Schreibersite is almost absent, but may be found as short, 5-10 μ wide grain boundary folia. Rhabdites are not observed. The bulk phosphorus content is estimated to be between 0.05 and 0.10%.

Troilite is scattered as small nodules and lenticular bodies, ranging from 1 to 5 mm in size. They occur with a frequency of about one per 20 cm^2, and contain 10-20% daubreelite in the form of parallel bars, 0.1-0.5 mm wide.

Spencer & Hey (1930) reported cohenite, but this could not be confirmed.

Piedade do Bagre is a somewhat annealed, medium octahedrite with an anomalously small bandwidth if compared to Henbury, Costilla Peak, Wabar and other irons of similar composition. The trace-element determination indicates that it is in some degree related to these irons; Wasson (personal communication) feels, however, that it should be earmarked anomalous, since its combination of Ni, Ga, Ge and Ir places it outside the normal IIIA range. This conclusion is supported by the bandwidth-Ni combination which is anomalous, too.

Specimen in the U.S. National Museum in Washington:
398 g (no. 1559, 12 x 8.5 x 0.5 cm)

Pierceville (iron), Kansas, U.S.A.
37°52'N, 100°40'W

A mass of 100 kg was found in 1917 near Pierceville, Finney County (Meteoritical Bulletin, No. 8, 1958). About half went to London (Hey 1966: 381), and 22.7 kg is in Tempe. The material, which is extremely weathered, was described by Huss (1965), who presented three photomacrographs of polished sections.

Among the weathered fragments, samples can be found which still display inconspicuous remains of the meteoritic minerals. I have, on various sections, been able to identify taenite lamellae, comb plessite and rather large schreibersite lamellae, e.g., 5 x 2 and 10 x 1 mm in size. The few structural details suggest that Pierceville originally was a medium octahedrite of group IIIB, related to Chupaderos, Grant and Narraburra.

Pima County, Arizona, U.S.A.

Hexahedrite, H. Shock-recrystallized to about 0.5 mm kamacite grains. HV 175±25.

Group IIA. 5.60% Ni, 0.52% Co, about 0.25% P, 60 ppm Ga, 181 ppm Ge, 8.9 ppm Ir.

Damaged along two sides by oxy-acetylene cutting.

Figure 1367. Pima County (U.S.N.M. no. 1447). The meteorite, originally a hexahedrite, is recrystallized due to shock and the associated reheating. A heat-affected rim zone is present along the edge A-A. Imperfectly polished, black patches are due to corrosion. Deep-etched. Scale bar 10 mm. (Perry 1950: volume 7.)

HISTORY

A small mass of 210 g was in 1947 acquired by S.H. Perry from Professor E.G. Wilson of the University of Arizona in Tucson. Nothing is known of its history, except that it was brought to the university by someone (Bob Heineman?) who was supposed to have found it in the vicinity of Tucson (Pima County). For years it had been lying unnoticed among other small mineral specimens and sometimes used as a paperweight. The mass was provisionally described by Henderson & Perry (1949a), who presented photographs of the exterior and of etched slices. The remarkable surface features were interpreted as the result of ablation during flight, but, as discussed below, this cannot be the case. The 210 g mass is only a fragment of a larger, unidentified meteorite. Since it is not certain that the fragment was found in Pima County, or even Arizona, there is no point in attributing coordinates to it. It is unrelated to Navajo and to other Arizona meteorites, a conclusion easily derived from the descriptions given here.

COLLECTIONS

Washington (150 g).

PIMA COUNTY – SELECTED CHEMICAL ANALYSES

Henderson & Perry also reported the composition of the kamacite and of the schreibersite. This was found to be unusually rich in cobalt, containing 2.0%.

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson & Perry 1949a	5.64	0.52	0.10		30							
Wasson 1971, pers. comm.	5.56								60.3	181	8.9	

DESCRIPTION

The mass is a somewhat pyramidal fragment, 44 x 38 x 35 mm in size. Three of the present sides are artificial cleavage fractures while the remaining two sides are covered by a remarkable fused crust. The cleavages are intercrystalline, passing along the boundaries of the 0.5 mm ferrite grains. Several square centimeters of the fractured surfaces have been cold-hammered later and deformed, with a little plastic flow appearing. The fused crust is somewhat porous and exhibits several melted spherules, 0.1-1 mm in diameter, and loosely adhering to the crust. A close examination of the fused crust reveals that it must be artificial and probably produced by oxy-acetylene cutting by some early possessor of the mass. The fused crust was distinctly developed *after* some weathering had taken place and *after* the hammering was performed, since parts of the melt spills over the corroded and cold-worked surfaces. Moreover, the fused crust appears to have been formed in two steps. Probably the two sides were cut successively with the torch, resulting in the characteristic pattern.

Under the artificial fusion crust is a heat-affected α_2 zone which ranges from 1 to 3 mm in thickness. In the exterior part of this zone the phosphides are melted or resorbed, and the graphite spherules have formed various martensitic-ledeburitic structures with some retained austenite. These nests are 25-100 μ across. In thickness and structure, the heat-affected zone resembles a genuine α_2 zone; however, it can be distinguished by the structure of the included corrosion products. These have reacted and developed complicated lace-like patterns, such as those typically seen in, e.g., Burlington and Cacaria.

The original, preatmospheric structure of Pima County is preserved below a depth of 3-4 mm. It is a granohexahedrite composed of numerous equiaxial kamacite grains, ranging in size from 0.2 to 1.0 mm. Neumann bands only appear to be present along a few intercrystalline cracks that extend to a depth of about 1 cm below the surface. Corrosion has taken place along the grain boundaries, and the sensitized loops, particularly, have been converted to limonite. Each grain is subdivided into a large number of almost equiaxial subgrains, 25-50 μ in size. The microhardness is 175±25; a hardness track perpendicular to the surface, cut by an oxy-acetylene torch, shows a hardness of 170±15 in the rim zone and a minimum of 145 in the recovered transition zone, before the interior, unaffected level is reached.

Schreibersite is present as a few, irregular units, 0.2-1 mm in size. Each unit is surrounded by a 200 μ wide zone rich in amoeba-like taenite and wedge-shaped phosphides, each bleb being 2-10 μ across and situated in

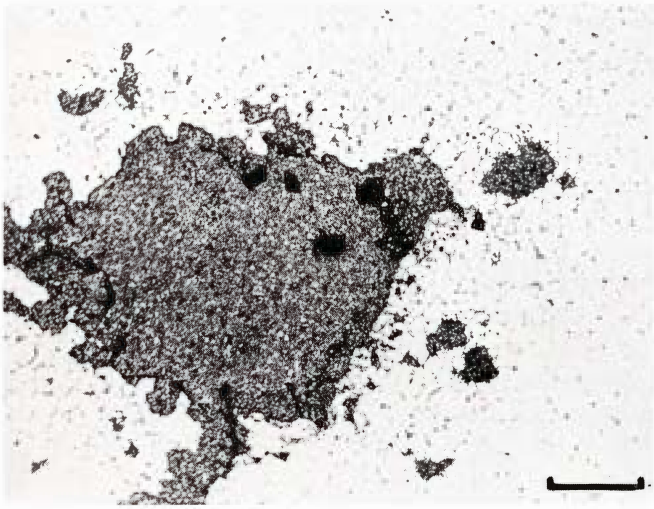

Figure 1369. Pima County (U.S.N.M. no. 1447). A shock-melted troilite-daubreelite nodule displaying frayed edges towards adjacent kamacite which is rich in subboundaries. Etched. Scale bar 300 μ. (Perry 1950: volume 7.)

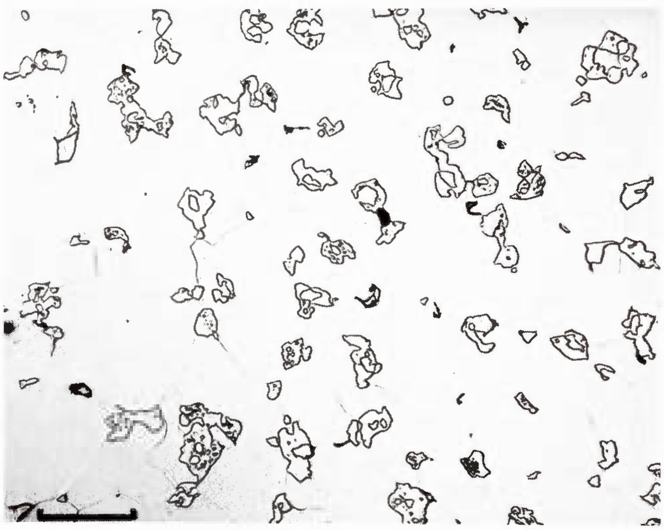

Figure 1368. Pima County (U.S.N.M. no. 1447). Around the decomposed schreibersite crystals there is a dense population of amoebae-like taenite particles and angular phosphide particles. Compare Mejillones and Kopjes Vlei. Etched. Scale bar 30 μ. (Henderson & Perry 1949a.)

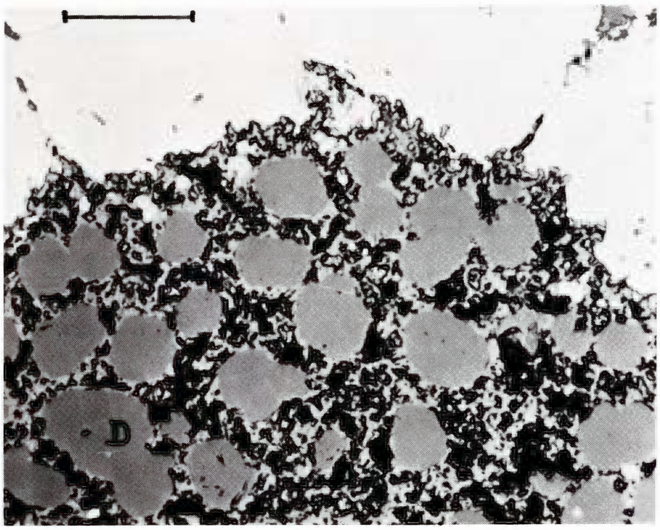

Figure 1370. Pima County. Detail of Figure 1369. Subangular daubreelite fragments (D) are dispersed through a fine-grained iron-sulfur eutectic. Part of the eutectic iron has been dissolved by etching, leaving black micropits. Etched. Scale bar 20 μ. (Henderson & Perry 1949a.)

polycrystalline kamacite. These phosphide-rich zones are visible to the naked eye as diffuse blotches on an etched section. Phosphides are further common as 1-2 μ thick wedges and blebs in both grain and subgrain boundaries. Phosphides are also common as 0.5 μ thick "rhabdites" and beads inside the kamacite grains. The reported phosphorus content of 0.1% is probably too low; the bulk phosphorus content is likely to be 0.25%.

The sensitized angular loops that range from 5 to 15 μ across and occur with a frequency of about 400 per mm^2 are particularly annoying. Upon routine preparation of a polished section, they disappear and leave angular holes. Careful preparation discloses what appears to be unequilibrated ferrite with a significant amount of phosphides in the form of irregular particles surrounding the metal and, thereby, creating the impression of loops. The loops are the first to corrode, as mentioned above. It is suggested that they represent former rhabdites which, due to a particular cosmic event – probably shock-heating, – were transformed to an intricate, unequilibrated, perhaps martensitic, form of ferrite. This interpretation is in accordance with the size, frequency, mode of occurrence and chemistry and conforms with the occurrence in irons which, from other observations, appear to be shock-altered, rhabdite-containing hexahedrites, e.g., Forsyth County and Wathena.

Troilite is present as 0.1-2 mm irregular nodules. They have been shock-melted and have solidified rapidly to extremely fine eutectics of sulfide and metal, where the metal component ranges from 15% at the nodules' contact with the iron, to 0 in the interior. Daubreelite (erroneously called "phosphide particles" in Plate 20, Figure 1 in Henderson & Perry 1949a) constitutes 25-30% of the troilite nodules in the form of well-dispersed, subangular fragments, 5-15 μ across. Phosphides are only present in modest amounts as 1-2 μ beads, dispersed in the shock-melts.

Several graphite spherulites, 25-50 μ across, are present in the metal; some of them have additional graphite deposited as a 10-20 μ thick ring of an independent orientation.

Pima County is not as unique as suggested by Henderson & Perry (1949a). The beautiful fusion crust, which, if genuine, would indicate that Pima County was a very recent fall, is a result of oxy-acetylene cutting at an unrecorded date; and the polycrystalline shocked structure is similar to Wathena, Mejillones, Forsyth County, and many others belonging to group IIA, representing shock-altered hexahedrites. It is particularly interesting to note the close structural resemblance to Chico Mountains. Since both are poorly documented fragments from some unidentified main mass, located in the southwestern U.S.A. or northern Mexico, they may, in fact, come from the same meteorite.

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

130 g pyramidal fragment (no. 1447, 4 x 3 x 3 cm)
20 g polished sections (no. 1447)

Pine River, Wisconsin, U.S.A.

44°13'N, 89°6'W; 270 m

Anomalous, medium octahedrite with silicate inclusions. Neumann bands. HV 173±10.

Anomalous-Group I. 7.40% Ni, about 0.2% P, 76.9 ppm Ga, 234 ppm Ge, 2.6 ppm Ir.

HISTORY

This meteorite was briefly mentioned by A.D. Nininger (1940); a preliminary investigation of the metal phase with numerous photomicrographs was presented by Perry (1944). A full description, with photographs, appeared first in 1960 (W.F. Read). According to Read, the meteorite was found about 1894 by D.M. Waid, a farmer who spotted the dark, rusty-looking rock lying beside the "Old Back Road" between Saxeville and Waupaca, in Waushara County. The locality is near the east end of Long Lake (Section 8, Township 20N, Range 12E) and has the coordinates given above. For many years the meteorite was kept in the farmer's woodshed where it was used as an anvil for cracking hickory nuts. It was originally about 15 x 12 x 12 cm but gradually disintegrated into fragments. In 1932 the fragments were acquired by Professor Rufus M. Bagg of Lawrence College, Appleton. As Read pointed out, in the process some rusty, metamorphic rock fragments were also erroneously labeled "Pine River meteorite." Read examined the preserved material, discredited the rock fragments and concluded that the original meteorite probably weighed about 2 kg, of which 1,341 g could be accounted for in collections. Burnett & Wasserburg (1967a) examined the silicate inclusions and found a rubidium-strontium age of 4.6×10^9 years.

COLLECTIONS

Oshkosh Public Museum, Wisconsin (305 g), Washington (296 g), Lawrence College, Appleton, Wisconsin

PINE RIVER – SELECTED CHEMICAL ANALYSES

This analysis was performed on the metal phase. Read (1960) reported the silicates to be composed of orthopyroxene, olivine and plagioclase. Mason (quoted in Read) found the pyroxene to be nearly pure enstatite with a gamma index of 1.664, while the olivine was close to forsterite. In addition, Bunch & Keil (personal communication) found whitlockite and classified the inclusions as Copiapo type.

	percentage			ppm							
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970b	7.40								76.9	234	2.6	

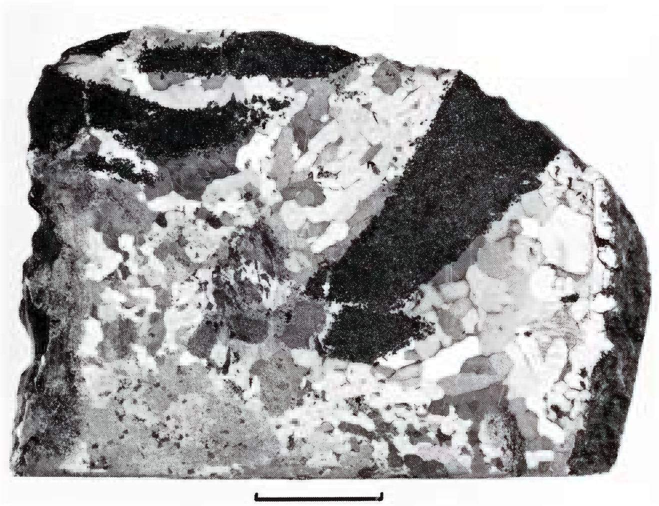

Figure 1371. Pine River (U.S.N.M. no. 1343). Anomalous medium octahedrite with angular silicate inclusions. Deep-etched. Scale bar 10 mm. S.I. neg. 37546.

Figure 1372. Pine River (U.S.N.M. no. 1343). The opposite side of Figure 1371. Metal veins are prominent in the silicates. Deep-etched. Scale bar 10 mm. S.I. neg. 37546A.

(236 g), London (141 g), Milwaukee Public Museum (134 g), Tempe (127 g), Chicago (102 g), Harvard (58 g), New York (7 g).

DESCRIPTION

The 272 g fragment in the U.S. National Museum is a solid endpiece which shows little tendency to crumble. The surface is corroded and no fusion crust is preserved. Locally, small pockets of quartz-rich soil are adhering, the soil being impregnated with limonite from the weathering meteorite. Part of the surface was evidently formed by late mechanical splitting along silicates and corroded grain boundaries.

Etched sections disclose that Pine River is an unusual composite of metal and angular silicate fragments. Various sections indicate that the silicates comprise from 15 to 45% by volume of the meteorite, with 25% as an estimated average.

Locally, the metal has developed a very incomplete Widmanstätten pattern where the straight, short ($\frac{L}{W} \sim 5$) kamacite lamellae have a width of 1.2±0.4 mm. In most sections the kamacite forms polyhedric, almost equiaxial, grains ranging from 1-5 mm in size, the smaller ones being more common. The kamacite has numerous subboundaries decorated with 0.5-2 μ phosphides; and Neumann bands are common. The microhardness is 173±10. Taenite occupies about 4% by area, mostly in the form of wedges or elongated ribbons between the kamacite ribbons. Comb plessite is absent, and it is difficult to see whether the metallic part was originally a single, parent taenite crystal or was composed of several units. The taenite has bluish-brownish stained edges due to carbon in solid solution, and the interiors display various grades of martensitic-bainitic structures. The microhardness of these ranges from 250 to 350.

Schreibersite occurs as 20-50 μ wide grain boundary precipitates and as units, up to 1 mm, that irregularly border the frayed silicate aggregates or fill the interstices between graphite crystals. The bulk phosphorus content is estimated to be about 0.2%. The microhardness of the schreibersite is 950±40.

The typical cohenite blebs and troilite nodules, so common in group I meteorites, are absent in Pine River; and rhabdites are also absent.

The unusual distribution of graphite is very characteristic for Pine River. Although present in significant amounts, ranging from 1 to 5 volume %, graphite has not been reported previously. It occurs as irregular cakes, 0.5-3 mm in diameter, which are intergrown with kamacite in varying proportions, the graphite comprising from 5-100%. The graphite is often developed as thin flakes with a hexagonal outline and oriented according to the particular kamacite grain in which they are found. In some sections the graphite appears as slender arrows or triangular patches, but it merely seems to be the result of different sectioning

Figure 1373. Pine River (U.S.N.M. no. 1343). Plessite field with cloudy taenite edges and martensitic interior, reflecting the $(111)_\gamma$ orientation of the parent taenite. Etched. Scale bar 200 μ. (Perry 1950: volume 3.)

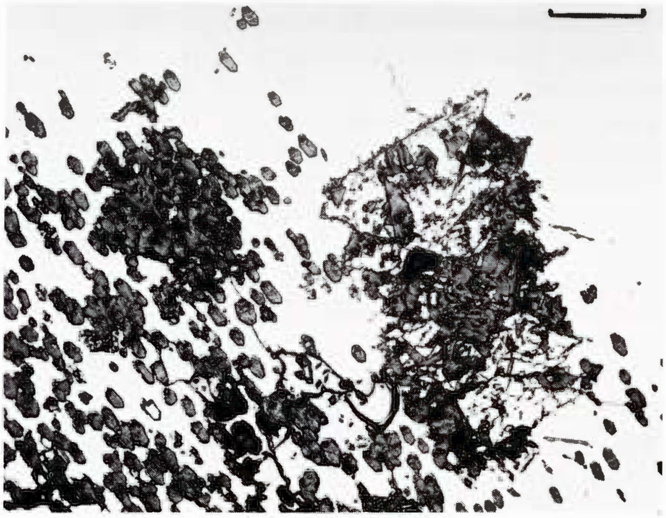

Figure 1374. Pine River (U.S.N.M. no. 1343). Cluster of acicular graphite crystals in kamacite. Also large triangular crystals. Compare Figures 168 and 989. Polished. Scale bar 150 μ. (Perry 1950: volume 3.)

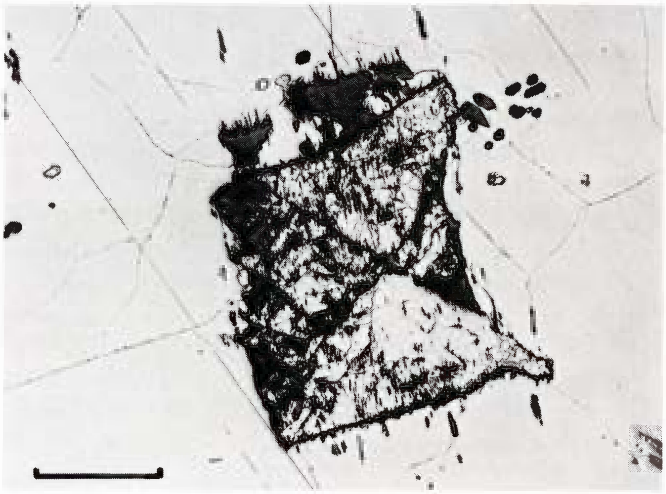

Figure 1375. Pine River (U.S.N.M. no. 1343). An enigmatic graphite development. Numerous angular and acicular graphite crystals are arranged within a superstructure resembling cliftonite. The interior is mainly kamacite with subboundaries. Etched. Scale bar 200 μ. (Perry 1950: Volume 3.)

angles. The individual flakes are apparently 2-20 μ thick and often 50-100 μ across. They frequently become dislodged by improper grinding and polishing and disappear, leaving angular loops with cubic or hexagonal outlines. The graphite flakes are situated mostly in kamacite but are also present in schreibersite and taenite, so they probably formed rather early. No graphite is precipitated as rims around the silicates, a feature which is common in Four Corners, Woodbine, and several other silicate-bearing meteorites. In a few cases the graphite, with the kamacite, was found to form a definite crystallographical pattern, 0.5 mm across, suggesting a primitive cubic arrangement similar to a Maltese cross. The graphite distribution and morphology resemble in many respects what is described under Morrill, Kendall county and Mundrabilla and deserve further study.

The silicates constitute on the average 25% by volume. As shown by Read, Mason, and Bunch & Keil, they are composed of pyroxenes, olivine and plagioclase. The individual grains are about 50 μ across; together with kamacite and troilite that fill the concave interstices between the silicate grains, they form aggregates of varying dimensions, up to 4 x 3 x 2 cm in size. These aggregates have the appearance of angular fragments, often separated from each other only by narrow sheets of metal. The kamacite and troilite associated with the silicates range in size from 10-100 μ; the troilite is monocrystalline and contains modest amounts of daubreelite in form of short, 5-10 μ wide bars. Read (1960) reported a particular angular fragment to be composed of 45.5% pyroxene, 32% olivine, 0.5% plagioclase and 22% opaques; the fragments examined herein correspond well to this description; the opaques consist of about 80% kamacite, 19% troilite and 1% daubreelite in the troilite.

Pine River is an unusual meteorite. In its metallic part it resembles Morrill significantly, while the silicate part has analogies to Campo del Cielo, Copiapo, and Netschaevo. The texture suggests a rather random mixture of loose silicate and metal fragments that were later compressed and sintered to the present configuration. It is difficult to accept that either the metal or the silicate was completely melted in the process, but small amounts of low-melting sulfur-phosphorus and carbon-rich eutectics may have been present for a while and helped to consolidate the mass. The confusing graphite texture may contain a further clue to the early history of Pine River. Wasson (1970b) classified it as group I, but anomalous, together with Copiapo and other silicate-bearing irons.

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

272 g endpiece (no. 1343, 5 x 4 x 3 cm)
24 g polished part slice (no. 1421, 3.5 x 3 x 0.2 cm)

Piñon, New Mexico, U.S.A.

32°40'N, 105°6'W; 1600 m

Nickel-rich ataxite, D. α-spindles 15±10 μ wide. HV 165±15.

Anomalous. 16.28% Ni, 0.69% Co, 0.34% P, 2.5 ppm Ga, 1.2 ppm Ge, 15 ppm Ir.

HISTORY

A mass of 17.85 kg was found in 1928 or 1930 by a sheepherder named Apolonio Garcia somewhat east of the Sacramento Mountains, in Chaves County. The exact coordinates, as given by Nininger, are quoted above. They represent a locality in the desolate canyon-filled country 30 km east to north of Piñon, and some kilometers north of Piñon Creek. The meteorite was acquired by the Department of Chemistry of the State Agricultural College of New Mexico at Mesilla Park (the present New Mexico State University) from which Nininger (1939c) obtained it for

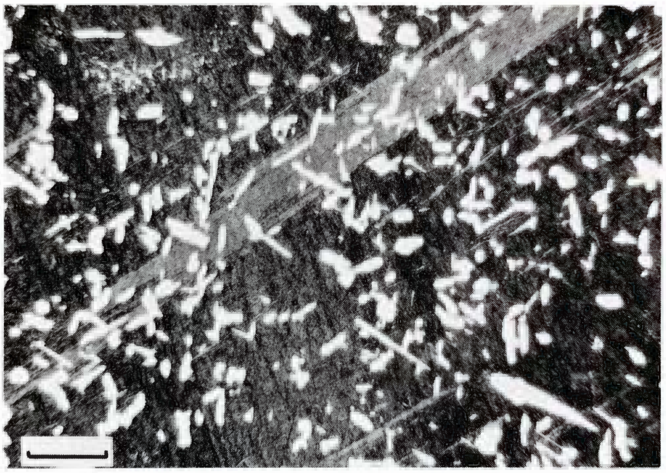

Figure 1376. Piñon (U.S.N.M. no. 861). Nickel-rich ataxite with numerous fine kamacite spindles. The matrix shows light- and dark-shaded areas that are crystallographically related. Etched. Scale bar 500 μ.

cutting and description. He presented a photograph of the exterior shape and a good analysis by Hawley. Nininger cut the mass near the middle and apparently distributed about one-third, while the rest was returned to Mesilla Park. Wood (1964) gave two photomicrographs and presented the results of four line scans with the microprobe across the composite structure. Herr et al. (1961) determined the osmium and rhenium isotopes and estimated the solidification age to be 4.0 x 10^9 years. Bauer (1963) measured the helium isotopes and estimated the cosmic ray exposure age to be as high as 1,140 million years, while Voshage (1967) from his $^{40}K/^{41}K$ determinations found a cosmic ray age of 780±125 million years. Hulston & Thode (1965b) found that cosmic ray-produced spallation ^{36}S and ^{33}S were present in minute amounts.

COLLECTIONS

Mesilla Park (about 12 kg, see above), London (2,187 g), Washington (1,240 g), Tempe (883 g), Ann Arbor (480 g), Chicago (410 g), Perth (88 g), Albuquerque (45 g).

DESCRIPTION

The mass had the approximate overall dimesnions of 22 x 17 x 12 cm and weighed 17.85 kg. It is covered by shallow regmaglypts which are significantly modified by weathering. Terrestrial oxides form an irregular crust, 0.1-2 mm thick; and cup-shaped corrosion pits are common. The fusion crust has disappeared. Sections show, however, that the heat-affected α_2 zone is preserved in places as a layer, up to 1 mm thick; so the iron appears to have lost about 1-3 mm of its surface in a rather irregular way.

Etched sections display an ataxitic structure, the homogeneity being broken only by a few scattered troilite nodules, 0.5-2 mm across. When the section is tilted against the light faint traces of an oriented sheen may be seen. The individual patches are 5-10 mm across but very irregular. There is a tendency for the patches to be bordered by straight lines in three or four directions, but the pattern is far more diffuse than in Hoba, Tlacotepec, and other group IVB meteorites, which it otherwise resembles somewhat. At high magnification, patches of different sheen show a slight difference in the orientation of the vermicular $\alpha + \gamma$ mixture of the matrix.

The structure is a microscopic composite of kamacite spindles, kamacite blebs around schreibersite, and a fine-grained plessite. The kamacite spindles are oriented along the octahedral planes of the parent austenite, and they are straight and long ($\frac{L}{W} \sim 20$) with a width of 15±10 μ. The kamacite blebs are, in fact, swathing kamacite, which has formed as 10-50 μ wide rims around schreibersite nuclei of the same general size. Kamacite in these two forms covers

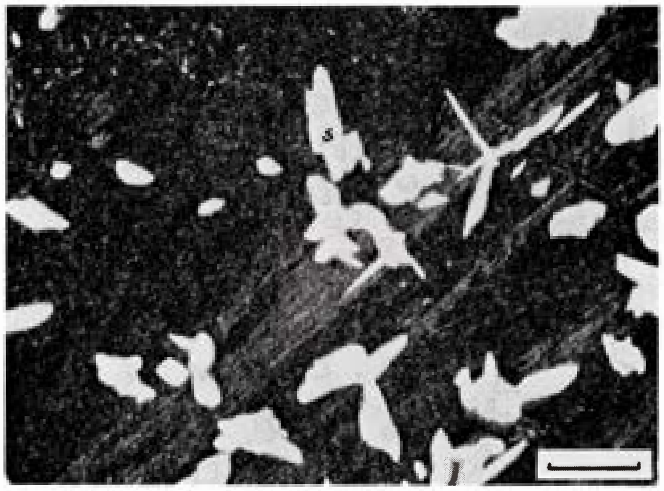

Figure 1377. Piñon (U.S.N.M. no. 861). Kamacite has nucleated and grown around numerous fine schreibersite particles (S; only one is marked). In addition, narrow kamacite lamellae have nucleated homogeneously and grown in a Widmanstätten pattern. Etched. Scale bar 150 μ.

PIÑON – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Hawley in Nininger 1939c	16.32	0.67	0.40	300	1000	190	300					86.4*
Goldberg et al. 1951	16.58	0.87							2.39			
Lovering et al. 1957		0.59				112	37		2.9	<1		
Lewis & Moore 1971	16.66	0.63	0.27	30								
Wasson & Schaudy 1971	15.54								2.32	1.15	15	

*The unusually large value of 86.4 ppm includes all platinum metals and is from a paper by Hawley (1939).

about 10% of the sections; the latter form dominates, while the former only occurs with 1 or 2 spindles per mm^2. The microhardness is 165±15.

The matrix is an extremely fine-grained, oriented intergrowth of kamacite and taenite in the approximate proportions 6:4. The taenite forms short, vermicular bodies, less than 0.5 μ wide. It also forms the 1-5 μ wide, yellow rims around the kamacite grains. Wood (1964) found the matrix to contain about 17% Ni and the rims to increase to about 27% Ni. At low magnification the matrix has a streaky martensitic appearance. The microhardness of the matrix is 205±15. It decreases to 180±5 in the transition zone and increases to 200±10 in the heat-affected α_2 zone. However, the α_2 phase is only visible in the kamacite grains – not in the matrix.

Characteristic for Piñon is the large number of rather evenly dispersed, small schreibersite bodies. They are generally 5-50 μ across, irregular-angular and occur with a frequency of about 30 per mm^2. They are enveloped in swathing kamacite that only occasionally continues its growth outwards along Widmanstätten directions. Rhabdites are not present, although reported by Nininger (1939c); but tiny schreibersites, 0.5-3 μ across, are present in the fine-grained matrix.

The troilite nodules are shock-melted. They have solidified to fringed, microcrystalline (~ 1 μ) mixtures of troilite, ferrite and daubreelite; and schreibersite fragments from the original rim occur scattered through the melts.

Piñon is a nickel-rich ataxite which resembles Shingle Springs. In many respects it also resembles the ataxites of group IVB, particularly Tawallah Valley and Skookum Gulch. However, its phosphorus content is significantly higher. On the basis of structure alone, it is probably difficult to separate it from group IVB, but as Wasson (1966) has shown, the Ga-Ge content is about 10 times higher in Piñon than in IVB.

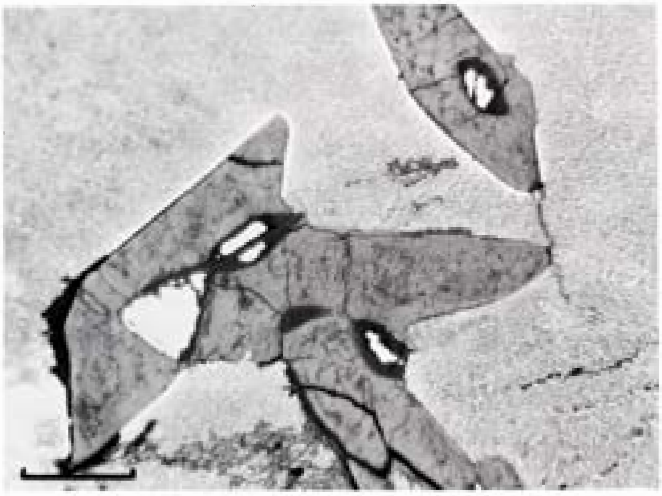

Figure 1378. Piñon (U.S.N.M. no. 861). Near-surface section. The kamacite is corroded (gray) both within spindles and within the duplex ataxitic matrix. Four schreibersite crystals (white) survive within the kamacite spindles. Polished. Scale bar 40 μ.

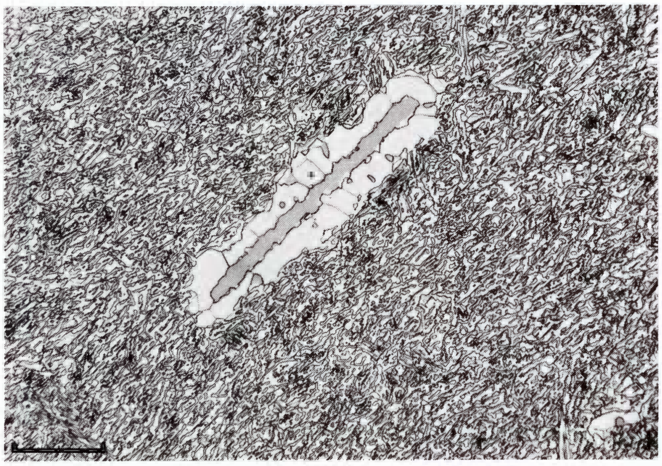

Figure 1379. Piñon (U.S.N.M. no. 861). The matrix is a fine-grained mixture of kamacite, taenite and a few phosphide particles. Occasionally a larger lamellar phosphide particle occurs within swathing kamacite. Cosmic annealing has caused fine γ-particles to segregate along the phosphide. Etched. Oil immersion. Scale bar 20 μ.

Figure 1380. Piñon (U.S.N.M. no. 861). Duplex matrix with several fine kamacite grains. Many of them developed around schreibersite particles (gray). Etched. Oil immersion. Scale bar 20 μ.

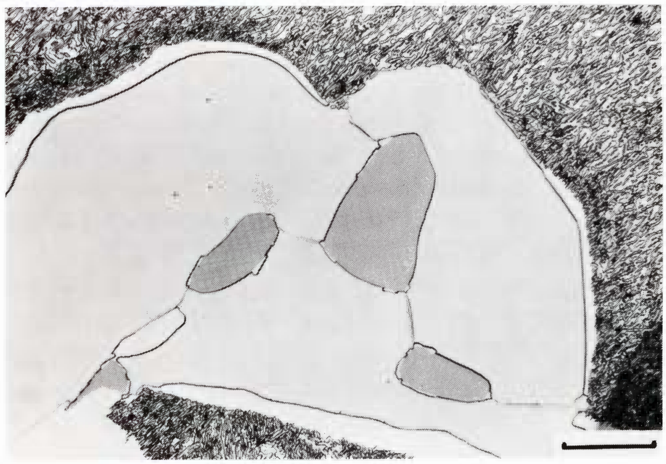

Figure 1381. Piñon (U.S.N.M. no. 861). Four schreibersite crystals and their associated bulky kamacite grains. Cosmic annealing caused fine γ-particles (white) to segregate along the phosphide-ferrite interfaces. Etched. Oil immersion. Scale bar 20 μ.

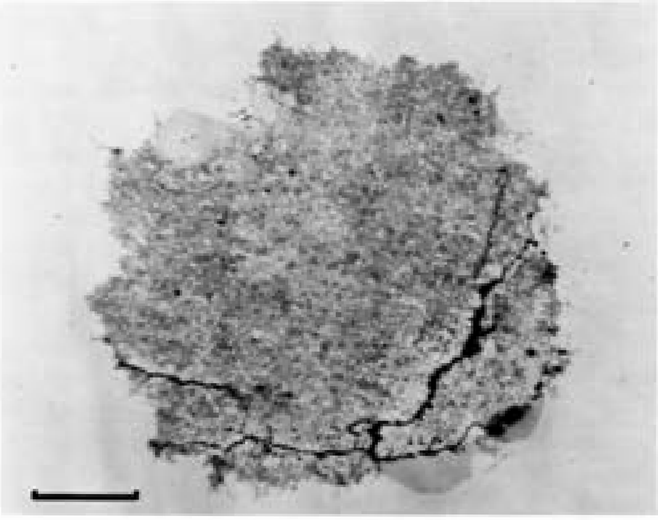

Figure 1382. Piñon (U.S.N.M. no. 861). Shock-melted troilite-daubreelite nodule with slightly affected schreibersite crystals along the edge. Polished. Scale bar 50 μ.

Specimen in the U.S. National Museum in Washington:
1,240 g slice (no. 861, 16.5 x 12 x 1.2 cm)

Pirapora, Minais Gerais, Brazil
Approximately 17°20′S, 44°55′W

Hexahedrite, H. Single crystal larger than 5 cm. Neumann bands. Group IIA. About 5.45% Ni, 0.3% P.

HISTORY

A mass of 2.56 kg was briefly described by Curvello (1954) who could provide only a little information as to the circumstances of discovery. The meteorite was apparently found in the vicinity of the town of Pirapora at an unknown date and was acquired about 1950 (?) by the Technological Institute in Belo Horizonte. About 1953 it was donated to the National Museum in Rio de Janeiro where Curvello examined the structure and Ferreira analyzed it.

Later, Curvello (1958) gave a few additional observations. Otherwise, the iron appears to be unexamined and undistributed.

COLLECTIONS

National Museum, Rio de Janeiro (main mass).

DESCRIPTION

The main mass in Rio de Janeiro is a triangular prism, 12 cm long and 8 x 7 cm in cross section. At the somewhat pointed end a rough cut of 8 x 5 cm shows where an endpiece of about 500 g has been removed. Two of the prismatic sides are rather smooth and a little convex, while the third is slightly concave and covered with regmaglypts 10-15 mm in diameter. Locally, the surface is damaged by hammering, though not so much that weathered fusion crusts cannot be distinguished in places. Artificial reheating has apparently not occurred.

Etched sections show Pirapora to be a hexahedrite in which Neumann bands extend across the entire surface, abruptly stopping at the heat-affected α_2 zone. This is up to 2 mm wide, but discontinuous due to parts having been lost to terrestrial weathering.

Troilite occurs as nodules and bars, e.g., 2 x 1 and 10 x 1 mm in size. They are shock-altered to complex, frayed aggregates of fine grained troilite, daubreelite, and a little kamacite and schreibersite. Rhabdites are common and schreibersite may be found as partly broken rims around the troilite nodules.

Thus, Pirapora appears to be a shocked and reheated hexahedrite which may be related to Indian Valley and Angra dos Reis. Considering the uncertainties of origin of both Angra dos Reis and Pirapora, a cross examination ought to be carried out to determine whether the two small irons are a paired fall.

Pitts, Georgia, U.S.A.
31°58′N, 83°33′W; 125 m

Fine octahedrite with much troilite and minor graphite and silicate. Bandwidth 0.20±0.05 mm. Neumann bands. HV 165±12.

Anomalous – group I. 12.9% Ni, 0.52% Co, about 0.2% P, about 5% S, 33 ppm Ga, 94 ppm Ge, 0.9 ppm Ir.

HISTORY

A small shower of irons fell near the town of Pitts, Wilcox County, about 9 a.m. April 20, 1921. The four fragments recovered had individual weights of 1.62, 1.24, 0.85 and 0.05 kg and thus totaled less than 4 kg. The fall was witnessed by many people, and the circumstances were well described by McCallie (1922), from whom the following main points are extracted. At the time of the fall no clouds were in view and the sun was shining brightly. The meteorite was nevertheless seen as a brilliant fireball that moved in a northeasterly direction and was clearly visible from an area of several thousand square miles, extending from Moultrie in the south to McDonough in the north. The dense smoke in the wake of the fireball was referred to

PIRAPORA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Ferreira in Curvello 1954	5.45	0.58	0.30		trace							

by the Albany and Moultrie witnesses as a luminous trail. The smoke lingered for several minutes and gradually assumed zigzag shapes due to the prevailing winds at various altitudes. The first sound heard was compared to thunder; some witnesses distinctly noted at least two terrific explosions followed in quick succession by a number of lesser explosions. The roaring and whizzing noises and the impact of the falling fragments were heard only in the immediate vicinity of the fall.

The largest fragment, of 1.62 kg, fell about 20 m from a house and was dug up a few minutes later, still warm. The fragment penetrated the freshly plowed sandy soil to a depth of about 40 cm, forming an inconspicuous hole less than 45 cm in diameter and about 20 cm deep. The second largest fragment, of 1.24 kg and now in the U.S. National Museum, fell by the roadside 210 m southeast of No. 1. It fell within 1 m of a Negro boy and buried itself about 20 cm in the ground, spattering the boy with flying earth. The third fragment fell about 1,200 m southwest of No. 2 in a cotton field. It had been cut in pieces when McCallie heard of if, but was estimated to have weighed less than 850 g. The fourth fragment, of 50 g, was picked up on the surface of a public road, about 1,500 m southwest of No. 1. McCallie tried without success to fit the different pieces together and concluded that not all fragments had been recovered. He gave a map showing the locations of the recovered pieces; the strewnfield is about 1.5 km long and 0.35 km wide with the largest pieces at the northeastern end.

While Nos. 1, 3, and 4 still are in private possession, S.H. Perry fortunately enough was able to purchase No. 2 in 1939. He subsequently donated it to the U.S. National Museum and commented briefly on the primary, ablated surfaces and the late, secondary fractures with little sculpturing, proving that disruption occurred after the flight through the air had been partly completed (Perry 1944: 93). Henderson & Furcron (1957) reviewed the case and gave photomacrographs of the ablated surfaces. Marvin (1963) X-rayed the fusion crust and identified magnetite with minor wüstite, the lines from this being rather diffuse. Fireman & Schwarzer (1957) determined the amount of ^{3}He and ^{6}Li, while Nyquist et al. (1969) examined the spallogenic $^{36}Ar/^{38}Ar$ ratio and found the cosmic ray exposure age to be above 5 million years. Begemann & Vilcsek (1970) measured ^{3}H, ^{4}He, ^{21}Ne, ^{36}Ar, ^{38}Ar and ^{40}Ar and arrived at an exposure age of 20-60 million years. The notable discrepancy from previous results was assumed to be due to a secondary cosmic breakup.

COLLECTIONS

Washington (1,022 g, No. 2), New York (47 g, of No. 2); the remainder of No. 2 has been used up. Nos. 1, 3, and 4 are still in private possession in Georgia.

DESCRIPTION

The specimen in the U.S. National Museum (No. 2, originally 1,240 g) is an irregular fragment, displaying about equal amounts of primary, severely ablated surfaces, and of

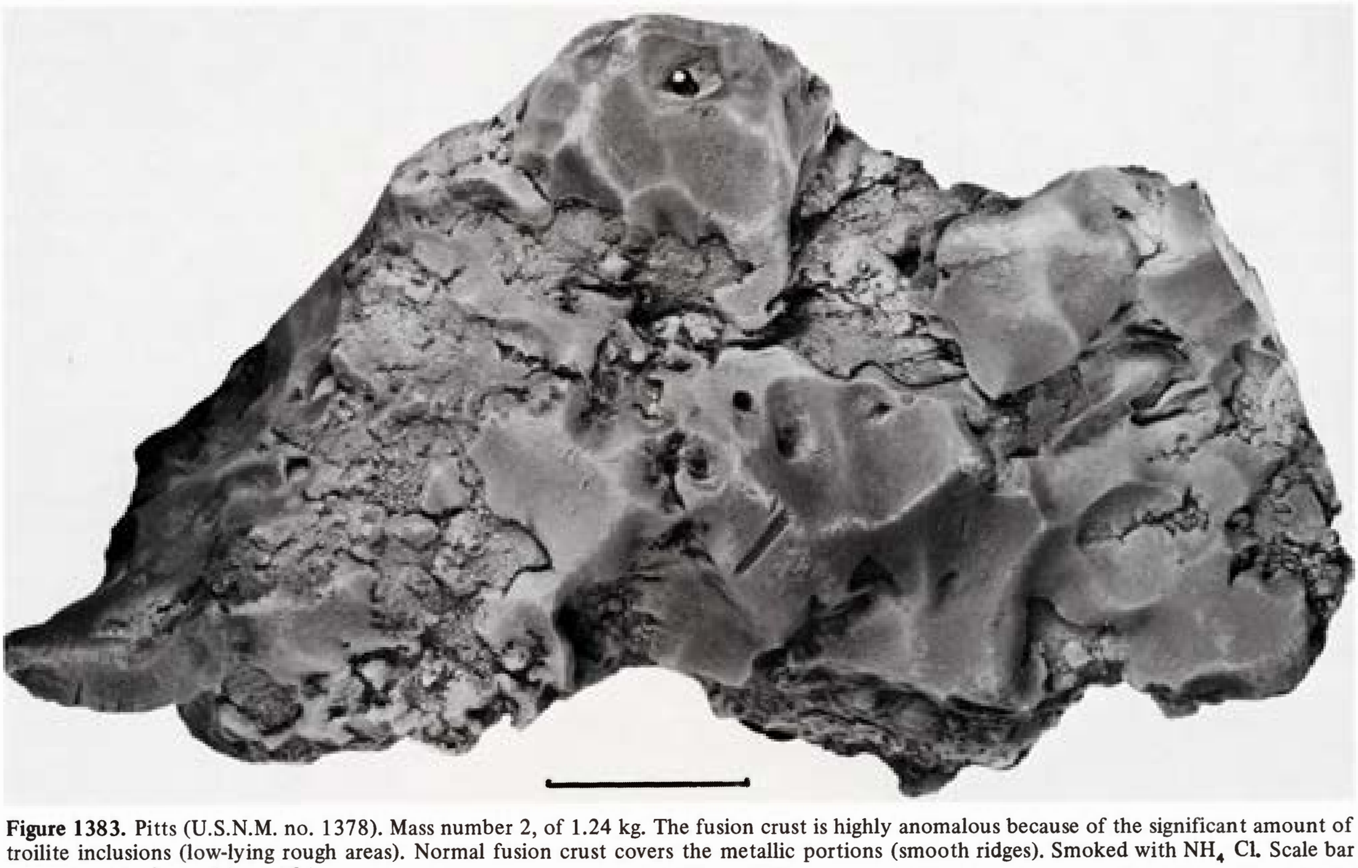

Figure 1383. Pitts (U.S.N.M. no. 1378). Mass number 2, of 1.24 kg. The fusion crust is highly anomalous because of the significant amount of troilite inclusions (low-lying rough areas). Normal fusion crust covers the metallic portions (smooth ridges). Smoked with NH_4 Cl. Scale bar approximately 2 cm. S.I. neg. 9A.

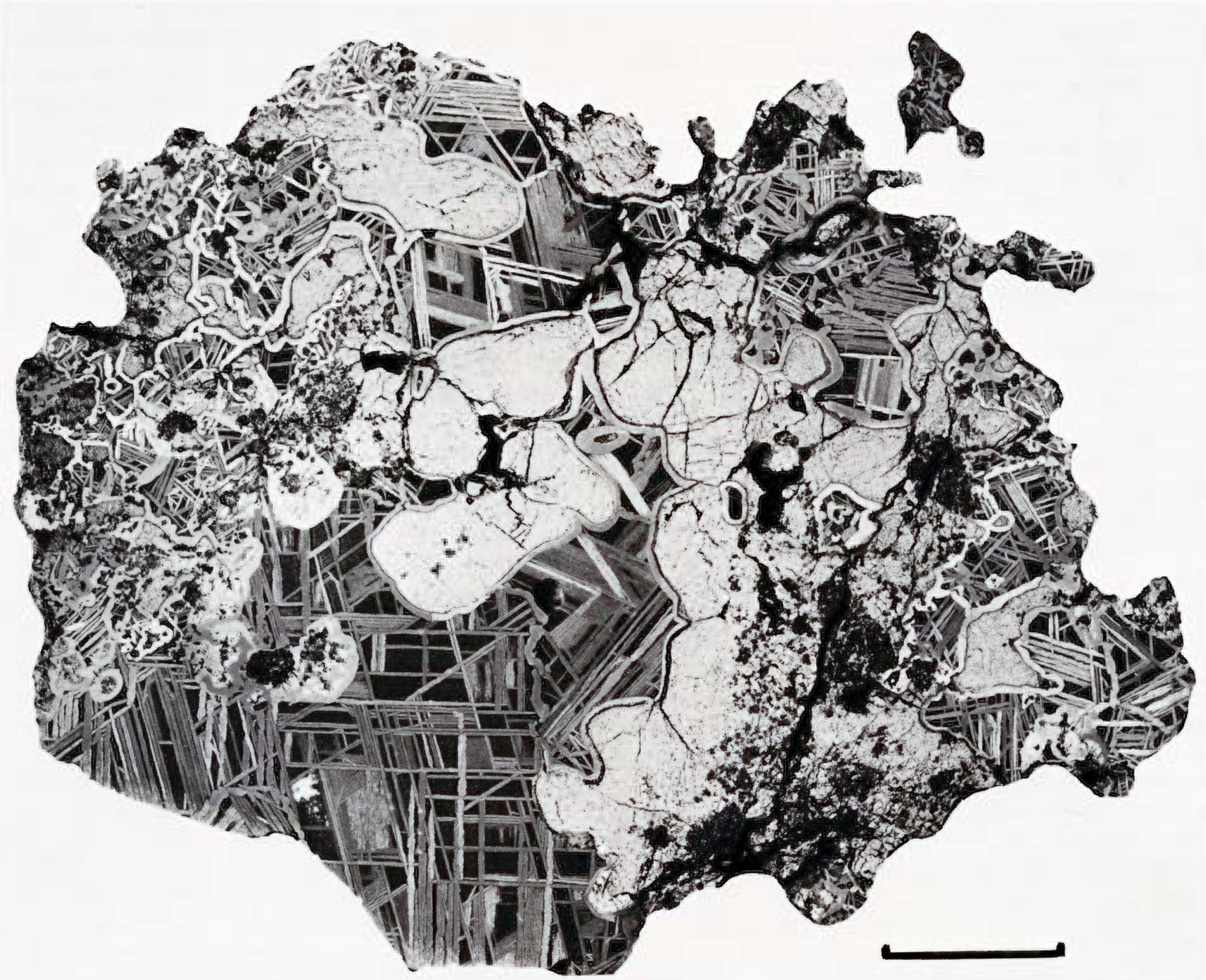

Figure 1384. Pitts (U.S.N.M. no. 1378). The meteorite exhibits a very unusual mixture of polycrystalline taenite and rounded troilite crystals with silicate inclusions. Each precursor taenite grain is enveloped in swathing kamacite and independently transformed to a fine Widmanstätten pattern. Deep-etched. Scale bar 10 mm. S.I. neg. 1516B.

secondary, less ablated surfaces. Since troilite is an essential component of Pitts, comprising about 25% by volume, the regmaglypts are very irregularly developed. The low-melting troilite melted well in advance of the adjacent metal and disappeared, leaving undercut cavities and depressions in the surface. At one place, the thin rim is completely penetrated by a hole, 1-2 mm in diameter, formed by the burning out of troilite. All ridges and knobs on the surface are composed of solid metal, covered with paper thin, warty crusts that are somewhat corroded. In several exposed places the crust is worn off by excessive handling, probably when in private possession.

The secondary fractures follow mainly the silicate- and troilite-rich parts of the meteorite. The rough surfaces are partially smoothed by ablation, and some parts are covered

PITTS – SELECTED CHEMICAL ANALYSES

McCallie (1922) reported that 90% of the four fragments was metallic, and Merrill (in McCallie 1922) identified olivine, diopside and plagioclase in the silicate fraction. These silicates were confirmed by Bunch & Keil (personal communication) who examined their composition with the microprobe. Mason (personal communication 1970) determined the indices for olivine, $\gamma = 1.674$, and for enstatite, $\gamma = 1.670$.

	percentage			ppm								
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Cobb 1967	13.0	0.52					475		43		1.8	
Wasson 1970b	12.80								33.0	94.2	0.86	

by sulfur-rich melts; again, the solid metal stands out as projecting ears and knobs.

Sections through the surface reveal that the fused crust is actually composed of various types. The magnetite-wüstite crust commonly met with is 10-100 μ thick and corresponds to that described in, e.g., Bogou. The metallic fusion crust is 10-150 μ thick and composed of numerous layers, each 10-20 μ thick. It is dendritic with significant amounts of low-melting, interdendritic, sulfur-rich melts. The third type of fusion crust is a ternary Fe-S-O eutectic, evidently formed from melting and burning of the troilite-rich parts of the meteorite in the lower parts of the atmosphere. It consists of deposits, up to 100 μ thick, particularly upon the secondary surfaces.

Under the metallic fusion crusts on the primary surfaces are α_2 zones, 2 mm thick, with micromelted phosphides in the exterior 50%. The fused metal evidently had a high carbon activity, since the adjacent metal is carburized to a depth of 10 μ. The graphite rims around the silicates are partly transformed to ledeburitic melts, partly dissolved, thus having created 10-50 μ wide martensitic-bainitic zones. Locally, a schreibersite crystal has burned out, and its cavity has become filled with melts.

Under the sulfidic fusion crusts on the secondary surfaces the heat-affected α_2 zone is only 0.1-0.2 mm thick, indicating that the temperature of the surface melts here was only about 900-1000° C, while the melts on the primary surfaces must have been about 1500° C.

While the three types of fusion crust have been described above in their pure forms, they often intermingle and wedge out in an irregular way. Fused sulfides are, e.g., present in the metallic crust.

Etched sections show that Pitts is an unusual mixture of metal and troilite with silicates. The metallic portions apparently constitute from 60 to 90%, while the troilite constitutes at least 80% of the nonmetallic fraction. The metallic part is a polycrystalline aggregate of austenite grains which range from 1-30 mm in size. Identifiable Widmanstätten structure has developed in grains as small as 2 mm in diameter. The individual grains are separated by 0.3-0.5 mm wide, continuous α-ribbons, or by sulfides and silicates. The beautiful Widmanstätten structure is that of a fine octahedrite with straight, long ($\frac{L}{W} \sim 25$) bands with a width of 0.20±0.05 mm. The kamacite has Neumann bands, particularly around the fissures and cracks that developed during the atmospheric disruption, and it has numerous fine phosphide precipitates, 0.5-1 μ across, on subboundaries and in the interior of the grains. The microhardness is 165±12, while the hardness of the heat-affected α_2 zone is 190±15.

Taenite and plessite cover about 60% of the metallic parts. The taenite-kamacite interface is often a jagged zigzag line, which is very unusual. The taenite has brown-etching rims, except in the heat-affected zone, and it has martensitic interiors. The martensite is either of the low-nickel type developed parallel to the Widmanstätten pattern, or of the acicular, high-nickel type developed in numerous directions. In the α_2 zone the taenite is surrounded by 10-50 μ wide martensitic-bainitic zones, formed when carbon from the taenite diffused out.

Schreibersite occurs as short, 5-50 μ thick blebs in the grain boundaries, or as blebs still enveloped by taenite. A few, larger skeleton crystals, up to 1 mm across, occur together with troilite, graphite and silicates. Their microhardness is 875±25. The bulk phosphorus content is estimated to be about 0.2%.

Troilite is a conspicuous constituent, sometimes covering 40% of the etched sections. It forms large clusters of globules, 5-25 mm across. These are subdivided into elongated cells with undulatory extinction; or have, in shear zones and along phase boundaries, recrystallized to aggregates of small grains, 1-10 μ acorss. The texture indicates that the troilite has been plastically deformed and reheated, almost to the point of local melting, probably as a result of shock. Daubreelite, chromite and cohenite were not observed. Haxonite is, however, present in minute amounts (E. Scott, personal communication 1971).

The silicates occur as irregularly distributed grains, 50-300 μ across. They may be found loosely dispersed in the troilite or in the metal, or they may form compact aggregates up to 15 mm across. The individual grains are frequently covered with a 5-30 μ thick graphite rim upon which schreibersite may have precipitated later. Graphite forms, in addition, 25-100 μ spherulites with a radial extinction, often clustered to compact aggregates, 1 mm across. The silicates have inclusions of kamacite, taenite and troilite; these inclusions are only 2-50 μ across and have not developed Widmanstätten patterns but resemble the inclusions common to stone meteorites. The silicates and, in particular, the troilite and the larger schreibersite crystals are enveloped by a 0.3-0.5 mm wide zone of swathing kamacite, nucleated here before the rest of the metal transformed to a Widmanstätten pattern.

Considering that Pitts is an observed fall, rapidly recovered, it is surprisingly corroded. Limonitic deposits, 10-25 μ thick, are common on the surface, and limonitic veins, 10-200 μ wide, are found in the interior between troilite and kamacite and along α/γ interphases. It appears that the meteorite is crisscrossed by extremely fine grain boundary fissures, developed perhaps during the atmospheric disruption, and it is these fissures that rapidly oxidized during the years in Georgia before the specimen was purchased by Perry, and probably also during later, repeated wet-sectioning, polishing and etching.

Pitts is a fine octahedrite with large amounts of troilite and minor amounts of graphite and silicate. It resembles Soroti very much, while its metal phase taken alone resembles Carlton. Wasson (1970b) suggested that Pitts, from a chemical standpoint, forms a natural extension to high nickel contents of the group I irons. This seems to be in harmony with the bandwidth and with the significant graphite, silicate and troilite contents, although the overall structure does not immediately suggest such a relationship.

Compare also San Cristobal which may be interpreted as a still further extension.

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

841 g fragment with polished face (no. 1378, 8.5 x 8 x 5 cm)
88 g slice (no. 1378, 6.5 x 5 x 0.6 cm)
93 g slice (no. 1378, 5 x 3 x 1.5 cm)

Pittsburgh, Pennsylvania, U.S.A.
40°20′N, 80°8′W

Coarse octahedrite, Og. Bandwidth 2.2±0.4 mm. Neumann bands and α_2. HV 130-185.

Group I judging from the structure. 7.0% Ni, 0.22% P.

The 13.2 kg mass was almost lost in forging operations; the surviving fragments have been reheated between 500 and 900° C.

HISTORY

This mass, hitherto assumed to weigh 292 pounds (Henderson & Perry 1958: 366; Hey 1966: 384), was found about 1850 by a farmer in a field near Miller's Run, Allegheny County. Part of it was acquired by Professor Silliman at Yale College, who quoted the following letter from his informer (1850):

"– A farmer was ploughing in the field, where, seeing a snake, he seized a stone, as he supposed, to destroy the animal, but, finding it remarkably heavy, he was attracted, after accomplishing his purpose, to examine the body which possessed such a remarkable weight. It was carried to Pittsburgh, where it was found to be very malleable, and unfortunately wrought into a bar, which has since been lost sight of. The mass was an ovoidal figure, almost six or seven inches in diameter, and weighed nearly 292 pounds (sic!)."

From a critical study of this piece of information it can be deduced that an ovoidal mass of 6-7 inches must weigh somewhere between 12 and 16 kg, depending on the detailed shape. It is certainly out of the question that it could weigh anything like 292 pounds (132 kg); it may however, have weighed 29 pounds (13.2 kg). There is reason to believe that the shape and dimensions are correctly rendered, – the figures indicate a range and cannot be a simple misprint – while the weight has been quoted uncritically, perhaps misread by one of Professor Silliman's informers. From the text, not quoted here, it appears that the finder gave the material to a nearby blacksmith, where a Mr. Baily noted the remains and informed a student of Silliman's (at New Haven, Connecticut) who in turn drew Silliman's attention to the meteorite. The information was thus third or fourth hand, so the facts may easily have been altered along the way.

Another indication that Pittsburgh must have been a small mass was that the farmer would naturally look for a 6-7 inch stone to throw after a snake, rather than attempt to pick up a stone, corresponding to a 132 kg mass of iron. So, if in the original report 292 is substituted with 29 pounds, the history of discovery is entirely without conflicting statements. It appears that Silliman acquired fragments of this 13.2 kg mass totaling about 1 kg, while the remaining part was forged into a bar.

Small samples were distributed from Yale and examined by Clark (1852), Reichenbach (1861), Genth (1875), Brezina (1885: 218; 1896: 290) and Cohen (1903e). While Brezina concluded that Pittsburgh, or Miller's Run as he called it, was a hexahedrite, Reichenbach and Cohen correctly classified it as a coarse octahedrite. Further references to the older literature may be found in Wülfing (1897) and Farrington (1915).

Stone (1932) and Stone & Starr (1967) reviewed the literature and gave a photomacrograph of a small polished slice. Henderson & Perry (1958) reexamined the iron and presented two photomacrographs and three photomicrographs of etched sections in the Yale and Harvard collections. They showed that the idea entertained by Stone (1932) that Pittsburgh, New Baltimore and Mount Joy should be paired falls, was untenable from a structural and compositional viewpoint, a conclusion that is fully supported in this study. They also discussed the variable structures which were supposed – as Cohen suggested – to be due to artificial reheating.

The locality of discovery, Miller's Run, is a creek which runs southwest-northeast and reaches the larger Chartiers Creek at Bridgeville, 12 km southwest of the center of Pittsburgh. The corresponding coordinates are given above.

COLLECTIONS

London (199 g), Yale (158 g), Göttingen (80 g), Amherst (47 g), Chicago (39 g), Harvard (33 g), Calcutta (8 g), New York (4 g), Vienna (2 g), Berlin (1 g), Tübingen (0.7 g). Apparently only about 600 g is preserved today in collections.

DESCRIPTION

As discussed above, it is here assumed that the original mass was an ovoid or lenticular mass with the approximate maximum dimensions 17 x 15 x 15 cm and weighing 13.2 kg. All the samples which I could examine turned out to be irregular fragments, (Chicago No. 1187, 4.5 x 1.5 x 0.5 cm, 22 g; Amherst, 3 x 2.5 x 1.3 cm, 47 g), or corner pieces (Yale No. 26, 6 x 3 x 2 cm, 158 g) or wedge-shaped pieces (London No. 35418, 4 x 1.5 x 1 cm, 28 g). None of them had much of the original surface preserved, and if so, it was considerably marred by hammering and chiseling.

PITTSBURGH – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson & Perry 1958	6.99	0.67	0.22	10	180							

The samples mentioned above are alike in all major characteristics but differ slightly in minor details, which is easily explained when we remember that Pittsburgh belongs to the coarse inclusion-rich octahedrites and, furthermore, that it has been artificially reheated and hammered. The following description is, therefore, applicable to a hypothetical type specimen containing all features within one large section.

Pittsburgh is a coarse octahedrite with bulky, short ($\frac{L}{W} \sim 8$) kamacite lamellae with a bandwidth of 2.2±0.4 mm. Local grain growth has created almost equiaxial kamacite grains, ranging from 5 to 15 mm in size. Subboundaries, decorated with less than 1 μ phosphides, are common, and Neumann bands are well developed. If the structure had not been artificially damaged, the hardness would probably have been 185±15.

Taenite and plessite cover 2-5% by area. Comb plessite of a degenerated variety locally attains sizes of 2 x 5 mm. Taenite lamellae in grain boundaries, and taenite wedges with interiors of martensite or with acicular α-sparks, 5-10 μ wide, are also common. The taenite rims stain brown or blue on etching.

Schreibersite occurs as cuneiform skeleton crystals, typically 0.5 mm thick and up to 5 mm long. They are the center of large kamacite crystals that can be interpreted as swathing kamacite, 5-8 mm wide. Schreibersite is also common as 20-100 μ wide grain boundary veinlets. Rhabdites are very well developed and a large number are 10-20 μ in cross section. Smaller rhabdites, in the 1-2 μ range, also occur. The bulk phosphorus content is estimated to be 0.20-0.25%.

Troilite, graphite and silicates were not detected in the available sections. Cohen (1903e), however, saw troilite, daubreelite and chromite in his material.

Cohenite occurs as rounded bodies, typically 3 x 0.6 mm in size, and elongated in the Widmanstätten directions. The cohenite crystals display 20-500 μ windows of kamacite, taenite and schreibersite; graphite decomposition has not started. In the kamacite, carlsbergite occurs as 10 x 1 μ hard platelets that have often nucleated a rhabdite crystal.

The meteorite is only slightly corroded; if the original mass had remained, possibly both fusion crust and heat-affected α_2 zones would have been preserved. However, the entire mass was violently broken up just before 1850.

As a result, the surviving fragments display hammered and overfolded surface parts and deep chisel marks. Some specimens even display oxide-shales from artificial reheating. Etched sections, containing the worked surfaces, show high-temperature intergranular oxidation and heat-affected α_2 zones (HV 130-185), and the preexisting corrosion products are slightly altered. The taenite lamellae have lost their stain and now appear yellow with mosaic structures (HV 200-230). Some additional martensite platelets may be detected inside the massive plessite wedges. Around many taenite borders, 10 μ wide dark-etching zones of martensite occur, due to the outward diffusion of carbon from the taenite. On the other hand, no micromelted phosphides were detected. It appears that the maximum temperature in reheating was about 900° C. At a distance from the worked surfaces the Neumann bands reappear, but often in an altered state, showing incipient recrystallization or dissolution (HV 130-155). Other specimens show, in addition, the effects of cold working: the kamacite is heavily deformed, with lenticular deformation bands and bent Neumann bands, the grain boundaries are split open, and the brittle phosphides and carbides are brecciated and sheared.

Pittsburgh is a coarse octahedrite closely related to Canyon Diablo, Cosby's Creek and Silver Crown, and is undoubtedly a normal member of group I. When the blacksmith worked the major part of the mass, the minor parts which have survived in collections were reheated and hammered, too, to varying extents. Reheating in the 500-600° C range annealed and recovered the metal to low hardnesses, while reheating in the 700-900° C range altered the kamacite to α_2 and also affected the details of the taenite-plessite areas. A similar reheating, carried to about 600° C, was observed in Waldron's Ridge, another typical group I iron.

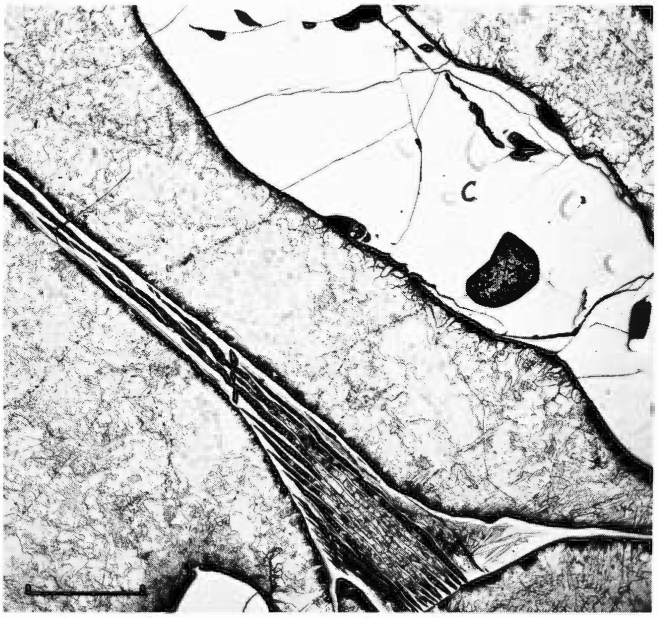

Figure 1385. Pittsburgh (Yale no. P26). A coarse octahedrite of group I which has been artificially reheated to about 800° C. The kamacite is unequilibrated α_2. The comb plessite and cohenite (C) are slightly affected. Etched. Scale bar 400 μ. (Henderson & Perry 1958: plate 15.)

Plymouth, Indiana, U.S.A.

Approximately 41°14'N, 86°27'W; 225 m

Medium octahedrite, Om. Bandwidth 1.30±0.30 mm. Partially recrystallized. HV 190±10.

Group IIIA. 8.69% Ni, 0.50% Co, 0.25% P, 23 ppm Ga, 42 ppm Ge, 0.66 ppm Ir.

HISTORY

A mass was plowed up by J.J. Kyser in 1883 (?) on his farm about 8 km southwest of the town of Plymouth, Marshall County. It was acquired by Ward who described it briefly and gave a photograph of the exterior and of an etched slice (1895). Unfortunately Ward did not state the original weight; from the total known weight preserved and from the overall dimensions, as taken from Ward, I estimate the weight to have been 13-15 kg. Ward noted that the discoverer had already, in 1872, found another, larger meteorite in the same field. Since this mass, about 4 x 3 x 2/3 feet in size, had been seriously interferring with the field work, Mr. Kyser, aided by his son, had dug a hole deep enough to bury the mass completely. In 1894 Ward tried without success to relocate the buried main mass, which – if the account is reliable – must have weighed about 1,000 kg. Ward's own account is, unfortunately, marred by omitting the weight of the small specimen and of several inconsistencies with respect to dating of the various events. A critical examination of his paper appears to place the find in 1883, and not in 1893 as quoted in all later catalogs.

The mass was sliced and distributed by Ward. In his catalog (1904: plate 1) he gave a photomacrograph of an etched section. Another macrograph was published by Mauroy (1913: plate 1). Brezina (1896: 285) gave a brief description.

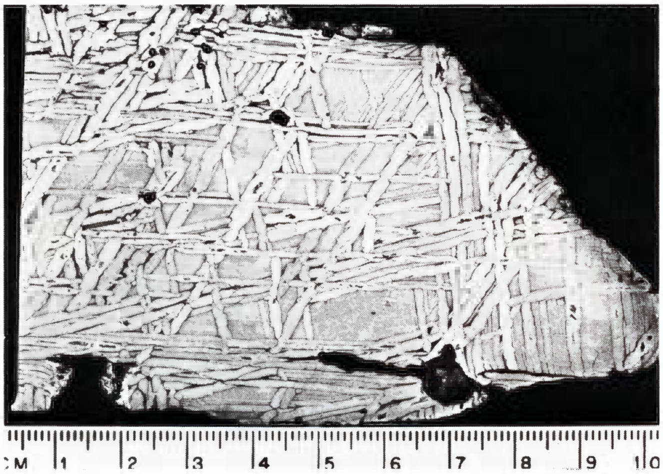

Figure 1386. Plymouth (Tempe no. 160a). Partly recrystallized medium octahedrite of group IIIA. Schreibersite crystals (black) are common in the center of the kamacite lamellae. Black nodules are troilite and terrestrial corrosion. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

COLLECTIONS

New York (3,572 g endpiece), Chicago (1,086 g), Vienna (893 g), Calcutta (757 g), Washington (600 g), Harvard (565 g), Budapest (472 g), London (445 g), Leningrad (390 g), Tempe (349 g), Yale (205 g), Amherst (147 g), Vatican (145 g), Sarajevo (140 g), Rome (137 g), Bonn (126 g), Stockholm (105 g), Berlin (103 g), Paris (50 g), Prague (39 g), Ottawa (24 g), Copenhagen (20 g), Strasbourg (12 g), Total recorded: 10.5 kg.

DESCRIPTION

The average dimensions of the only piece recovered were 31 x 18 x 5 cm, and the estimated weight 13-15 kg. Its shape was elongated, lenticular, and Ward (1895) stated that the surface was deeply eroded by weathering. This is, however, a superficial observation, since the various sections all show that a heat-affected α_2 zone is well preserved as a 2 mm wide rim, indicating that only small amounts have been removed by corrosion. Moreover, fused, metallic crusts are present in numerous places, particularly as complex whirlpools that irregularly penetrate to a depth of 1-5 mm below the general surface. The fused metal of the whirlpools is deposited as dendritic-cellular material with an armspacing of 2-4 μ and a cell size of 20-50 μ. It is converted to martensite and has a microhardness of 300±20. Similar deposits are present on Arlington, Jamestown and other irons, suggesting a play of vortices on the rear side of the penetrating meteorite fireball. Locally, a near-surface troilite nodule on the front side has been partially burned out, leaving a gaping hole, 1 cm across and 1 cm deep (No. 2995).

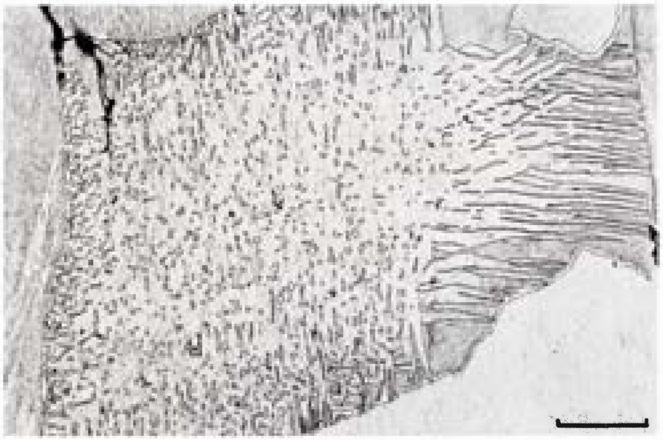

Figure 1387. Plymouth (U.S.N.M. no. 2995). A large comb and net plessite field, surrounded by annealed shock-hatched kamacite. Etched. Scale bar 400 μ.

PLYMOUTH – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore & Lewis 1968	8.69	0.50	0.25	155	45							
Wasson 1971, pers. comm.	8.4±0.5								23.1	42.4	0.66	

The bulk phosphorus content may be somewhat higher, 0.30-0.35%, than this analysis indicates.

The exterior part of the α_2 zone has an unusual high microhardness of 275. The reason is the presence of partially dissolved, finely dispersed taenite grains. The interior part of the α_2 zone has the normal hardness of 200±20. A minimum of 170 is found at the transition from α_2 to the untransformed interior (hardness curve type II).

Etched sections display a medium Widmanstätten structure of slightly undulatory, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 1.30±0.30 mm. The wider lamellae frequently contain plate-shaped, 0.5 mm thick schreibersite crystals, situated in the central parts of the lamellae. Taenite and plessite cover about 40% by area, both as comb and net plessite and as dense, duplex fields of varying fineness.

After the primary structure had developed, a cosmic reheating led to the decomposition and partial recrystallization of the kamacite. Presently the kamacite lamellae consist of a duplex structure where well dispersed γ-beads, 0.5-1 μ across, occur through a serrated, oriented α-phase. At low magnification the structure resembles a hatched ϵ-matrix, but a 40x objective shows that the matrix is two-phased as a result of annealing. Well-recrystallized, equiaxial ferrite units, 10-50 μ across, are developed only where the nickel content was relatively low, particularly in 10-50 μ wide zones around the phosphides. The microhardness of the duplex matrix is 190±10.

The taenite borders also display annealing effects; they are regularly marked with what appears to be an oriented grid of submicroscopic precipitates (kamacite-beads?). The interior of the taenite and the plessite forms distinctly two-phased $\alpha + \gamma$ structures, the microhardness ranging from 200 to 250.

Schreibersite occurs as 0.5 mm wide, platy skeleton crystals centrally in the kamacite. They are generally only 1-2 mm long, but may reach lengths of 15-20 mm. They are monocrystalline, but severely brecciated, and have a microhardness of 900±25. Schreibersite is further common as 20-80 μ wide grain boundary precipitates and as 2-25 μ blebs inside the plessite fields.

Troilite occurs as 3-20 mm nodules, that appear to be heavily corroded; they could not be studied in detail. They are surrounded by 0.2 mm wide schreibersite rim and sometimes associated with 1-2 mm subangular chromite crystals.

Cohenite was reported by Brezina (1896), but this seems to be a misinterpretation of schreibersite. Graphite was reported by Ward (1895); nor could this observation be confirmed.

The mass is somewhat corroded. Particularly the fused metal deposits and the brecciated minerals and their surroundings are attacked. It also appears that, when it reached the ground, the mass had several intercrystalline

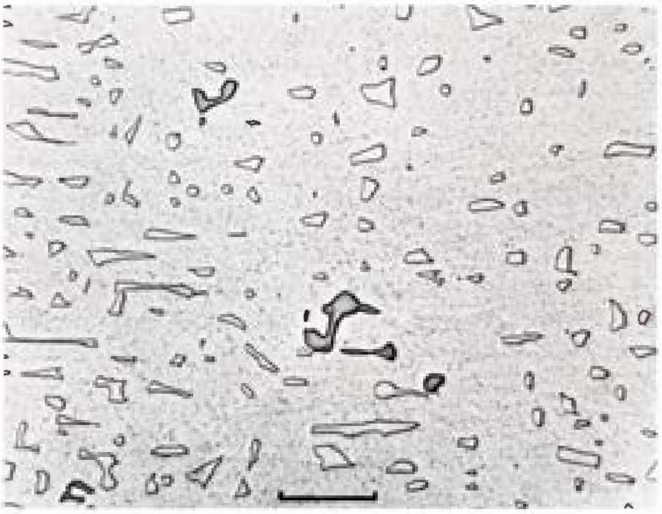

Figure 1388. Plymouth. Detail of Figure 1387. Around phosphide particles (dark) recrystallization of kamacite has started. The kamacite is loaded with almost submicroscopic γ-particles. Etched. Scale bar 100 μ.

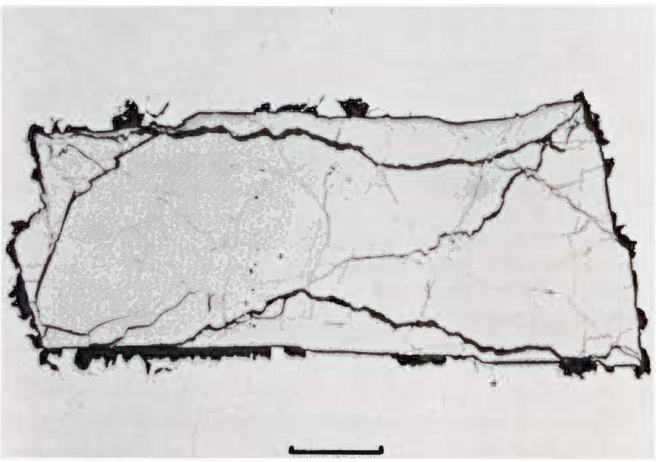

Figure 1389. Plymouth (U.S.N.M. no. 2995). A fissured schreibersite crystal that is recemented by terrestrial corrosion products. The surrounding kamacite is recrystallized. Lightly etched. Scale bar 100 μ.

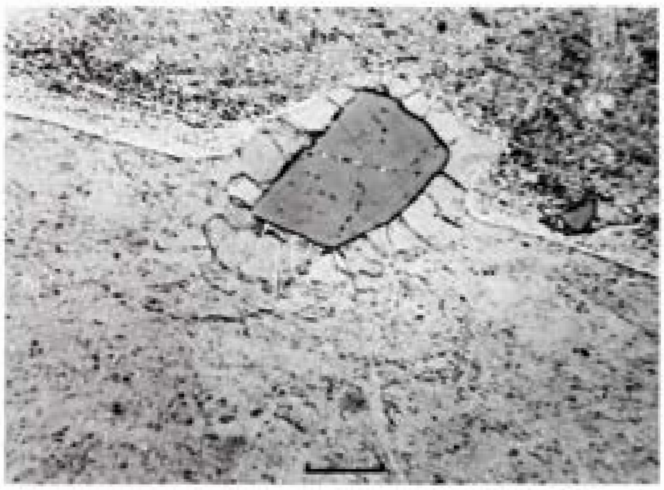

Figure 1390. Plymouth (U.S.N.M. no. 2995). Above, annealed plessite with taenite edges that are decomposing in a $(111)_\gamma$ grid. In center a schreibersite crystal around which kamacite has recrystallized. Below, kamacite with almost submicroscopic γ-particles and some fine recrystallized grains. Etched. Crossed polars. Scale bar 20 μ.

fissures along which weathering could easily proceed to produce 0.1-1 mm wide limonite veins. It takes only little imagination to conceive that these cracks could have been formed simultaneously with another large crack that led to the formation of another, much larger and still undiscovered fragment, the mass which was reburied by the farmers.

Plymouth is a medium octahedrite, rather normal in its primary structure but anomalous in its secondary, reheated structure. It is somewhat similar to Sandtown and Casimiro de Abreu, perhaps representing a stage intermediate between those two in reheating intensity. The temperature appears to have been of the order of 500-600° C and must have been maintained for a long time, or have recurred a number of times. Chemically, Plymouth is intermediate between group IIIA and group IIIB, resembling, e.g., Casimiro de Abreu, Campbellsville and Aggie Creek.

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

181 g part slice (no. 203, 6 x 5.5 x 0.8 cm)
26 g part slice (no. 2995, 5 x 4 x 0.2 cm)
393 g almost full slice (no. 2996, 12 x 6 x 1 cm)

Point of Rocks (iron), New Mexico, U.S.A.

About 36½°N, 104½°W

A fragment of 23.4 g of an octahedrite, allegedly found in 1956 near Point of Rocks, Colfax County, is in Albuquerque (La Paz 1965: 110). An analysis by Wasson (1971, personal communication), showing 8.36% Ni, 21.1 ppm Ga, 41.4 ppm Ge and 0.46 ppm Ir, indicates that the material belongs to a very common type of medium octahedrite of which several large meteorites from the American Southwest are known. In particular, it should be checked to see whether the fragment could have been detached from Drum Mountains, Quinn Canyon, Bartlett or Spearman.

Pojoaque. See Glorieta Mountain

Ponca Creek. See Ainsworth

Pooposo, Bolivia

Approximately 18°20'S, 66°50'W

Coarse octahedrite, Og. Bandwidth 2.6±0.6 mm.

Probably group I, judging from the structure. About 6.6% Ni, 0.2% P.

Probably another fragment of the meteorite listed as Bolivia, page 335.

HISTORY

A mass of unknown weight was briefly mentioned by Berwerth (1912: 237). According to letters in the British Museum (Prior 1923a; Hey 1966: 289), the mass was obtained in 1910 by the mineral dealer J. Böhm from a missionary who had brought it from the Pooposo Estate in Bolivia. Böhm evidently sold the main mass to Vienna, while a sample was purchased by the British Museum.

COLLECTIONS

Vienna (main mass), London (26 g).

ANALYSES

From a cursory examination it appears that the mass must contain 6.6±0.2% Ni and 0.20±0.05% P.

DESCRIPTION

The main mass in Vienna weighs about 12 kg and measures 20 x 15 x 10 cm in three perpendicular directions. It is weathered and shows indications at one end of severe deformation, apparently due to the application of tools in order to split the mass. The fractured surface is very rough. It is not known where the other part of the mass is.

The deep-etched sections display a coarse Widmanstätten structure of bulky, short ($\frac{L}{W} \sim 6$) kamacite lamellae with a width of 2.6±0.6 mm. Local grain growth has created almost equiaxial kamacite grains, 5-15 mm across. Within these, scattered taenite lamellae and plessite fields are located, in addition to what is present along grain boundaries. The total amount of taenite plus plessite is estimated to be 1-3%.

Schreibersite occurs irregularly as 0.5-1 mm wide lamellae and cuneiform crystals. Troilite was seen as a 10 x 6 mm nodule.

Pooposo is an inclusion-rich coarse octahedrite of a rather common type, related to Seeläsgen, Sardis and Cosby's Creek, and no doubt a normal member of the resolved chemical group I.

Considering its supposed Bolivian origin, it is quite interesting that the only other known iron meteorite from Bolivia is a coarse octahedrite, Bolivia, page 335. Both irons were apparently acquired by some unknown missionary at approximately the same time, about 1900, and brought out of Bolivia. Since the two masses may, thus, have the same origin and show the same structure and degree of weathering, it appears probable that they belong to the same shower-producing fall. A modern examination and complete analysis of Pooposo is recommended in order to solve this problem finally.

Prambanan, Soerakarta, Java

Approximately 7°32'S, 110°50'E

Finest octahedrite, Off. Bandwidth 125±50 μ. Artificial α_2 matrix.

Probably anomalous. About 9.4% Ni, 0.16% P.

All specimens in collections have been artificially reheated above 900° C.

HISTORY

This meteorite is only insufficiently known through a small fragment of 1/4 kg which was sent to the Netherlands from Soerakarta in 1865. It was described by Baumhauer (1866) who presented five galvanoplastic figures of polished and deep-etched surfaces. He noted that his fragment