered with small shallow pittings 1 or 2 mm in diameter."

A slice from this mass was kindly loaned to me by Dr. Hutchison, British Museum. It measured 55 x 35 x 4 mm

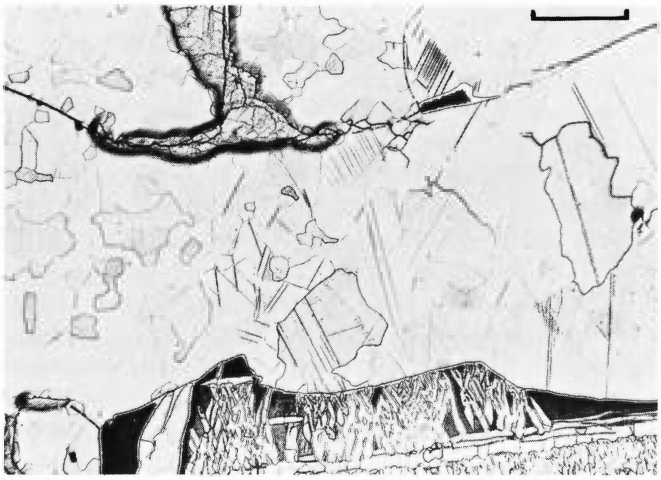

Figure 932. Joel's Iron (Brit. Mus. no. 35782). Recrystallized medium octahedrite, transitional between group IIIA and IIIB. Fissured schreibersite crystal above. Etched. Scale bar 400 μ.

JOEL'S IRON – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Fletcher 1889	8.80	0.54	0.26	tr.			tr.					
Scott et al. 1973	8.40								22.6	43.6	0.26	

Figure 933. Joel's Iron. Detail of Figure 932 under slightly crossed polars. The recrystallized grains are larger in the kamacite lamella than in the plessite field. Etched. Scale bar 200 μ.

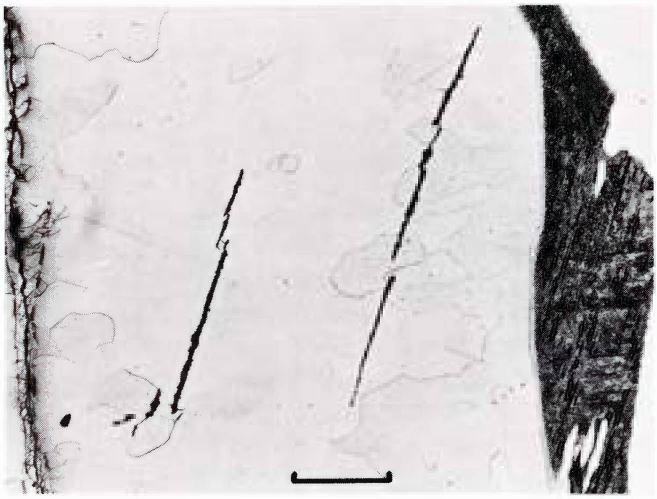

Figure 934. Joel's Iron (Brit. Mus. no. 35782). The fine cracks follow cubic cleavage planes of the original kamacite lamella and, therefore, antedate the recrystallization. Tempered plessite on the right and fissured schreibersite on the left. Etched. Scale bar 200 μ. See also Figure 105.

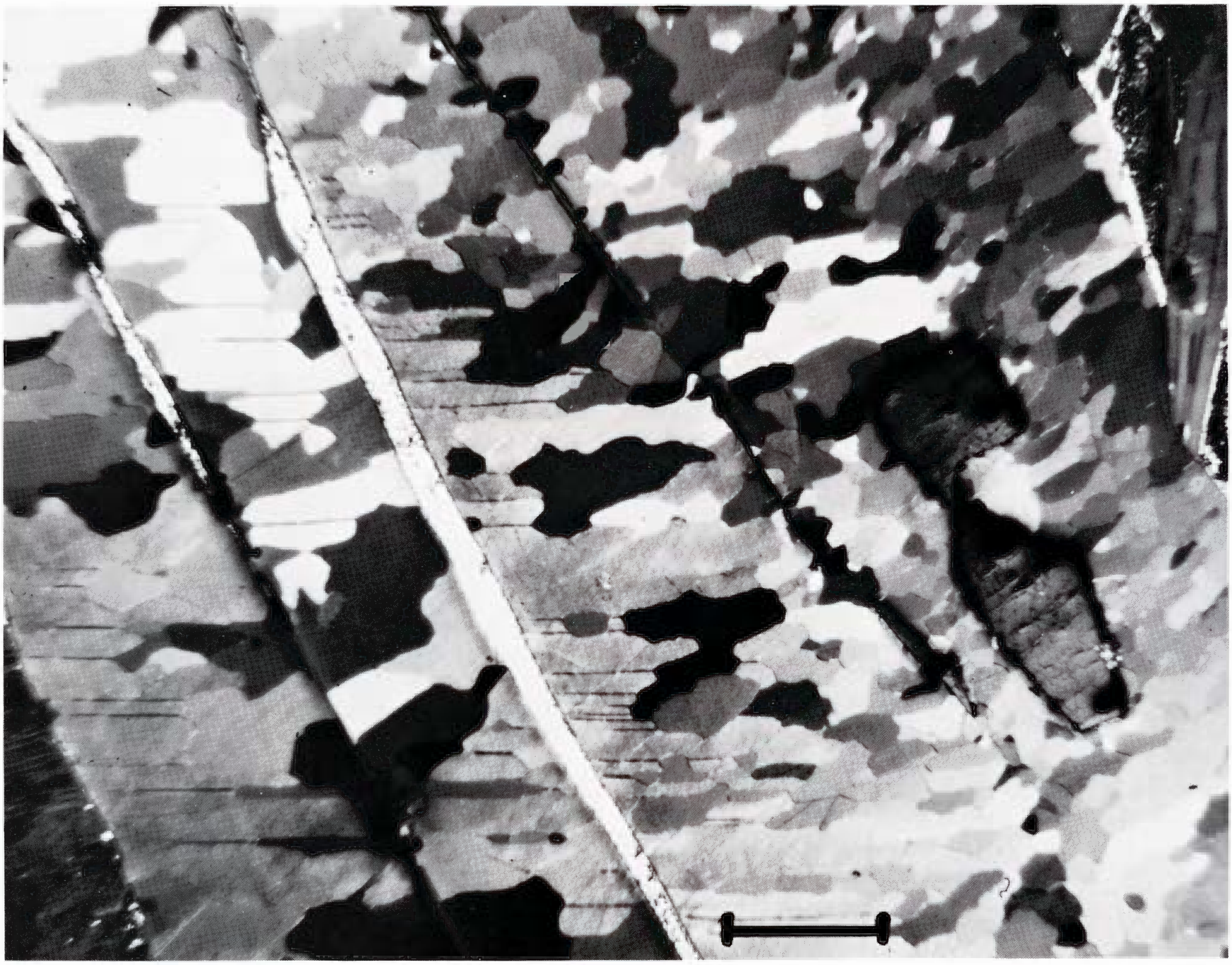

Figure 935. Joel's Iron (Brit. Mus. no. 35782). A part of the meteorite which is not entirely recrystallized: dark horizontal streaks are original Neumann bands. Three oblique taenite lamellae and two dark schreibersite crystals are also seen. Etched. Crossed polars. Scale bar 500 μ. See also Figure 219.

and weighed 55 g (Brit. Mus. no. 35782). When etched, it exhibited a medium Widmanstätten structure with straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.10±0.15 mm. The kamacite is recrystallized to almost equiaxial ferrite units, 50-500 μ across. Only local patches of non-recrystallized kamacite remains; enough, however, to disclose that the kamacite originally was rich in distorted Neumann bands. These are now visible as degenerated cellular structures with a few < 1 μ phosphide particles lining their boundaries. The recrystallized matrix covers about 99% by area and exhibits a low hardness of 155±5, corresponding to well-annealed material. A new generation of sharply delineated Neumann bands is present in some of the recrystallized grains, apparently as a result of deceleration and breakup (?) in our atmosphere.

Taenite and plessite cover 30-35% by area, mainly as comb and net plessite and as easily resolvable duplex mixtures of $\alpha + \gamma$. The taenite rims are slightly ragged and frequently rather wide, 5-25 μ. The taenite etches yellow without tarnishing and is soft (HV 165±5). There is no intercalated martensitic zone between taenite and the duplex interiors which have hardnesses of 195±10, depending on the grain size and nickel concentration. All observations are well explained on the assumption that the meteorite has been exposed to secondary cosmic reheating, leading to annealing.

Schreibersite is common as large angular crystals located in the interior of the kamacite lamellae. The skeleton crystals assume rectangular or dovetail shapes and measure for example 0.4 x 0.3 mm, 5 x 0.3 mm or 2 x 0.7 mm. Smaller schreibersite crystals, 20-60 μ wide, occur in the grain boundaries, and still smaller ones, 2-50 μ across, are found as an integrating part of the duplex plessite fields. Numerous very fine phosphide particles, 0.5-2 μ across, are scattered throughout the kamacite or situated on the grain boundaries of the recrystallized kamacite. The smaller phosphides, i.e., less than about 30 μ wide, display reaction halos in the form of minute 1-3 μ particles loosely attached to the phosphides. The small phosphides are nickel-rich (30-40%) and have apparently regulated their nickel-content downwards during annealing by the precipitation of fine γ-particles.

Troilite was not observed in the section available. The "troilite reaching 5 mm in length" (Fletcher 1889: 263) is probably a misinterpretation of the schreibersite crystals located in the kamacite and parallel to its edges.

The sample shows one major and numerous minor cracks. The major crack follows a plane rich in large phosphides. It is now severely corroded and little can be said of its origin. There are, however, numerous minor fissures that are old. They are typically 0.1-1 mm long and 1-10 μ wide; they follow the cubic cleavage planes of the kamacite and are now partially filled with corrosion products. They are surrounded by many recrystallized grains which developed after the cracks had formed.

The schreibersite crystals are heavily sheared and brecciated. They are often displaced 1-10 μ and prove independently that the meteorite has been exposed to a heavy shock. Since recrystallization of the kamacite took place after the fissuring, and since no artificial reheating has taken place, the cracks must date back to a preterrestrial, cosmic event, perhaps associated with the release from the parent body. Joel's Iron provides a good example of an iron meteorite which has circled for millions of years in cosmos with numerous internal cavities and fissures. Another example is Russel Gulch.

Joel's Iron still exhibits 2-3 mm thick heat-affected α_2 zones. The α_2 forms serrated units, 10-50 μ across; in the outermost part micromelted phosphides are present. The hardness is 230±15; a rapid drop through 50-80 units occurs at the transition from α_2 to the recrystallized kamacite of the interior (hardness curve type III).

Joel's Iron is a recrystallized medium octahedrite, transitional between group IIIA and group IIIB. It is chemically closely related to, e.g., Cleveland and Plymouth, and it also has certain recrystallization features in common with the last mentioned.

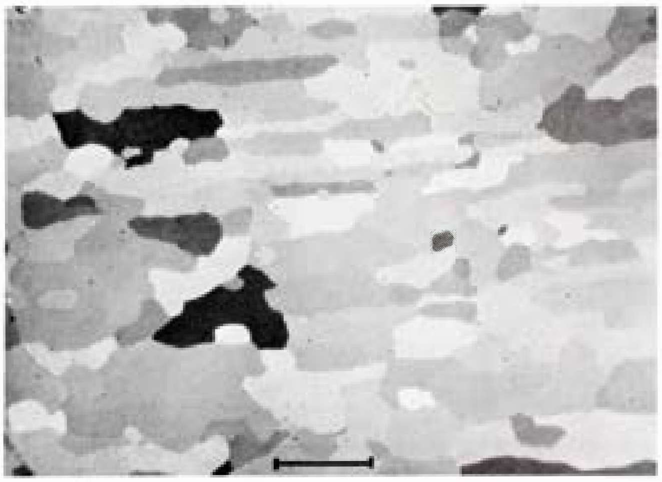

Figure 936. Joel's Iron (Brit. Mus. no. 35782). Fully recrystallized portion, with strong orientation from former Neumann bands. Etched. Crossed polars. Scale bar 300 μ.

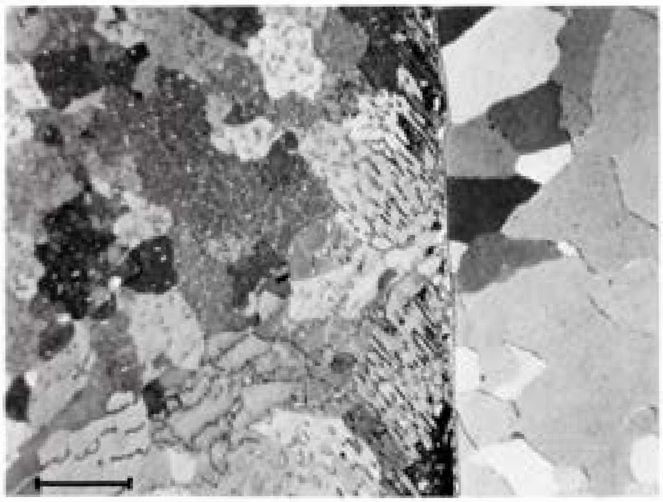

Figure 937. Joel's Iron (Brit. Mus. no. 35782). Spheroidized plessite field (left) and kamacite lamella (right), both fully recrystallized. Etched. Crossed polars. Scale bar 200 μ.

Figure 938. Joel's Iron (Brit. Mus. no 35782). A schreibersite crystal surrounded by minute exsolved γ-particles (white). Below, a tempered plessite field with a clear taenite rim. Etched. Scale bar 20 μ.

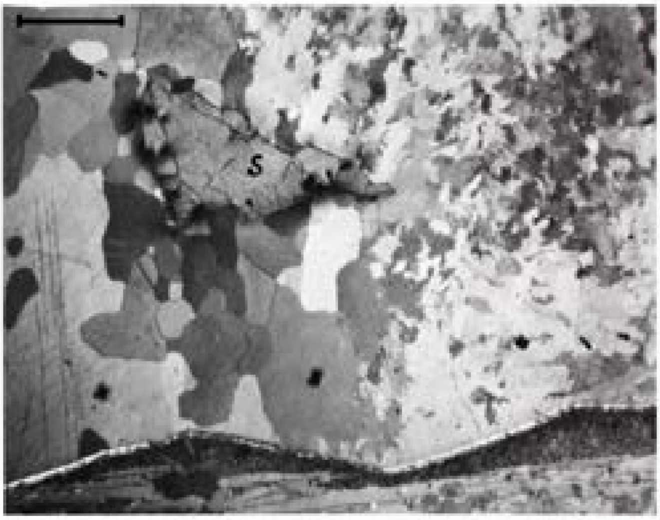

Figure 939. Joel's Iron (Brit. Mus. no. 35782). Heat-affected zone to the right, consisting of granulated, unequilibrated α_2 units. Unaffected recrystallized interior to the left. Schreibersite (S). Etched. Crossed polars. Scale bar 300 μ.

With regard to the possible pairing with other Chilean octahedrites, it is difficult to arrive at a conclusion on a chemical basis alone, since Joel's Iron resembles Baquedano, Chañaral, Ilimaes (Iron), Sierra Sandon and Tamarugal too much. However, the structural features, as discussed above, prove unambiguously that Joel's Iron must represent an individual fall. The partial preservation of the heat-affected α_2 zone may, in addition, suggest that Joel's Iron, which has been exposed to similar climatic conditions as the other Atacama meteorites, is a more recent fall.

Joe Wright Mountain, Arkansas, U.S.A.

Approximately 35°46'N, 91°32'W; 150 m

Medium octahedrite Om. Bandwidth 0.85±0.20 mm. Distorted Neumann bands. HV 280±25.

Group IIIB. 9.16% Ni, 0.51% Co, 0.47% P, 0.6% S, 20.1 ppm Ga, 35.5 ppm Ge, 0.015 ppm Ir.

Only one individual known, found in 1884.

HISTORY

A mass of 42.7 kg was found in 1884 by George W. Price on a small hill known as Joe Wright Mountain, about 11 km east of Batesville, in Independence County. The meteorite was found on the surface in a place where several gullies met (Hidden 1886b). Unfortunately the exact locality is difficult to pinpoint, since the name does not appear on modern maps (1:24,000), and Hidden gives conflicting statements, namely, "seven miles east of Batesville . . . and the town of Sulphur Rock is about three miles distant, southwest, from the place of discovery." The coordinates given above are, therefore, approximate. A second individual of 9.4 kg was reported to have been found in 1938 in Section 21, Township 15N, Range 6W (Nichols 1939; Hey 1966: 222). The coordinates of this locality are 35°56'N, 91°38'W, so the distance from the first reported find must be at least 20 km. During this work I examined the second mass and found it to be an individual meteorite. It will be described under the name Sandtown.

Hidden (1886b) described the first mass and presented two figures. Cohen (1891) gave a short description with an analysis. Brezina (1896; 1904a) gave a more complete description and measured the traces of the Brezina and the Reichenbach lamellae. Ward (1904a: plate 2) gave a photomacrograph. Thode et al. (1961) examined the sulfur isotopes.

COLLECTIONS

The main mass was for a short while in the collection of Banquier Zwiklitz but came to Vienna before 1889 (33.1 kg). Washington (541 g), Amherst (422 g), Rome (375 g), London (372 g), New York (277 g), Chicago

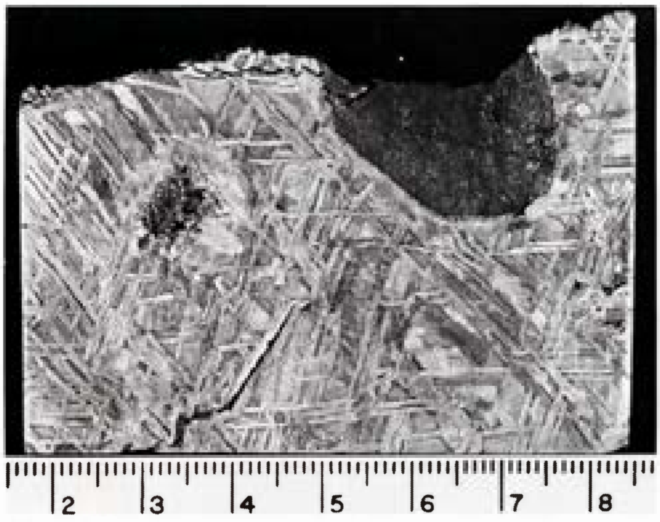

Figure 940. Joe Wright Mountain (Tempe no. 484.1). A medium octahedrite of group IIIB. A large troilite nodule with a narrow schreibersite rim. Slightly deformed kamacite lamellae. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

(265 g), Bonn (240 g), Stockholm (163 g), Prague (137 g), Berlin (125 g), Yale (104 g), Tempe (96 g), Paris (96 g), Moscow (86 g), Vatican (78 g), Harvard (75 g), Strasbourg (26 g).

DESCRIPTION

The 42 kg meteorite is an oblong, pitted mass with the average dimensions 40 x 20 x 15 cm. The pits are 2-5 cm in diameter, and although they may roughly represent the original regmaglypts, they are considerably modified by later corrosion. The fusion crust and the heat-affected α_2 zone are lost, and the surface is covered with 0.5-1.5 mm thick, adhering, terrestrial oxides. A hole, about 4 cm long and 1.5 cm wide, through one edge probably represents the site of a troilite nodule that was burned out in the atmosphere.

Etched sections display a Widmanstätten structure which in places is rather distorted. The lamellae are irregular, long ($\frac{L}{W} \sim 25$) and 0.85±0.20 mm wide. The Neumann bands are locally severely distorted. Also common are macroscopic deformation bands as well as a microscopically visible flow of hardened kamacite around the larger schreibersite inclusions. The latter have obviously acted as passive, brittle obstacles to the plastic movement of the surrounding kamacite. The schreibersite crystals are often brecciated, sheared and displaced 20-50 μ. The microhardness of the kamacite is 280±25 in harmony with the considerable cold-working.

Plessite occupies about 40% by area, partly as comb plessite, partly as martensitic plessite repeating the (111) directions of the Widmanstätten structure, and partly as duplex $\alpha + \gamma$ structures of varying fineness. When the duplex $\alpha + \gamma$ becomes so fine to be barely resolvable under the optical microscope, the impression is that of a dark-etching mess, which often has been called "black taenite."

Schreibersite occurs as scattered Brezina lamellae in a dodecahedral arrangement. They are typically 30 x 5 x 1 mm but are not as dominant as in Chupaderos and Bear Creek. They are brecciated but monocrystalline. They often display internal, 2-20 μ wide, very long veinlets of troilite with a little metal. Corrosion has, however, frequently altered these veinlets to limonite. Schreibersite is further common as 20-50 μ grain boundary precipitates and as 1-20 μ angular blebs in the plessite interiors. The finer the duplex $\alpha + \gamma$ structure, the finer are the schreibersite nodules. Rhabdites were not observed.

Troilite occurs as 5-30 mm nodules which have 0.5 mm schreibersite rims and an exterior 1-2 mm wide zone of swathing kamacite. Particularly characteristic for Joe Wright Mountain are the numerous Reichenbach lamellae that occur with a frequency of one per 15 cm^2. They are slightly distorted or undulating and typically 25 x 5 x 0.05 mm, so they are, in fact, paper-thin lamellae. They are selectively corroded, but in places remnants of troilite and schreibersite may be found. Originally they were probably troilite lamellae upon which some schreibersite precipitated. Later a zone of swathing kamacite developed asymmetrically on the two sides of the lamellae, and still later the Widmanstätten structure formed around them. Brett & Henderson (1967) have discussed the Reichenbach lamellae from some irons in which they were better preserved; see also Cleveland and Kayakent herein.

Joe Wright Mountain is a medium octahedrite, with Reichenbach lamellae, closely related to Cleveland and Ilinskaya Stanitza. Judging from the structure and confirmed by Wasson's analysis, it is a group IIIB iron, intermediate between Cleveland and Grant.

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

282 g part slice (no. 139, 13 x 9 x 0.4 cm)
114 g part slice (no. 354, 6.5 x 5 x 0.5 cm)
105 g part slice (no. 2842, 6 x 6 x 0.4 cm)
40 g minor slices (nos. 1049, 1654, 2842)

JOE WRIGHT MOUNTAIN – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	9.22	0.51	0.47	140	50							
Scott et al. 1973	9.10								20.1	35.5	0.015	

Jonesboro, Tennessee, U.S.A.

36°18′N, 82°28′W

A single piece of 30 grams was offered for sale by Ward's Natural Science Establishment (Ward 1892: 15) and purchased by Vienna (Berwerth 1903: 18). It was described by Brezina (1896: 272) and Cohen (1905: 388) who assumed it was an independent meteorite from the vicitinity of Jonesboro in Washington County.

From their descriptions, it appears that the material was a weathered fragment of a normal fine octahedrite of group IVA. Major masses of several fine octahedrites have been discovered in the Appalachian Mountains, not far from Jonesboro: Bristol somewhat to the north, Duel Hill (1854) somewhat to the south, and Wood's Mountain somewhat to the east. From the reported structural details, it appears most plausible that Jonesboro was a weathered fragment of Duel Hill (1854); this supposition could be easily checked by a modern metallographical comparison. It is almost certain that Jonesboro is not an independent meteorite, as it is hardly likely that the zealous collector, H.A. Ward, would have sold the only known sample to Vienna.

Juncal, Atacama, Chile

Approximately 25°50′S, 69°3′W

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. ϵ-structure. HV 310±15.

Group IIIA. 8.1% Ni, 0.21% P, 20.5 ppm Ga, 41.2 ppm Ge, 1.8 ppm Ir.

HISTORY

A mass of 104 kg (or more likely 107 kg; see below) was found in 1866 by Lisaras Fonseca near the watershed on the western side of the Alta Cordillera of the Andes between Rio Juncal and the dried up Salinas de Pedernal. Fonseca was mineral exploring when he spotted the large black mass close to the road. Thinking it to be silver, he decided to take it to Copiapo; but on his arrival there he learned of its true nature. Fonseca was of the opinion that the mass had been moved previously by a party of miners from the other side of the Andes and then abandoned with the intention of removing it later. The meteorite was acquired by the government of Chile and presented to France where it was exhibited in 1867 at the Paris Exhibition as the main attraction of a large Chilean mineral collection (Daubrée 1868a; Buchner 1869: 609; Domeyko 1879: 129; Fletcher 1889: 261). Fletcher (ibid.) discussed the localities and presented a sketch map from which the above quoted coordinates are taken.

Brezina (1880b) examined the Reichenbach lamellae and presented two macrographs of etched sections. Later (1885: 204 and plate 3) he showed that a 1-1.5 mm thick heat-affected zone was partially preserved. He noted that fusion crust was present, and he assumed erroneously that Juncal was a paired fall with Cachiyual and Ilimaes (Iron) (1885: 212; 1896: 278). Wülfing (1897: 171) summarized the literature. After that apparently no work has been published on material from Juncal, except for the recent analysis quoted below.

COLLECTIONS

Paris (main mass of 104.8 kg), Vienna (871 g), Budapest (200 g), New York (165 g), Chicago (110 g), London (72 g), Berlin (57 g), Rome (30 g), Prague (26 g), Vatican (24 g), Hamburg (19 g), Strasbourg (12 g), Amherst (11 g), Stockholm (8 g), Bonn (3 g). The total weight is thus about 106½ kg. Including loss during the cutting operations and loss in analytical work, etc., the mass must originally have weighed about 107 kg.

DESCRIPTION

According to Daubrée (1868a) the mass is irregularly cone-shaped, 48 cm long and with a 19 cm wide elliptical base. The surface is marked by numerous depressions and pits which are the result of atmospheric sculpturing during flight plus salt desert corrosion.

The following examination was carried out on a near-surface section which was purchased in May 1892 from the mineral dealer, J. Böhm in Vienna, by the British Museum (no. 68580). Böhm probably got his material from Brezina at the Museum of Natural History in Vienna. The specimen is an endpiece which measures 7 x 4 x 0.9 cm and weighs 70 g; no part of the etched section is more than 0.9 cm distant from the natural surface. The surface is only slightly corroded. Regmaglypts, 2-3 cm across, are clearly marked, and minute amounts of a warty but corroded fusion crust are preserved in places. Elsewhere the corrosion has primarily attacked the kamacite phase so that taenite and plessite stand in low relief and form a distinct Widmanstätten grid.

The etched section confirms the good state of preservation. The heat-affected α_2 zone is 1-2 mm thick although lost completely in some places. The α_2 forms serrated units that are very small, 2-25 μ across, because they were created from a preexisting shocked ϵ-structure. The hardness is 200±10. Below the transition α_2/ϵ the hardness rapidly increases to the interior level of 310±15 (hardness curve type I).

Juncal is a medium octahedrite displaying straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.10±0.15 mm. The kamacite has subboundaries with a few small phosphide precipitates. It is, due to shock above 130 k bar, transformed to the densely hatched ϵ-type of high contrast and hardness (310±15). No cosmic annealing has taken place after the shock-hardening.

Taenite and plessite cover about 35% by area, mostly as comb and net plessite fields. The taenite lamellae and rims are tarnished and of high hardness (HV 385±10) except in the heat-affected α_2 zone where they are yellow and soft. A typical plessite field will display a tarnished taenite rim (HV 385) followed by a martensitic transition zone (HV 415±15). Next follows duplex unresolvable $\alpha + \gamma$ mixtures ("black taenite," HV 355±20) and, finally, easily resolvable $\alpha + \gamma$ mixtures with 1-2 μ γ-blebs (HV 310±15).

Schreibersite is common as up to 0.1 mm wide grain boundary veinlets and as 5-50 μ wide, vermicular precipitates inside the plessite fields. Locally, the schreibersite veinlets are continuous for several millimeters. Rhabdites proper are absent.

The Reichenbach lamellae were described and pictured by Brezina (1880b) at an early date. To his description may be added that they are generally 5 to 20 mm long and 0.05-0.1 mm wide. Their examination is difficult because they are always first to corrode, presumably because they are microfissured and provide easy lanes for terrestrial groundwater. Samples examined here indicate that the

JUNCAL – SELECTED CHEMICAL ANALYSES

Daubrée (1868a) quoted an analysis by Damour which yielded 7.00% Ni, 0.62% Co and 0.21% P. While good for its day, only the phosphorus value can be accepted today.

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	8.05								20.5	41.2	1.8±0.3	

backbone of a Reichenbach lamellae consists of a 20-50 μ thick chromite foil upon which minute blebs of troilite and schreibersite have successively precipitated. The troilite is either monocrystalline with undulatory, patchy extinction, or it is an irregular polycrystalline aggregate of 5-20 μ grains. Brezina (1880b) believed that the Reichenbach lamellae consisted exclusively of troilite; however, this seems not to be the case. Chromite appears, in fact, to be the primary mineral which has determined the crystallographic orientation parallel to $\{100\}$ of the parent austenite. Not until later were troilite and schreibersite precipitated upon the lamellae.

Large troilite nodules were not observed in this study. They are nevertheless present, since they have been reported as imperfect cylindrical inclusions on the main mass (Daubrée 1868a; Domeyko 1879).

Juncal is a shock-hardened medium octahedrite of group IIIA. It is particularly closely related to Kayakent which it resembles in almost every respect. It is also related to Bagdad, Veliko-Nikolaevsky Priisk, Thule and Merceditas, but it is not a paired fall with any of the Chilean octahedrites described in this work and definitely not with Cachiyual. Between the two closest possibilities, Merceditas and Juncal, there are significant differences in macrostructure (Reichenbach lamellae), microstructure (schreibersite development) and chemical composition (Ni, P, Ir).

Juromenha, Alentejo, Portugal

38°44′25″N, 7°16′12″W; 150 m

Ataxite, D. Polycrystalline kamacite with a grain size of 0.07 mm. HV 170±15.

Group IIIAB. 8.7% Ni, 0.52% Co, about 0.3% P, 21 ppm Ga, 40 ppm Ge, 0.24 ppm Ir.

HISTORY

A mass of 25.2 kg was observed to fall near Alandroal at 17:55 GMT on November 14, 1968. The fireball had traveled from southwest to northeast, accompanied by an intense glow visible for two or three seconds. No luminous train and no smoke trail were observed, but the farmers near the impact site heard a violent noise which they compared to the firing of guns. The meteorite made a funnel-shaped hole about 60 cm deep and 60 cm wide at the top, in slightly moist, cultivated soil. It was located immediately, but since it seemed to be incandescent, it was left in the hole until the next morning at 11 a.m. when it was still warm. The exact place of fall was on the Herdade de Tenazes farm about 3 km from Juromenha, with the coordinates given above (Teixeira 1968b; Smithsonian Institution, Center for Short-Lived Phenomena, Event Reports of Dec. 2, Dec. 26, 1968, and Jan. 17, 1969; Krinov:Meteoritical Bulletin, No. 45, 1969).

It is surprising that so many eyewitness reports agree that meteorites are still "incandescent" when they have landed. While a real incandescence based upon high temperature can almost certainly be ruled out – the small meteorites fall sufficiently slowly in their last part of the trail to become effectively air-cooled – it may be that ionization phenomena of a luminous character occur in the surface crust of the meteorite immediately after its fall and that such phenomena, viewed at night, could frighten the casual observer. Or is the human imagination sufficiently vivid to create light out of nothing?

The meteorite was acquired by the Department of Mineralogy and Geology, Faculty of Sciences, Lisbon from where a 128 g sample was rapidly dispatched to the Smithsonian Astrophysical Observatory in order to have the short-lived isotopes measured. Preliminary results have been published by Fireman (Transactions American Geophysical Union, Volume 50, 1969: Abstract P-56), Stoenner & Thompson (ibid.: Abstract P-51), and Fireman (1969), who also gave two photomacrographs of the specimen examined. A detailed investigation by Fireman & Goebel (Smithsonian Astrophysical Observatory, August 1969: Preprint 906-164) reported an anomalous amount of ^{37}Ar, ^{39}Ar and

Figure 941. Juromenha. The main mass shows soft contours and a depression which is subdivided in angular regmaglypts. The shape is typical for a large number of medium-sized iron meteorites. Scale approximately 5 cm. (From Teixeira 1968b.)

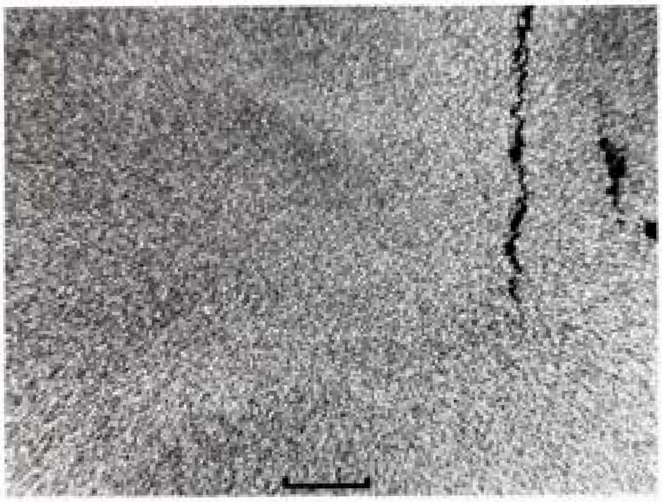

Figure 942. Juromenha (U.S.N.M. no. 3543). A general view of the structure. The surface is just above the picture, and a hot crack extends through the heat-affected A-zone. Etched. Scale bar 500 μ.

^3H. They calculated the cosmic radiation age to be 33.6±1.3 million years and suggested that the meteorite had moved in a very eccentric orbit. Comerford (1970: personal communication) examined the structure and found it quite similar to that of Washington County. Quantitative X-ray diffraction analysis indicated that the fine-grained α- and γ-grains showed preferred orientations to a significant degree.

COLLECTIONS

Lisbon (main mass), Washington (16 g).

DESCRIPTION

According to Teixeira (1968b) who gave two photographs of the exterior, the mass is a somewhat flattened ellipsoid with the dimensions 30 x 20 x 10 cm in three perpendicular directions. One surface is rather smoothly domed. The opposite surface was apparently the same at an earlier stage, but it is now partly excavated by distinct regmaglypts, 2-4 cm across. The small specimen in the U.S. National Museum is cut from a knob on the 25.2 kg main mass and, therefore, possesses a high amount of heat-affected rim zone. It has a composite 0.2-0.5 mm thick fusion crust of oxides and metallic melts; the laminated metal occurs in successive, dendritic-columnar sheets, each on the average 50 μ thick. They wedge out irregularly, so the fused oxides may be deposited directly on the unmelted metallic matrix. The oxide crust is two-phased, composed of wüstite, FeO and magnetite, Fe_3O_4. The optical examination indicates that wüstite formed at high temperatures (~ 1370° C, see the Fe-O equilibrium diagram by Darken & Gurry 1946) as a polycrystalline aggregate of 10-20 μ grains. Upon cooling it partially decomposed by a solid state reaction to magnetite which nucleated and grew along the grain boundaries and now forms 5-10 μ wide zones here. Magnetite was further nucleated in the interior and grew to form 1-5 μ wide, cubic skeleton crystals. In the last part of the flight the oxygen pressure apparently was sufficient to oxidize the exterior wüstite grains to a continuous sheet of magnetite, 10-100 μ thick. The wüstite did not further decompose at 570° C (to α-iron and magnetite) but was preserved as a metastable phase due to the rapid cooling.

Numerous, 2-15 μ metallic spherules which are only partially oxidized are embedded in the oxide fusion crust. Numerous 1-10 μ oxide spherules are embedded in the fused metal laminae.

The unmelted metallic matrix is, to a depth of 3-5 mm, transformed to α_2 with a microhardness of 200±10 (hardness curve type II). Micromelted phosphides are present in the exterior 50% of this zone. The phosphides form 0.1-1 μ thick liquid films that penetrate and weaken the polycrystalline structure to such an extent that several intercrystalline hot cracks have developed in the exterior 1.5-2.5 mm of the meteorite's rim. Some of these fissures are covered with 1-2 μ thick oxide crusts, presumably the results of the attack by hot gases during flight. The fissures are only to an insignificant extent filled with oxide melts.

Etched sections display a matte, ataxitic structure which is stained in an irregular way. Several cavities measuring up to 7 x 5 x 2 mm in aperture, are conspicuous

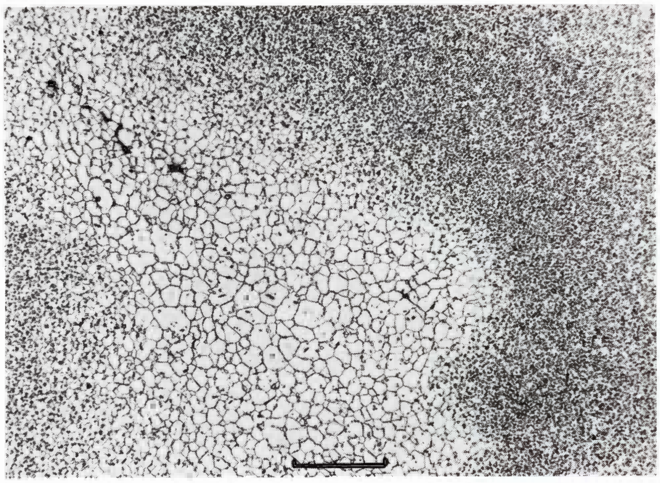

Figure 943. Juromenha. Detail of Figure 942, showing different α-grain size and different particle concentration in adjacent areas. Etched. Scale bar 300 μ.

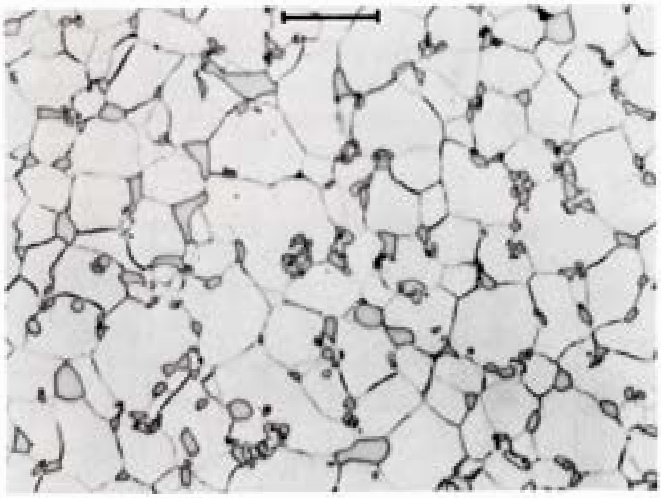

Figure 944. Juromenha. Detail of open-meshed structure in Figure 942. The particles are of two kinds: angular phosphides and irregular cavernous taenite amoebae. Etched. Scale bar 40 μ. See also Figure 116.

JUROMENHA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Stoenner & Thompson 1969	8.6	0.52										
Scott et al. 1973	8.81								21.2	40.3	0.24	

and to a certain degree interconnected. They are situated below the heat-affected zone and have no openings to the surface. They are empty, but, since the meteorite was not cut in this laboratory, it is not known whether they were empty from the beginning. It appears, however, that the cavities are genuine and preatmospheric. The convex smooth walls seem to indicate that they were created at high temperature, either representing pores that were never closed by sintering or, more likely, shrinkage holes from a rapid solidification. Since these cavities are the largest and best documented ever seen in an iron meteorite, they deserve a thorough study. On the other hand, the cavities cannot occupy any large volume fraction, because Teixeira (1968b) reported a specific gravity of 7.82 which is similar to unaltered octahedrites of the same bulk composition.

Juromenha is polycrystalline with grain sizes comparable to those of technological steel alloys. The kamacite is equiaxial and 30-100 μ across in the light etching main part but only 10-25 μ across in the dark stained patches, which

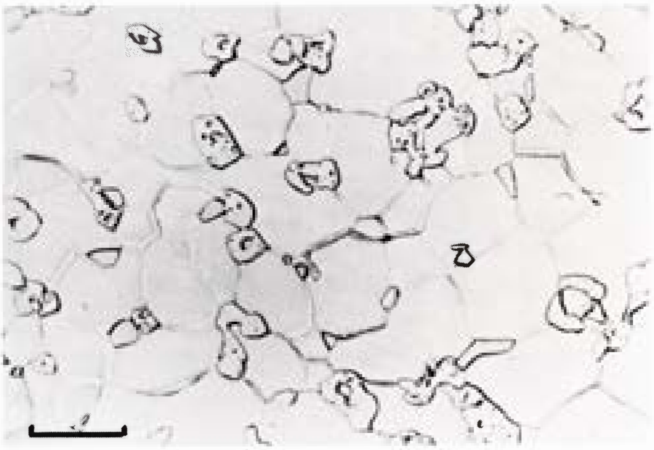

Figure 945. Juromenha. Detail of an area rich in cavernous γ-amoebae. Angular phosphides are often in direct contact with the γ-particles. Etched. Oil immersion. Scale bar 20 μ.

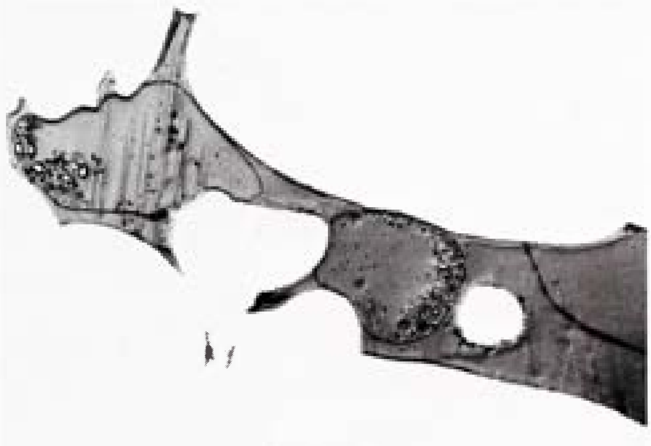

Figure 946. Juromenha (U.S.N.M. no. 3534). An internal cavity. An extremely anomalous occurrence in the otherwise fully massive iron meteorites. (The internal "structure" of the cavity is due to filling with plastic cement). Polished. Scale bar 1 mm.

may be 0.5-1 mm across. The difference between light and dark parts lies partly in the grain size but largely in the taenite population. The taenite bodies, which are subangular, cavernous, amoebae-like blebs, are mainly located in the grain boundaries and constitute about 3% by area in the light areas but 15-25% in the dark areas. The taenite ranges in size from 2 to 10 μ, and in numbers from 800 to 4,000 per mm^2. The morphology and density suggest that the light-etching areas were once kamacite while the dark-etching areas were taenite and plessite. According to the analytical information available it appears that the light- and dark etching areas represent the indistinct remnants of kamacite and plessite areas in a medium octahedrite that originally had a structure similar to Cleveland, Lenarto or Ruff's Mountain.

The microhardness of the kamacite grains is 170±15, measured at a depth of 10 mm; this is still a little too close to the curved surface to be regarded as the unaffected interior.

Phosphides are common as angular and wedge-shaped precipitates, 1-15 μ across, that are mainly located in the kamacite grain boundaries. They are frequently intimately associated with the taenite amoebae but are easily distinguished by their higher hardness (~ 900), clear interior and straight to concave outlines. The bulk phosphorus content is estimated to be 0.30±0.05%. Locally, a larger concentration of angular, concave phosphides is observed, frequently associated with 5-50 μ subangular chromite grains and indistinct, 1-2 μ wide troilite filaments. The morphology suggests that this was once the location of a millimeter-sized schreibersite crystal associated with minor chromite and troilite inclusions. Such inclusions are known to occur in the related octahedrites, Cleveland and Luis Lopez. On the other hand, large troilite inclusions are apparently absent.

Juromenha is structurally anomalous. The observations seem to indicate that it was originally a normal medium octahedrite but that a violent cosmic event altered its structure. My feeling is that a rapid heating to peak temperatures of 1400-1500° C, immediately followed by rapid cooling, could produce the kind of disorder observed.

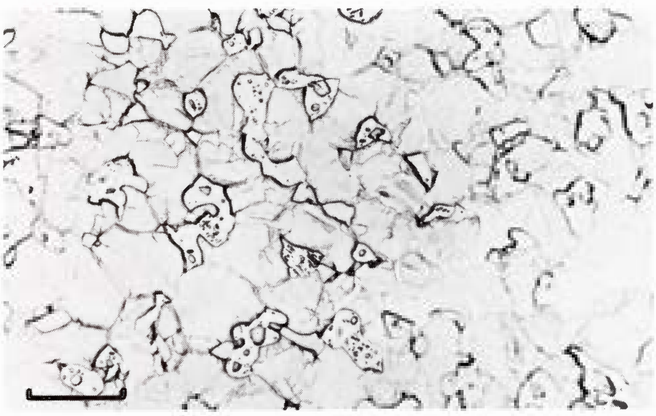

Figure 947. Juromenha (U.S.N.M. no. 3534). Detail of the heat-affected surface zone with unequilibrated α_2, but unaffected γ- and phosphide-particles. Etched. Oil immersion. Scale bar 20 μ.

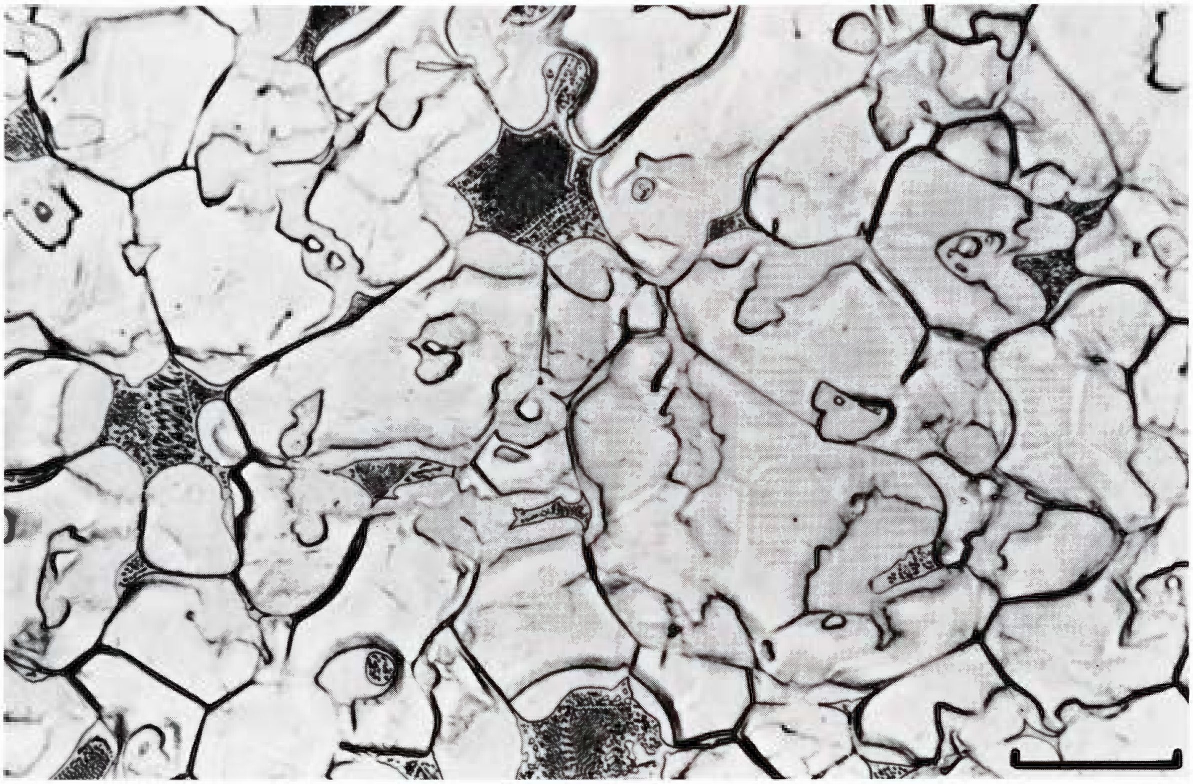

Figure 948. Juromenha (U.S.N.M. no. 3534). Detail of the heat-affected zone A, with fused phosphides. Even the taenite particles are almost resorbed. Etched. Oil immersion. Scale bar 20 μ.

It would account for the decomposition of the kamacite, taenite, phosphide, troilite and chromite, and might explain the preferred orientation observed by Comerford (personal communication) as being due to surviving, original building blocks. It would, furthermore, explain the anomalous variation in population densities of taenite and phosphides, which does not resemble segregation from a liquid pool but rather reflects the original distribution of taenite and phosphide. That melting and solidification occurred rapidly is also suggested by the presence of the shrinkage cavities mentioned above.

I do not know whether such a cosmic rapid melting in situ, where a homogeneous melt was never created, can occur. It seems to me, however, that other iron meteorites display cosmic shocking and reheating to various degrees; from mild reheating with no melting, through medium reheating with inclusions melting (e.g., Indian Valley, Reed City) to violent reheating with complete melting and

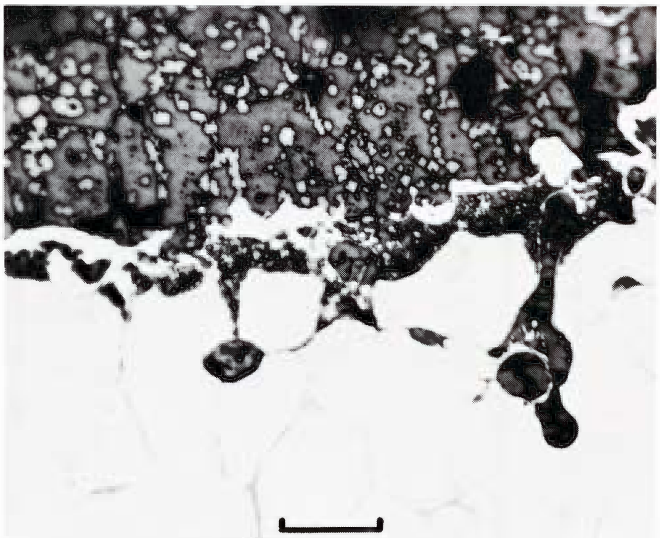

Figure 949. Juromenha (U.S.N.M. no. 3534). Fusion crust of iron oxides, with cubic skeleton crystals of magnetite (white) in undecomposed wüstite (dark gray). Lightly etched. Scale bar 20 μ.

Figure 950. Juromenha (U.S.N.M. no. 3534). Fusion crust of iron oxides, underlain by a cream-yellow nickel-rich metallic fusion crust (N). Further inwards the heat-affected A zone displays shrinkage holes (black) in the melted schreibersite pockets. Etched. Scale bar 20 μ.

homogenization (Nedagolla). Juromenha might, with Santiago Papasquiaro, Washington County and a few others, belong to a group which only just melted and then cooled very rapidly.

Finally, it is only correct to point out that we do not have a classification term for Juromenha and its relatives. Nickel-rich ataxite has been used but mainly as an emergency, since these irons are not nickel-rich. Ataxite alone may solve the problem temporarily, remembering that the definition of the term exactly covers what we see: no structure at low magnification.

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

16 g corner with polished faces (no. 3534, 18 x 17 x 15 mm)

Kaalijärv, Saaremaa (Ösel), Estonian S.S.R.

58°24'N, 22°40'E

Coarse octahedrite, Og. Bandwidth 2.0±0.4 mm. ε and recrystallized. HV 160-300.

Group I judging from the structure. 6.6% Ni, 0.41% Co, about 0.20% P.

HISTORY

The small group of craters called Kaalijärv is located 20 km northeast of Kingisepp (Kuressaare) on the island of Saaremaa (= Ösel). The craters were described as early as 1827 by von Luce, but it was not until a hundred years later that Reinvald & Luha (1928), mining engineers, proved their meteoritic origin. The excavations by Reinvald and others have been summarized by Spencer (1938) with a full bibliography. Further work was described by Reinvald (1938; 1939; 1946) who also proposed the construction of pavilions over some of the craters to protect them. So far nothing has happened. Zavaritskij & Kvasha (1952) examined two of the small fragments excavated by Reinvald and presented structural sketches. Aaloe (1958; 1963) and Krinov (1960b; 1961) reexamined the crater field and gave a full account with numerous photographs and cross sections through the craters. Krinov (1966a) summarized the previous investigations in English.

Yudin & Smyshljajev (1963) and Yudin (1968) described the structure of some of the better preserved fragments and gave photomicrographs. Yudin (1968) suggested on this evidence, that Kaalijärv was an enstatite achondrite related to Norton County. This view is not supported by the present examination. Short & Bunch (1968) compared the craters to other known meteorite craters, and Dietz (1968) reported the discovery by Krinov of small dolomitic shatter cones in the main crater. Kaalijärv is thus the only known example of an accepted meteorite crater from which both shatter cones and meteoritic fragments have been identified.

The crater field consists of a circular main crater, 110 m in diameter, and six small craters – or rather impact holes – ranging from 12 to 50 m in diameter. The distance between the main crater in north-northwest and crater No. 3 in south-southwest is about 1 km and the largest distance between the impact holes in a direction perpendicular to this is 0.6 km. The main crater has at present a bottom which is 9-10 m lower than the surroundings and a rim which is raised 6-7 m above the surroundings. The Silurian dolomite outcrops, which are horizontal where undisturbed, rise at angles of 60° in the crater wall. In the lower part of the crater the dolomite is totally crushed to a stone flour similar to that known from Canyon Diablo, but the minerals and their possible high pressure transformation products have apparently not yet been fully examined.

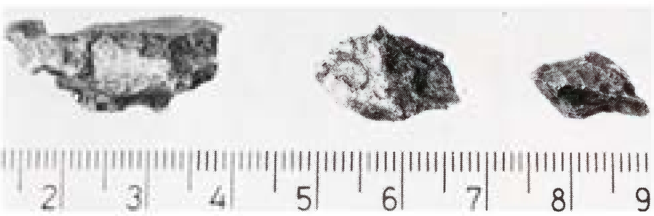

Figure 951. Kaalijärv (Tartu). Three small explosion fragments from the crater field. They only weigh 6.7, 5.7 and 2.6 g, respectively, yet constitute an essential part of what has been recovered. Scale in centimeters.

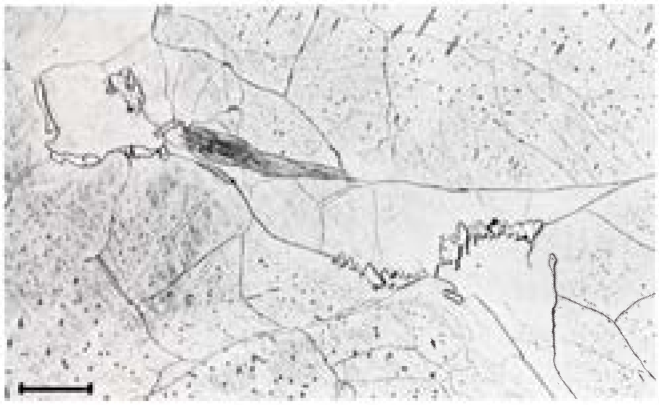

Figure 952. Kaalijärv (Tartu; the 6.7 g mass from Figure 951). The structure indicates that the impacting body was a coarse octahedrite of group I, similar to Canyon Diablo and Campo del Cielo. Etched. Scale bar 500 μ.

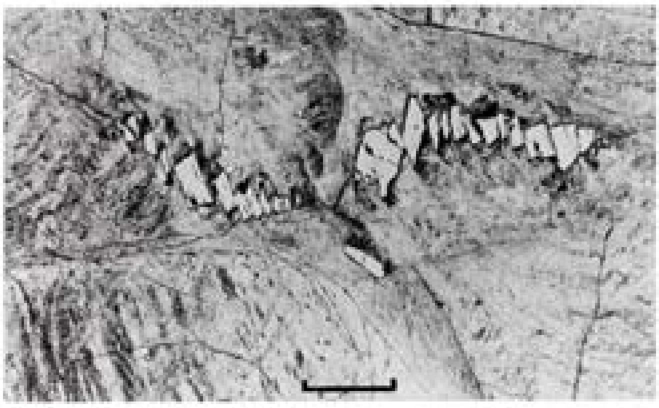

Figure 953. Kaalijärv. Detail of Figure 952. An original schreibersite crystal has been sheared and displaced in a number of steps, due to the violent plastic deformation associated with the explosive breakup. Etched. Scale bar 300 μ.

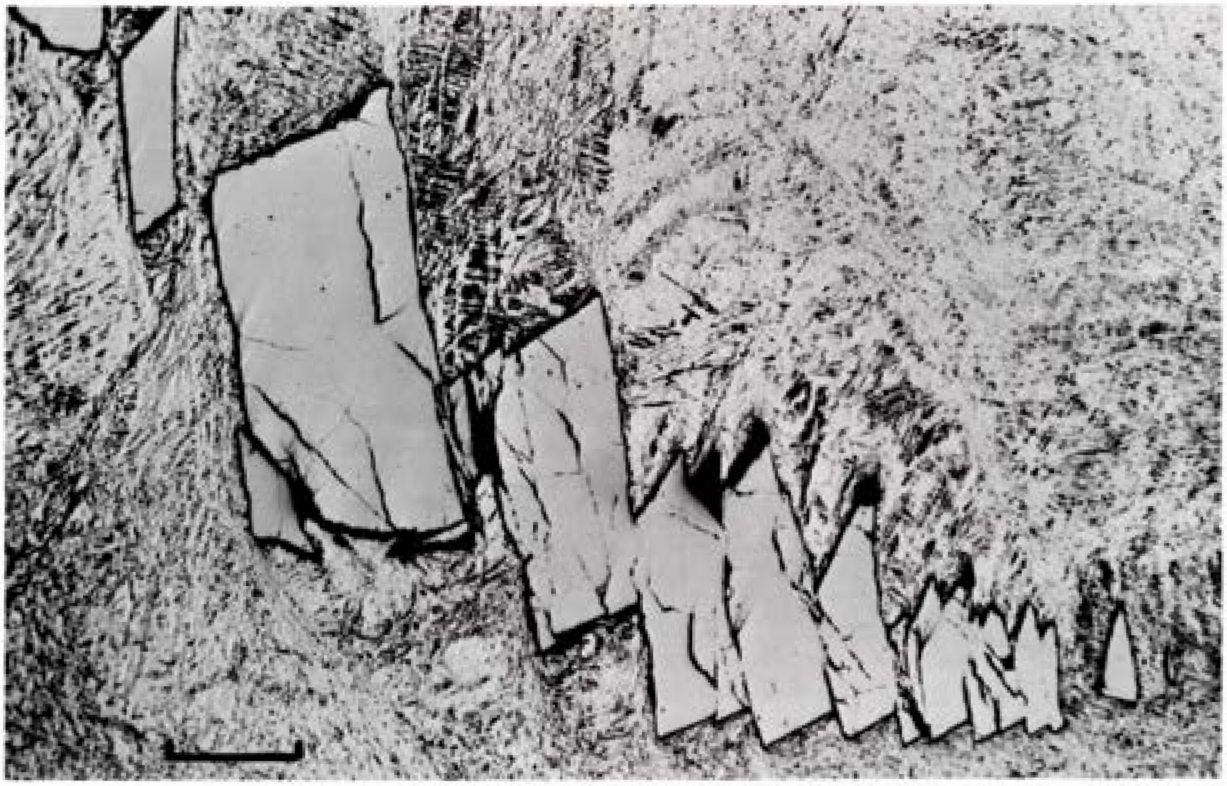

Figure 954. Kaalijärv. Detail of Figure 952. The sheared schreibersite is situated in a shock-hardened kamacite matrix. Etched. Scale bar 50 μ.

Meteoritic fragments have only been found in the impact holes. They range in size from 38 g and downwards and total less than 0.5 kg. They are mostly in a badly weathered condition, but some still permit recognition as similar to the sharply twisted slugs known from the Henbury, Canyon Diablo and other crater fields.

Aaloe (1958) discovered in crater No. 5 a number of fragments and even whole shells of land molluscs which are characteristic of a damp coastal region. He estimated on this basis that the Kaalijärv craters were formed in the litorina period, 4,000-5,000 years ago. In a brief remark, Krinov (1966b) noted that carbon-14 dating indicated a terrestrial age of 2660 years.

Pokrovskij (1963) estimated the preatmospheric mass to have been 4.8 m in diameter with a weight of 450 t and a velocity at impact of 21 km/sec. Bronsten (1962) and Bronsten & Stanyukovich (1963) estimated the preatmospheric mass to have been larger than 400 t and the velocity at impact 10-20 km/sec. The released energy was computed to 4×10^{19} erg (4×10^{12} Joule).

Treumann (1963) reported that the original name of Kaalijärv (which means "the lake on the Kaali estate") used to be Pühha Järw, which means "the sacred lake." The older form seems to have come into disuse about 1800. It is interesting to note that the inhabitants of Saaremaa have noticed the peculiar shape of the lake and perhaps intuitively guessed its origin. Perhaps the fall was witnessed by the Stone Age population at the Baltic Sea. One reason that so little metallic material is found today is probably the continuous tilling of the land whereby larger fragments long ago were collected and used. This assumption was already proposed by Reinvald & Luha (1928).

COLLECTIONS

Geological Institute, Tartu (100 g), Moscow (65 g), London (14 g), New York (8 g), Washington (4 g).

DESCRIPTION

The following rests on an examination of two fragments in Washington and London, supplemented by four specimens which were kindly loaned to the author by Dr. A.O. Aaloe, Tallinn. These had not previously been cut. The 6 specimens had the approximate weights (as found) 4.3, 5.6, 6.7, 5.7, 2.6 and 1.9 g and represented individual

KAALIJÄRV – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Yudin & Smyshljajev 1963	6.60	0.41										

slugs produced by disintegration of the exploding meteorite. They are irregular ragged pieces with twisted ears and sharp edges, as are most other specimens from the site, compare, e.g., Figure 49 in Krinov (1966a).

Sections through the specimens disclose a coarse Widmanstätten structure with irregular, short ($\frac{L}{W} \sim 6$) kamacite lamellae with a width of 2.0±0.4 mm. In places local grain growth has created almost isometric α-grains 5-8 mm in diameter. The kamacite is very much distorted and transformed to the hatched ϵ-structure, suggestive of intense shock-loading. The hardness is high but rather variable, generally 275±25, in accordance with the variation in microstructure. The plastic deformation ranges from "normal" ϵ-structure through severely twisted ϵ-structures with many undulating deformation bands to recrystallized structures, frequently within the same square centimeter section. The recrystallized regions are concentrated within narrow (20-100 μ wide) shear zones which may extend from side to side of a fragment. The recrystallized grains are far from equilibrium. They are 2-10 μ across and show serrated edges. The hardness decreases in these zones to 185±25.

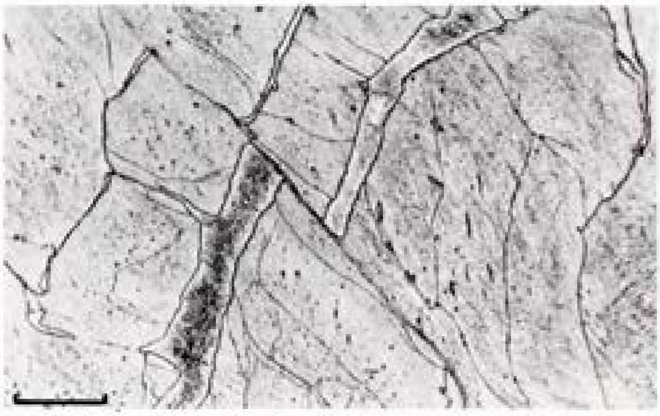

Figure 955. Kaalijärv (U.S.N.M. no. 1293). A narrow deformation zone runs diagonally across the picture and displaces the right half about 400 μ downwards. Etched. Scale bar 300 μ.

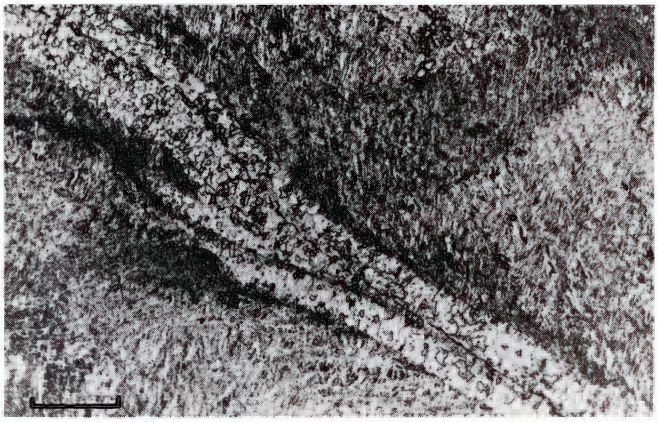

Figure 956. Kaalijärv (U.S.N.M. no. 1293). In another shear zone of the same specimen the released frictional energy has sufficed to recrystallize the kamacite within a narrow band. Etched. Scale bar 100 μ.

Taenite and plessite occupy 2-4% of the sections, mainly as pearlitic fields, or fields with martensitic-acicular interiors. The best developed fields observed are 4 x 3 mm in size and show pearlitic zones with 0.5-2 μ wide γ-lamellae and spheroidized zones with 5-20 μ γ-spherulites. The taenite generally has tarnished rims. The acicular fields have pointed, 1-10 μ wide γ-lamellae in a matrix of bainite-martensite or unresolvable, duplex $\alpha + \gamma$. Depending upon the degree of deformation and annealing at the crater-forming event, the present hardness varies from 350 for cold-worked taenite to values around 200 for duplex annealed fields.

Schreibersite occurs frequently, both as laths (e.g., 1 x 0.15 mm) and as 20-100 μ wide grain boundary veinlets. Rhabdites are common and range from 1 to 15 μ in cross section. Almost all phosphides became heavily sheared by the explosion, and the individual fragments may now be found 10-100 μ apart with cold-worked kamacite in between. The bulk phosphorus content is estimated to be 0.2%.

Figure 957. Kaalijärv (U.S.N.M. no. 1293). A deformed plessite field, sheared schreibersite crystals, and shock-hatched kamacite. Etched. Scale bar 200 μ.

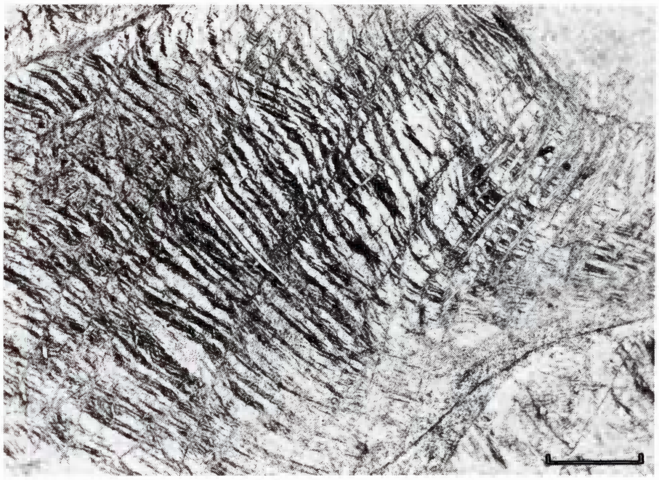

Figure 958. Kaalijärv (Brit. Mus. no. 1938, 135). Heavy deformation bands and shock-hatching in the kamacite of a small, weathered fragment of 4.9 g (originally 5.6 g). Etched. Scale bar 300 μ.

Cohenite was not positively identified, but it appears that the figure given by Spencer (1938: plate 3) does exhibit several branching, millimeter-sized cohenite crystals and not schreibersite as believed by Spencer. Graphite, troilite and silicate were not detected in this study but will undoubtedly be identified if more material should become available.

The plastic deformation is concentrated within narrow shear zones that frequently continue in internal fissures. Shear-displacements of 10-100 μ are very frequent, and a 500 μ fault through a plessite field was also observed. Ultimately the shear led to fragmentation, and most of the present specimen surfaces are such shear-surfaces, somewhat altered by later corrosion. Many Imilac fragments have a similar appearance. No fusion crust and no heat-affected α_2 zone from the atmospheric flight were detected in this study.

Corrosion mainly attacks along the explosion-induced fissures and is usually well developed along the phosphides. The kamacite of the pearlitic, acicular and duplex fields is selectively corroded and gives rise to beautiful, contrast-rich structures of dark limonite in light unattacked taenite.

Kaalijärv is a coarse octahedrite which is related to Campo del Cielo, Cranbourne, Seeläsgen and Yardymly. Although no trace element analysis has been performed and the examined sections are small, Kaalijärv is, no doubt, a normal member of the chemical group I, with somewhat less nickel than Canyon Diablo, another prominent crater-producing meteorite. The preserved fragments have primary structures (bandwidth, pearlitic, spheroidized and acicular plessite, possibly cohenite) which closely correspond to the group I meteorites mentioned above. The secondary structures of the fragments, such as ε, deformation bands, shear zones and recrystallization, date from the impact and are similar to what is present in Canyon Diablo, Henbury, Wabar and other crater-producing meteorites. There is, thus, no reason at all to maintain the classification by Spencer (1938) and Hey (1966): "Metabolitic ataxite to medium octahedrite."

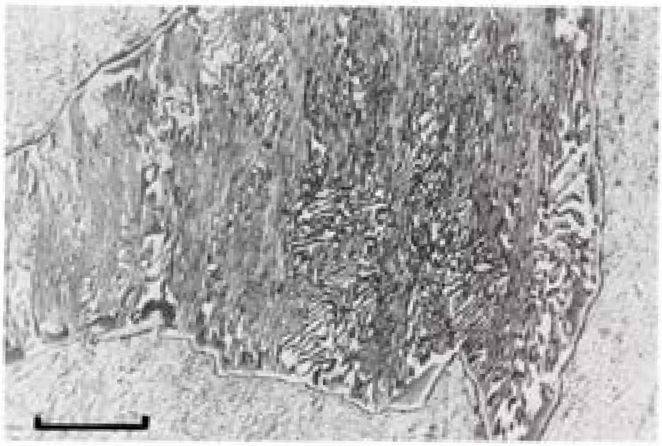

Figure 959. Kaalijärv (Brit. Mus. no. 1938, 135). Pearlitic plessite with cloudy taenite rims. This structure is almost exclusively found in group I irons with significant carbon contents. Etched. Scale bar 50 μ.

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

4.3 g individual (no. 1293, 15 x 10 x 5 mm)
3/4 kg Silurian dolomite (no. 1290) and 3 snail shells (no. 1292) from the crater field

Kalkaska, Michigan, U.S.A.

44°38′49″N, 85°8′12″W; 300 m

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm. ε-structure. HV 290±12.

Group IIIA. 7.4% Ni, about 0.1% P, 18.1 ppm Ga, 33.5 ppm Ge, 11 ppm Ir.

HISTORY

A mass of 9.4 kg (20.7 pounds) was plowed up in 1947 or 1948 by A.R. Sieting, about 10 km south-southwest of Kalkaska, in Kalkaska County. The field had been cultivated for over 30 years, so the sound of the cultivator blades striking metal was quite unexpected. The mass was shown to various peoples and to schools, before it was presented, in 1964, to Michigan State University where it was described with a photograph of the exterior and a photomacrograph by Chamberlain (1965) who also gave further details of the find. Schultz & Hintenberger (1967) measured the amount of various noble gases while Voshage (1967), from these values, estimated the exposure age to lie between 420 and 800 million years.

COLLECTIONS

Abrams Planetarium, Michigan State University, East Lansing (main mass), Washington (759 g).

DESCRIPTION

The irregular mass has the approximate overall dimensions 18 x 15 x 9 cm, and it shows numerous well developed regmaglypts 10-20 mm in size. Locally, deeper holes are carved out, as for instance, 10 mm deep with an

Figure 960. Kalkaska (U.S.N.M. no. 3217). The fusion crust is an intricate whirlpool structure of fused oxides and fused metal. Due to terrestrial corrosion, hydrated limonite is also prominent in the shown section. Lightly etched. Scale bar 200 μ.