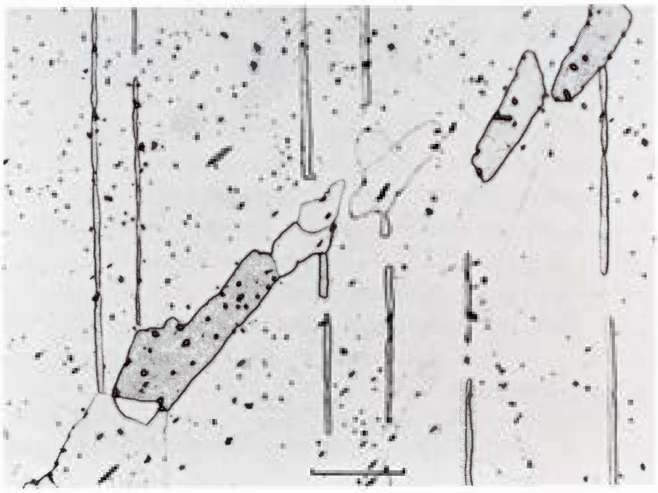

Figure 1698. Ssyromolotovo (Chicago no. 1148). Kamacite which shows annealed Neumann bands and small recrystallized ferrite grains. Etched. Scale bar 40 μ.

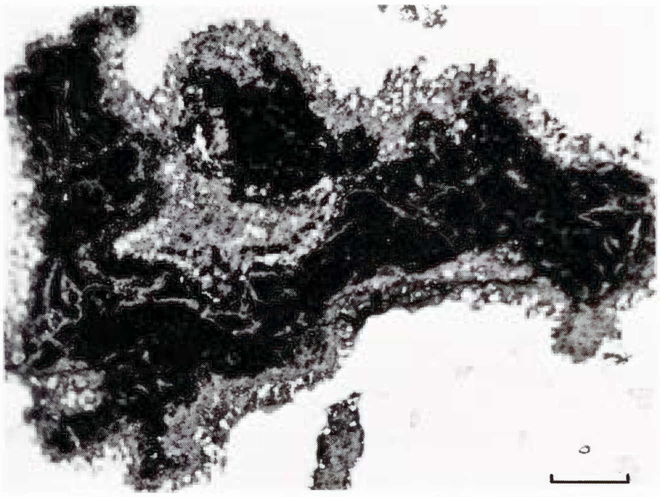

Figure 1699. Ssyromolotovo (Chicago no. 1148). Pocket of corrosion products (black) which have been decomposed by artificial reheating to about 650° C. Laceworks of metal and oxides along interfaces. Lightly etched. Oil immersion. Scale bar 10 μ. See also Figure 25.

which has a composition and structure very similar to Ssyromolotovo.

With this admittedly small and somewhat damaged sample for examination, it is difficult to be precise as to the bulk structure of Ssyromolotovo. It is, e.g., not known whether the whole mass was exposed to reheating or whether only the detached samples were reheated. On the main mass fusion crust and heat-affected α_2 zones should be present, but these could not be detected due to the extensive damage inflicted on the small piece examined.

On the whole, Ssyromolotovo must be chemically and structurally closely related to Cape York, Casas Grandes and Toubil River. Its trace-element composition will no doubt be found to place it well inside the resolved chemical group IIIA.

[J.T. Wasson (personal communication 1974): Group IIIA with 7.85% Ni, 19.6 ppm Ga, 40.9 ppm Ge and 3.3 ppm Ir].

Staunton, Virginia, U.S.A.

38°13′N, 79°3′W; 450 m

Coarse octahedrite, Og. Bandwidth 1.60±0.30 mm. Neumann bands. HV 252±18.

Group IIIE. 8.62% Ni, 0.49% Co, 0.31% P, 18.9 ppm Ga, 36.6 ppm Ge, 0.11 ppm Ir.

HISTORY

Two different meteorites are presently in collections under the name of Staunton. Both are octahedrites with 8-9% nickel, but they differ in kamacite bandwidth and hardness and in the amount of carbides and phosphides. They also show significant differences in the amount of minor and trace elements. In the following I will treat the one fall for which I propose to retain the name Staunton, while an account of the other material will be found under the entry Augusta County.

Mallet (1871) reported the discovery about 1869 of three irons of 25.4 kg (No. 1), 16.4 kg (No. 2) and 1.64 kg (No. 3). They had been plowed up north of Staunton, the largest by R. Van Lear in 1869, five miles north and a little east of Staunton; the other two, one mile southeast and one and one-half miles southeast of No. 1, respectively. Mallet reproduced figures of the exterior and of etched sections. He also presented chemical analyses of all three masses, unfortunately, however, he arrived at an erroneously high nickel value (10%) for all three. Since the problem today is to reidentify the original masses as found – they have later been cut and distributed with little information as to the mass from which the individual specimens were cut, – we can only rely on the structure and on one particular, significant element, phosphorus, which even at that early date was determined with sufficient precision. Mallet found 0.34-0.37% P in all three masses, and I think this is, together with the structure, in this case enough to conclude that Nos. 1, 2 and 3 really belonged to the same fall. Modern analyses on material that I have identified as coming from Nos. 1-3 will be found below.

Another mass (No. 4), of about 1 kg, was briefly described and pictured by Kunz (1887b) as coming from a place near No. 1. Mallet's analytical techniques and experience had improved considerably during the 16 years which had passed, so his analysis is quoted below.

Staunton material has been examined by several authors both chemically and structurally and also analyzed for gases. However, since the sources are rarely given, it is difficult at this date to detect whether the papers refer to the four masses discussed here or to the two discussed under Augusta County.

Perhaps the best cataloged and most comprehensive collection today of specimens from the various blocks is in

Vienna – the reason being that Brezina (1896: 278, 279, 302, 304) suspected at an early date that the blocks represented two different falls.

COLLECTIONS

Staunton and Augusta County belong to the best distributed iron meteorites. In the following I list only the specimens which I have checked and found to correspond to Staunton. It should, however, be possible for curators on the basis of the following description to sort their "Staunton" specimens and reidentify authentic Staunton and authentic Augusta County material. Vienna (No. 1 of 500 g, No. 2 of 187 g, No. 3 of 178 g, No. 4 of 761 g), London (No. 44761 of 1,583 g), Washington (1,228 g), Tempe (No. 155a of 637 g), Prague (557 g), Copenhagen (23 g), Harvard (No. 242c of 220 g, with J.L. Smith's old identification number 141 chiseled in).

DESCRIPTION

According to Mallet (1871) the average dimensions were: 28 x 19 x 12 cm (25.4 kg, No. 1), 27 x 15 x 9 cm (16.4 kg, No. 2) and 11 x 7 x 5.5 cm (1.64 kg, No. 3). The dimensions, but not the weight, of No. 4 were given by Kunz (1887b): 8.5 x 6.5 x 5 cm, which correspond to 125-150 cm^3 or 1-1.2 kg, considering the dimensions as those of an irregular, rounded mass. All the masses have rough and irregular surfaces, coated with 0.1-4 mm thick, terrestrial oxides. No fusion crust and no heat-affected α_2 zones were identified in this study; in a few places, however, there are tensile fractures with necking in the immediate surface layers indicating where the masses ruptured when being decelerated in the atmosphere.

Etched sections display a coarse Widmanstätten structure with short swollen kamacite lamellae ($\frac{L}{W} \sim 10$) with a width of 1.60±0.30 mm. The kamacite has subboundaries decorated with 0.5-2 μ rhabdites. It is rich in well defined, ragged Neumann bands with no precipitates. The hardness is 252±18, varying somewhat with the amount and size of the precipitates in the α-phase.

Taenite and plessite cover about 25% by area, mostly as dense, martensitic fields with a felt of 1-5 μ wide, crisscrossing α-spindles. Comb and net plessite proper are almost absent. The fields have conspicuously concave outlines due to the swollen shape of the kamacite lamellae, a feature which is characteristic and helps to separate Staunton from Augusta County specimens. A typical field will display a narrow taenite rim (HV 380±15) followed by light-etching, martensitic transition zones (HV 440±15). Then follows dark-etching martensite (HV 415±15) and an acicular kamacite felt on a background of martensite (HV 325±25). The acicular kamacite of the near-surface fields are selectively corroded.

Figure 1700. Staunton (Tempe no. 155a of 659 g). A coarse octahedrite of group IIIE and related to Rhine Villa and Willow Creek. Note the swollen kamacite lamellae. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

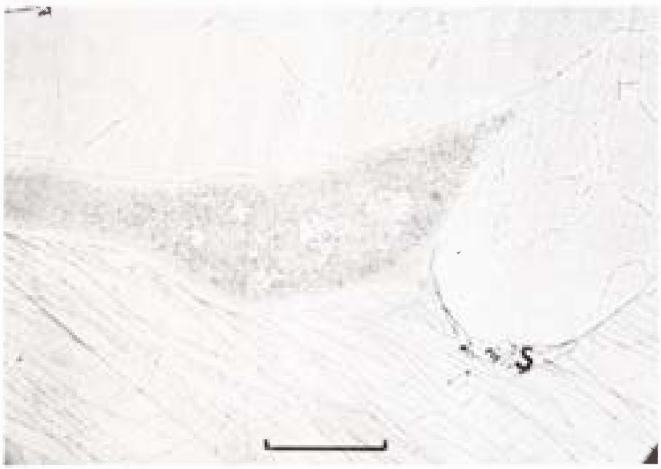

Figure 1701. Staunton (Harvard no. 242c; 220 g). A plessite field with several "carbide roses", i.e., haxonite (white). Brecciated schreibersite (S), subboundaries and Neumann bands. Etched. Scale bar 500 μ.

STAUNTON – SELECTED CHEMICAL ANALYSES

Mallet (1871) found 0.34, 0.36 and 0.38% P in Nos. 1-3, respectively. He also found iron chloride near the surface but was unable to detect chlorine in a 50 gm piece, devoid of fissures, taken from the interior of No. 1. He rightly concluded that the chlorine was not of meteoric origin but had been derived from the soil in which the iron had lain embedded.

	percentage			ppm									
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt	Mass No.
Mallet in Kunz 1887b	8.85	0.49	0.24	1770	120		160						4
Moore et al. 1969	8.80	0.48	0.24	460	270		140						
Scott et al. 1973	8.21								18.9	36.6	0.11		

In about every fourth taenite field carbide roses are present. They are 50-400 μ across and form complex intergrowths with taenite, martensitic plessite, kamacite and schreibersite. The massive carbide parts of the spongy masses are up to 25 μ across, and the foreign inclusions are 1-5 μ across. The hardness is 925±75, varying with the actual amounts of inclusions at the test site. The carbide roses are rather resistant to corrosion where exposed near the surface. They are isotropic and identical to the new mineral, haxonite, $M_{23}C_6$ (Scott 1971).

Schreibersite is common as angular bodies, typically 4 x 0.2 mm or 1 x 0.4 mm in size, centrally in some of the kamacite lamellae. It also forms an abundance of 20-100 μ wide grain boundary precipitates and 2-10 μ irregular blebs inside the plessite fields. Rhabdites occur as easily recognizable crystals, 1-4 μ across, and as a generation of very fine precipitates, less than 0.5 μ across, in the kamacite.

Troilite does not appear to be common as large nodules. It is however, present as 0.1-2 mm blebs which are intergrown with parallel daubreelite lamellae. The 2 mm blebs may contain 10% daubreelite, while the 0.1 mm blebs show as much as 50% daubreelite, frequently in the form of 1-5 μ wide lamellae. The troilite is monocrystalline but exhibits fine twin-sparks from plastic deformation. The troilite-daubreelite crystals have served as nucleation sites for 10-60 μ wide schreibersite precipitates. Once, a euhedral chromite crystal, 1.0 mm across, was observed associated with a little troilite in a kamacite lamella.

Staunton is an anomalous, coarse octahedrite with a structure, mineral association and chemical composition that resemble Rhine Villa and Paneth's Iron pretty much. Staunton is also very closely related to Willow Creek but, while Staunton is only little influenced by late cosmic reheating, Willow Creek is significantly altered. The crucial features that separate Staunton from Augusta County are summarized under Augusta County. Both these irons belong to the chemical group III. Staunton's bandwidth might suggest a relationship to Odessa (1.7 mm), Toluca (1.4 mm) and other group I irons. However, the resemblance is superficial, as Staunton's detailed composition and structure – particularly the carbide roses and the spindle-shaped α-lamellae indicate. Staunton is best classified as a group IIIE iron.

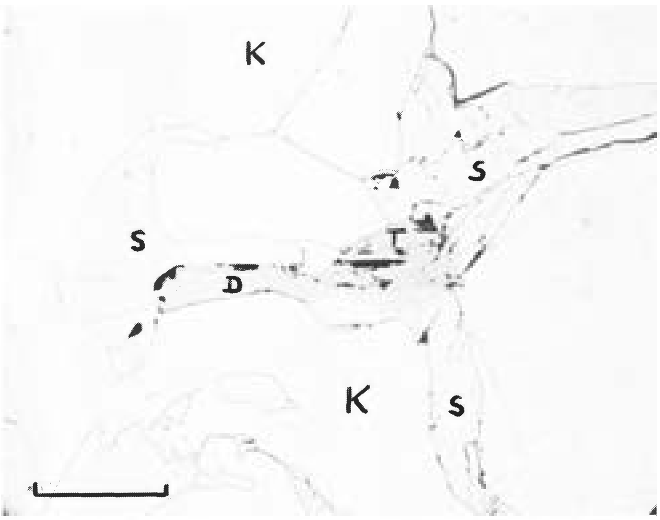

Figure 1702. Staunton (Harvard no. 242c). The troilite-daubreelite nodule (T,D) has served as a nucleus for schreibersite (S). This has grown irregularly along grain boundaries in the kamacite (K). Etched. Scale bar 200 μ.

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

1,157 g slice (no. 590, 20 x 10 x 0.9 cm). Previously a part of the Bement Collection. No information as to the block from which it was cut.

71 g part slice (no. 2204, 5 x 2 x 2 cm). Originally acquired for the Frank A. Lewis Collection from Professor Mallet. No information as to block number.

Sulechow. See Seeläsgen (Sulechow fragment)

Summit, Alabama, U.S.A.

34°11′N, 86°32′W; 250 m

Coarsest octahedrite, Ogg. Bandwidth 6±3 mm and 4 cm grains. Neumann bands. HV 235±15.

Group unknown, but possibly group IIB related to São Julião. About 5.7% Ni, 0.5% P.

HISTORY

A mass of one kilogram was found before 1890 by a six-year-old Negro girl near Summit, Blount County. For a while it was used for cracking hickory nuts but was eventually acquired by Kunz (1890a) who briefly described it and presented a figure of the exterior. He gave the locality as Fraction A, Section 10, Township 10, Range 1 East, which is 4 km southwest of Summit and corresponds to the coordinates given above. The mass formed part of Kunz's Collection until acquired by Brezina (1896: 234, 293), who classified it as a hexahedrite. Also, Cohen (1905: 245), Farrington (1915: 429), Henderson (1965) and Hey (1966: 466) have listed the meteorite as a hexahedrite, but as will be shown below, Summit is rather a coarsest octahedrite related to São Julião or, possibly, Tombigbee. Berwerth (1914: 1078) suggested that the mass had been artificially reheated. This was supported by Buchwald (quoted in Hey 1966: 466). My reexamination of authentic material from Vienna, Chicago, and New York shows, however, that I was in error.

COLLECTIONS

Vienna (three specimens totaling 374 g), London (45 g), Chicago (38 g), New York (33 g), Berlin (about (20 g), Ottawa (14 g).

ANALYSES

Venable (in Kunz 1890a) found 5.68% Ni, 0.58% Co, 0.31% P. Lawrencite was assumed to be present, forming deliquescent beads on the surface, but this appears to be a misinterpretation of terrestrial chloride introduced with the ground water.

DESCRIPTION

The meteorite had the maximum dimensions 12.5 x 7.5 x 5 cm. It showed only a slight trace of the original crust that was almost completely oxidized (Kunz 1890a). This was confirmed in the present study. The fusion crust is lost, but locally a 100-200 μ thick, heat-affected α_2 zone could be identified. The hardness of the interior is 235±15, but it drops significantly towards the surface where it reaches a minimum of 180±10, corresponding to annealing in the atmosphere (hardness curve type I, where only the portion right of the minimum is preserved). It is estimated that on the average 2 mm has been lost by terrestrial weathering.

Etched sections display a mixture of elongated kamacite grains and large equiaxial kamacite grains. The kamacite lamellae are 3-10 mm wide and 10-50 mm long, while the equiaxial grains are 3-5 cm in diameter and normally have large schreibersite rosettes in the center. The kamacite displays many subboundaries, decorated with 1-2 μ rhabdites, particularly in the clear kamacite around the large schreibersite crystals. Neumann bands are common and best developed in the clear kamacite. The hardness is 235±15, which indicates considerable cold-deformation. This is supported by the appearance of the phosphides; they are heavily brecciated and often shear-displaced 10-25 μ in successive steps.

Schreibersite is common as 100-600 μ wide precipitates, separating the various kamacite grains. It further occurs as scattered skeleton crystals, ranging from 0.5-5 mm in thickness. Locally it forms eutectic intergrowths with iron, as may be seen e.g., in Figure 33 in Brezina (1896). The eutectic pockets cover 3 x 2 cm, and schreibersite constitutes about 30% of the eutectic. Troilite is associated with the eutectic as 1-5 mm blebs and elongated bodies.

Rhabdites are extremely common as (i) a dense population of 0.5-2 μ thick prisms in the matrix, (ii) precipitates of 2-10 μ wide rods on one of the Neumann band systems, and (iii) thin plates typically 1 x 1 x 0.003 mm in size. The bulk phosphorus content is estimated to be 0.5%.

Taenite and plessite are present, but only in limited amounts, in or near the present grain boundaries. Two typical, tarnished taenite ribbons measured 200 x 100 μ and 400 x 50 μ, respectively, and had a hardness of 430±20. A small plessite field, measuring 400 x 150 μ, was partly decomposed to spheroidized taenite in 2-10 μ blebs.

From the description above it is evident that Summit is not a hexahedrite. It is composed of several kamacite grains, exhibiting a remnant octahedrite structure; and taenite and plessite occur locally between the kamacite lamellae. Its closest structural relatives are Santa Luzia, São Julião and Tombigbee, but a detailed examination of the large specimens in Vienna – or a modern chemical analysis for main and trace elements – is necessary before it can be decided exactly where it belongs. The remote possibility that it is a fragment of Tombigbee should be considered.

I am grateful to Dr. V. Manson, New York, for permission to borrow the specimen in the American Museum of Natural History (No. 1, 33 g, 4 x 2.4 x 0.6 cm) for this study.

Surprise Springs, California, U.S.A.

Approximately 34°10'N, 115°55'W

Coarse octahedrite, Og. Bandwidth 1.4±0.3 mm. Neumann bands. HV 210±15.

Group I. 8.12% Ni, 0.22% P, 69.6 ppm Ga, 265 ppm Ge, 2.0 ppm Ir.

HISTORY

A mass of about 1.6 kg was discovered in 1899 by D.J. Hayes in the Mojave Desert. It was lying free on the surface of a quartz outcrop near Surprise Springs on the south slope of the Bullion Range, about 45 km south of Bagdad. An endpiece of 157 g (now in Vienna) was thoroughly described by Cohen (1901b) who also reproduced photographs of the exterior and of an etched slice that demonstrated in an excellent way the heat-affected rim zone of α_2. Farrington (1915: 430) translated Cohen's treatise into English.

COLLECTIONS

Chicago (993 g), Vienna (154 g), Paris (114 g), London (97 g).

DESCRIPTION

The mass is shaped like a truncated, slightly tapering cone with the average dimensions 9 x 8 x 5.5 cm. It is smoothly curved over most of the surface but displays a few indistinct regmaglypts, 10-20 mm across, on one side. Fusion crust covers much of the surface as 0.05-0.5 mm thick laminated layers; it has, however, been removed in many places by handling. On sections a 2-3 mm wide

SURPRISE SPRINGS – SELECTED CHEMICAL ANALYSES

In the old analysis, the total of nickel plus cobalt seems to be correct, but the quantitative separation did not succeed. Cohen also found chlorine (0.024%) in the analysis and reported it as lawrencite. This chlorine was no doubt introduced with the ground water as chloride ions during the terrestrial exposure.

	percentage			ppm								
References	Ni	Co	P	C	S	Cu	Cr	Zn	Ga	Ge	Ir	Pt
Cohen 1901b	7.65	0.89	0.22	240	810	700	370					
Wasson 1970a	8.12								69.6	265	2.0	

heat-affected α_2 zone is well developed. The meteorite has lost, on the average, less than 0.1 mm by corrosion. Its shape and size, and the alternation between smoothly curved parts and regmaglypt-covered parts, closely resemble what is present in Bushman Land, Avce and Bagdad.

Etched sections display a coarse Widmanstätten structure of straight, slightly bulky ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.4±0.3 mm. The kamacite shows subboundaries and numerous Neumann bands. The hardness is 210±15 (Vickers, 300 g load).

Taenite and plessite cover 15-25% by area; the larger fields are comb and net plessite types, and the smaller are massive or acicular or with martensitic interiors.

Schreibersite is common as cuneiform or platy crystals, e.g., 3 x 3 or 10 x 1 mm in size, all enveloped in 1-2 mm wide rims of swathing kamacite. Schreibersite also occurs as 30-100 μ wide grain boundary veinlets and as 5-50 μ particles in the plessite fields, substituting for taenite of similar sizes.

Troilite, silicates, graphite and carbides were not detected on the sections in Chicago, Vienna and London. These are, however, common minerals in this type of meteorite and will probably be found on other sections.

Surprise Springs is a coarse octahedrite of group I, which has as its nearest relative such a well-known iron as Toluca.

Susuman, Magadan Oblast, RSFSR
62°43′17″N, 148°7′49″E; 745 m

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm. ε-structure. HV 320±20.

Group IIIA. 7.87% Ni, 0.47% Co, 0.15% P, 20.5 ppm Ga, 41.0 ppm Ge, 2.2 ppm Ir.

HISTORY

A mass of 18.9 kg was found in 1957 in the Frunze's Mine which was being worked for gold. The workman, Solukh, noted the heavy mass between blasted, alluvial material which had been brought from pit No. 34 at a depth of 32 m. In order to learn the nature of the mass the workmen split the mass in fragments of 12.1, 6.7 and 0.1 kg with sledge hammers, but eventually all material ended up in Moscow's Academy of Sciences. The circumstances of finding were thoroughly described by Vronskij (1960) who presented a map, geological sections and figures of the exterior of the mass. The mine was at the Zarya Creek, 2.3 km from its junction with the Sylgybast, a left tributary of the Susuman River. Susuman is a left tributary of the Berele River which is a left tributary to the large Kolyma River. The length of Zarya Creek is 3 km, and its valley is 200-300 m wide and filled with a 20-35 m thick alluvial blanket of clayey, sandy and marl-like rubble which is cemented together by ice (Permafrost region). The documentation for the meteorite having been found very near the bedrock (upper Triassic sandstone) at a depth of 32 m appears convincing. From the geological profile Vronskij estimated the terrestrial age of the meteorite to be 15-20,000 years.

Vronskij (1960) suggested that Susuman was a paired fall with Maldyak, found in 1939 under 4.6 m alluvium only 4.5 km west of Frunze's Mine. Kirova (1962) gave a full description with numerous photomicrographs of Susuman. Comparing the Susuman material with Maldyak she concluded that the two irons belonged to different falls, a conclusion supported by the present study.

COLLECTIONS

Moscow (12.1, 6.2 and 0.42 kg), Washington (74 g).

DESCRIPTION

The meteorite is an elongated, smoothly rounded mass with the average dimensions 27 x 15 x 12 cm. No regmaglypts are visible, and the fusion crust and the heat-affected rim zone are lost by weathering. The surface is roughened and covered by 0.1-2 mm thick limonitic deposits; however, the overall state of preservation is surprisingly good. Corrosion mainly penetrates along the schreibersite-filled Widmanstätten planes and forms 10-100 μ wide limonitic veins through the mass. The near-surface troilite has a few 1-3 μ wide pentlandite veins, and the α-phase of the plessite fields and around the rhabdites is selectively corroded. A rather unusual attack of the tarnished high-nickel taenite ribbons may also be observed near the surface. But, in general, it is the α-phase which is the more corroded phase on the surface, and the roughening is partly due to the taenite ribbons standing in slight relief.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.00±0.15 mm. The kamacite has subboundaries, decorated with less than 1 μ thick phosphides. The kamacite is shockhardened (HV 320±20) and shows the typical, unannealed, crosshatched ε-structure. No hardness

SUSUMAN – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Dyakonova & Charitonova 1963	7.87	0.47	0.15				200					
Scott et al. 1973	7.86								20.5	41.0	2.2	

gradient was found perpendicular to the surface, so it is estimated that, on the average, more than 5 mm has been lost due to terrestrial weathering.

Taenite and plessite cover 25-30% by area, mostly as open-meshed comb and net plessite with discontinuous taenite edges. Rhomboidal and wedge-shaped fields, displaying various incomplete stages of taenite decomposition, are also common. A typical wedge will have a tarnished taenite rim (HV 400±25) followed by a light-etching martensitic transition zone (HV 500±15). Then follows dark-etching martensite (HV 460±20) which eventually grades into duplex, poorly resolvable $\alpha + \gamma$ mixtures (HV 380±30). The easily resolvable, duplex centers with vermicular gamma, 1-2 μ wide, have hardnesses approaching that of the adjacent kamacite lamellae.

Schreibersite is present as 20-80 μ wide grain boundary precipitates and as 5-50 μ irregular blebs inside plessite. It is locally sheared and brecciated, and the adjacent ductile kamacite shows heavy flow lines. Rhabdites are common as 1-4 μ tetragonal prisms.

The chromium nitride, noted in Cape York, Schwetz and others, occurs as 15 x 1 μ oriented platelets in the kamacite.

Troilite is present in the U.S. National Museum sections as three grains 2 x 1.5, 2 x 1 and 1.5 x 0.2 mm in size, respectively. The largest is of rhomboidal shape and has several daubreelite lamellae parallel to the exterior faces. The second largest is situated only 4 mm away, but its daubreelite lamellae indicate that it is differently oriented. The troilite crystals appear to be randomly oriented with respect to the metallic lattice. The troilite is monocrystalline but shows beautiful twinning due to plastic deformation. The hardness is 270±10. The daubreelite constitutes 10-15% by area as 1-100 μ wide, lamellar wedges. Smaller, intergrown bodies of troilite and daubreelite are also present. It appears that, when their size decreases, the relative amount of daubreelite increases – to the point where 10-50 μ blebs are pure daubreelite.

The troilite is enveloped in 0.8-1.2 mm wide rims of swathing kamacite. Since the bulk phosphorus content of the mass is low, only discontinuous schreibersite bodies, 10-30 μ wide, have precipitated upon the troilite.

Susuman is a shock-hardened medium octahedrite chich is closely related to Merceditas, Canyon City, Dexter and Thunda. It is remarkable because it was found under 32 meters of alluvial deposits and still retained its overall shape after insignificant corrosion. At this depth the annual temperature is pretty constant and close to the average annual temperature (about -10° C) of the site. So perhaps, after an initial period of corrosion, the attack came practically to a stop when the access to oxygen and liquid water became severely limited.

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

74 g slice, now subdivided (no. 2347, 8 x 5.5 x 0.3 cm). Figure 3 in Kirova (1962).

Suwa, Honshu, Japan

36°2′N, 138°5′E

A mass of 203 g was listed by Hey (1966: 468) as found before 1915 and now in possession of Nagano Girl's High School. No details are available, and the possibility that the specimen is not a meteorite at all should be considered.

Ţabarz, Thuringia, German Democratic Republic

50°53′N, 10°31′E; 500 m

Coarse octahedrite, Og. Bandwidth about 2.0-2.5 mm. Neumann bands.

Possibly group I, related to Bohumilitz and Cosby's Creek.

HISTORY

A mass of unknown weight was found in 1854 by a shepherd who believed that he had observed the fall near Tabarz at the foot of the Inselsberg. Tabarz is situated in Thüringerwald 16 km west-southwest of Gotha, and has the coordinates given above.

The mass was broken by the finder and the major part was allegedly acquired by a mineral dealer in Berlin. This part had already been lost sight of in the 1850s. A small fragment of 150 g (three German Loths) was acquired by a student of Wöhler in Göttingen. The student, Eberhard, wrote a dissertation out of the study of it (1855). He published the only analysis known and compared its structure to Bohumilitz.

Buchner (1863) reported 121 g in Göttingen. This mass has since dwindled considerably by exchanges. Brezina (1885) noted that Tabarz was very similar to Black Mountains, Casey County, Bendego and, in particular, Bohumilitz and Cosby's Creek. The bandwidth was estimated to be the same as that of Cosby's Creek, i.e., 2.0-2.5 mm.

No other meteoritic irons have been reported from Thuringia, so Tabarz seems to have been an independent mass. Its weight was possibly between 1 and 10 kg, hardly more. As far as is known, the main mass has never reappeared.

COLLECTIONS

Göttingen (20 g), Vienna (16 g), London (9 g), Calcutta (5.8 g), Amherst (4.9 g).

ANALYSIS

Eberhard (1855) reported 5.69% Ni, 0.79% Co, and 0.9% P. The analysis, although good for its time, is insufficient for the purpose of classification.

DESCRIPTION

According to Eberhard, the meteorite was sufficiently corroded to exclude the possibility that it fell in 1854, as was believed by the finder. Several schreibersite crystals and a few troilite nodules were noted in the weathered crust. Etched sections displayed a coarse Widmanstätten structure, presumably with Neumann bands.

These observations, together with those of Brezina, indicate that Tabarz is a coarse octahedrite belonging to group I, and related to Bohumilitz and Cosby's Creek. It would be interesting to have this conclusion verified by an examination of one of the small preserved samples.

Tacubaya. See Toluca (Tacubaya)

Tajgha. See Toubil River

Tamarugal, Tarapaca, Chile

Approximately 20°48'S, 69°40'W

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Cold-worked matrix. HV 305±25.

Group IIIA. 8.52% Ni, 0.52% Co, 0.28% P, 0.1% S, 21.6 ppm Ga, 43.8 ppm Ge, 0.58 ppm Ir.

HISTORY

A mass of 320 kg was found in 1903 east of the railroad that leads from Iquique to the saltpeter works at Lagunas. The iron, which was partly covered by desert sand, was discovered by prospectors who reported that the locality was in Pampa del Tamarugal near Buenaventura and La Granja. The coordinates given above are those of Buenaventura. The prospectors drilled a 14 cm deep hole in the iron and tried unsuccessfully to blow the mass apart with dynamite. Later the mass was acquired by the mineral dealing firm, F. Kranz in Bonn, and it was cut into slices by the firm, Friedrich Krupp in Essen. The cutting resulted in 27 slices, each 7-20 mm thick and ranging from 0.8-16.56 kg in weight. The total yield was 198.5 kg, while 121.5 kg was lost as cuttings and millings. Rinne & Boeke (1907) who supplied the above information also gave a good description with photographs of the exterior and of etched slices. Their numerous illustrations are among the earliest successful photomicrographs of meteoritic iron. Smyshljajev & Yudin (1963) examined the microstructure, the composition of the kamacite and taenite phases and gave four photomicrographs. Jaeger & Lipschutz (1967b) detected shock-induced alterations by an X-ray diffraction technique and estimated the shock pressures to be 200-600 k bar.

Hintenberger et al. (1967) determined the amount of noble gases, while Voshage (1967) found a $^{40}K/^{41}K$ cosmic ray exposure age of 585±85 million years. Chang & Wänke (1969) estimated Tamarugal's terrestrial age to be extremely high, 2.7±0.6 million years, based upon the absence of detectable ^{36}Cl (half life 3.1 x 10^5 years) and rather low concentrations of ^{10}Be (half life 2.5 x 10^6 years). This is a surprisingly high terrestrial age for an iron which is pretty well preserved.

COLLECTIONS

Washington (17.0 kg), Mainz (12.37 kg), New York (11.2 kg), Vatican (9.38 kg), Budapest (8.26 kg), London (6.82 kg), Bonn (5.52 kg), Prague (4.08 kg), Rome (3.05 kg), Chicago (822 g), Copenhagen (684 g), Paris (550 g), Strasbourg (466 g), Los Angeles (337 g), Ljubljana (147 g).

DESCRIPTION

According to Rinne & Boeke (1907), the mass had the maximum dimensions of 57 x 52 x 37 cm and weighed 320 kg. It appears to have been covered by shallow regmaglypts, 5-9 cm across, somewhat modified by terrestrial corrosion. Sections perpendicular to the surface fail to reveal any fusion crust and heat-affected α_2 zone. There is, however, a significant hardness drop from the interior high level of about 300 to 240±10 at the present surface. By extrapolation it is estimated that on the average 3-4 mm has been lost by weathering. Corrosion also penetrates deep into the interior along preterrestrial fissures, particularly following zigzag paths along the phosphide-loaded (111) planes of the Widmanstätten structure. Some of the fine, 1 μ wide, branching oxide veinlets closely resemble stress corrosion cracks in commercial stainless steels.

Etched sections display a medium Widmanstätten structure of undulating, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.10±0.15 mm. The kamacite has subboundaries with 0.5-2 μ phosphide precipitates and further shows evidence of considerable deformation. Neumann bands, hatched ϵ-structure, lenticular deformation bands

TAMARUGAL – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Smyshljajev & Yudin 1963	8.63	0.48	0.29									
Buchwald 1967, unpubl.	8.52	0.55	0.27						18	42		
Wasson & Kimberlin 1967	8.40								21.6	43.8	0.58	

and 50-200 μ wide shear zones of densely crowded slip-planes occur mixed in various ways. The microhardness correspondingly ranges from about 280 to 350, a value which is found in the most severely kneaded shear zones.

Taenite and plessite cover about 35% by area, mostly as comb and net plessite and as martensitic fields. Duplex, easily resolvable $\alpha + \gamma$ fields are rare. Locally the net plessite has spheroidized patches of 2-20 μ wide taenite, but this is not typical. A normal martensitic field will show a tarnished taenite rim (HV 385±20) followed by a yellow, fine-grained transition zone of martensite (HV 435±20). The interior is normally developed as brownish-etching martensite platelets oriented parallel to the bulk Widmanstätten structure (HV 435±20).

Schreibersite occurs as 0.2-0.5 mm thick blebs centrally in the kamacite lamellae; their hardness is 915±15. Schreibersite is also very common as 10-50 μ wide grain boundary precipitates, as 1-30 μ wide blebs inside the plessite fields and, characteristically, as island-arcs of 10-30 μ thick blebs a few microns outside the taenite and plessite phases. Rhabdites are present as 0.5-2 μ precipitates which sometimes when near the larger schreibersite crystals, increase to 20-30 μ in diameter.

Troilite ranges from 50 μ to 15 mm in diameter but is unevenly scattered across the sections. Point counting of sections, totaling 925 cm^2, led to an estimate of 0.45 volume % FeS or 0.1 weight % S. The troilite is monocrystalline – but violently deformed in places – exhibiting a dense felt of lenticular twins. Daubreelite occurs as 5-100 μ wide lamellae, covering 5-15% by area of the nodules. Here and there a euhedric chromite crystal, 0.1-0.3 mm across, is found, often associated with troilite and often in direct contact with daubreelite. A few Reichenbach lamellae of troilite, 20 x 10 x 0.05 mm in size, are also present.

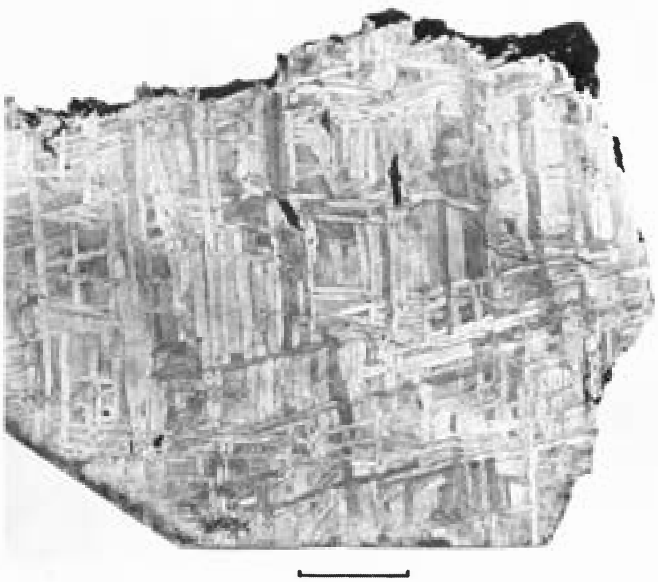

Figure 1703. Tamarugal (Copenhagen no. 1908, 80). A medium octahedrite that is transitional between group IIIA and IIIB. Deformed Widmanstätten pattern and troilite nodules (black). Etched. Scale bar 20 mm.

Rinne & Boeke (1907), expected cohenite to be present, but a thorough examination by me failed to disclose the mineral, and there is, in fact, little reason to expect significant amounts of it in a type IIIA iron.

The meteorite is severely deformed, probably as the result of the combined effects of "geologic" and shock events on its parent body. The kamacite and the taenite are hardened by cold-deformation, and all the metallic phases are distorted and sheared, frequently with 1-2 mm relative displacements. The same is true of the nonmetallic inclusions which display offsets ranging from 10 μ to 2 mm. The overall deformation resembles what is noted in, e.g., Sacramento Mountains, Puquios and Descubridora.

Tamarugal is a medium octahedrite of group IIIA. It is related to Aggie Creek, Welland, Drum Mountains, Sierra Sandon, Franceville and Gundaring but shows an intense deformation of all structural elements. Its terrestrial age remains questionable. As discussed below, it appears that "Tarapaca" is two further fragments, and that Tamarugal thus was a shower-producing meteorite.

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

212 g part slice (no. 744, 7 x 6 x 1 cm)
320 g part slice (no. 2294, 8 x 5.3 x 1 cm)
16.5 kg full slice (no. 3095, 44 x 31 x 2 cm). This slice was a part of the Bosch Collection, purchased by the Smithsonian Institution in 1967. It was labeled "Tocopilla, Chile" from Krantz, in Bonn. Its reidentification by me as the largest slice in existence of Tamarugal was possible because the macro- and microstructure were identical to authentic Tamarugal specimens, and because the cutting and milling technique was that used by Krupp, and, finally, because its weight coincided with the largest weight noted by Rinne & Boeke (1907) 16.56 kg.

Tamarugal (Tarapaca), Tarapaca, Chile

Medium octahedrite, Om. Bandwidth 1.10±0.20 mm. Cold-worked matrix. HV 300±30.

Group IIIA, judging from the structure. About 8.5% Ni, 0.25% P.

HISTORY

Three different types of material are in collections, labeled "Tarapaca." One is a lead-containing iron, found in 1840 near Hemalga. It was definitively proved to be a pseudometeorite by Cohen (1898d: 51). In the U.S. National Museum there is a 84 g fragment (No. 1154) of this material (Merrill 1916a: 196), in Tübingen there is a 76 g fragment (No. 9122212), and in the Yale collection there is another (No. P402, 17 g). All are still accepted as true meteorites. A 7 g sample in Tempe (No. 547.1) was likewise found to be an artificial wrought iron. The 100 g specimens in Harvard (No. 657) probably also belong in this category.

The second Tarapaca type was first mentioned by Wülfing (1897: 351) who stated that Brezina had acquired 462 g of a new octahedrite. Seven years later this fragment had dwindled to 264 g, presumably due to exchange (Brezina 1904b: 244). Ward (1900: 28) had obtained an 18 g section and noted that the iron had been known before 1894. Berwerth (1903: 80) gave the tentative coordinates 19°40′S, 69°30′W.

The third Tarapaca type is mainly preserved in the La Plata Museum. Although listed as a medium octahedrite by Radice (1959) and entered as Tarapaca in Hey (1966: 473) on the authority of Radice, it is clearly something else. In March 1973 the author had an opportunity to examine the 5.40 kg mass which was found in 1889. A smaller mass of 715 g, allegedly found in 1890 at the same place, was not accessible. The 5.4 kg mass measures about 17 x 11 x 9 cm and shows regmaglypts and some fusion crust, although it is mostly covered by caliche. It is cut only in one place, exhibiting a 5 x 3 cm rough section; however, this exposure sufficed to rule out any octahedrite classification. The 5.4 kg mass is clearly a mislabeled La Primitiva sample, displaying its unique large schreibersite rosettes in a kamacite matrix. Since a section has been removed, and the 715 g mass (not studied) may have been cut and exchanged, it is necessary in this work to note that La Primitiva material – mislabeled Tarapaca – may exist in other collections. See also the description of La Primitiva, page 756.

COLLECTIONS OF TARAPACA (Om)

La Plata (6.11 kg), Vienna (264 g), Harvard (100 g), Oxford (34 g), Washington (18 g), London (14 g), Copenhagen (3 g).

ANALYSES

No analyses are available, but since the octahedrite material is structurally identical to Tamarugal, its analysis must also be the same.

DESCRIPTION

In the following we will examine the second type closely. The specimen in Washington, originally a 22 g piece obtained for the Bosch Collection from Brezina about 1905, is a fragment two-thirds of which represents surface or chiseled surfaces. The etched section displays a medium Widmanstätten structure of distorted, long ($\frac{L}{W} > 20$) kamacite lamellae with a width of 1.10±0.20 mm. The kamacite has subboundaries with 0.5-1 μ phosphide precipitates, and it is severely cold-worked by a cosmic event. Although possibly detached from a larger mass by breaking, the cold working is much too intense to have been caused by man's efforts. Neumann bands and lenticular deformation bands alternate with 50-200 μ wide shear zones and patches with the hatched ε-structure. Most linear elements of the Widmanstätten structure are bent and distorted, and the schreibersite inclusions are shear-displaced in several successive steps. The largest relative displacement in the section is 0.6 mm; smaller displacements are very common. The hardness of the kamacite reflects this variation in cold working, ranging from 270 to 335. Numerous cracks and fissures follow a zigzag course along the phosphide-filled octahedral planes.

Taenite and plessite occupy about 35% of the section, mainly as net and comb plessite and as martensitic fields. The martensite plates of the interior of the fields are parallel to the bulk Widmanstätten structure and have a hardness of 435±15.

Schreibersite occurs as 0.2-0.4 mm wide blebs centrally in the kamacite lamellae, as island-arcs of 5-25 μ wide bodies and as 5-25 μ irregular blebs inside the plessite. Tiny rhabdites, 0.5-1 μ across, are common in the kamacite.

Troilite is present as an angular inclusion, 1.7 x 1.0 mm in size. It is monocrystalline but shows lenticular deformation twins. Daubreelite covers 5-10% by area as 5-70 μ wide, discontinuous, parallel lamellae.

From the description it may be seen that the Washington "Tarapaca" fragment corresponds in every detail to Tamarugal, the 320 kg mass which was found in 1903 and was described in 1907. As is so often the case, the original localities are only known with insufficient precision. If the labeling "Tarapaca," as is probable, refers only to the province of Tarapaca and not to the town of that name, then the 1894 fragment may have come from a location close to the Tamarugal main mass, which was found in the southern part of the province of Tarapaca. Therefore, it is concluded that since the locality, within our limited knowledge, corresponds well to Tamarugal, and since the macro- and microstructure and state of preservation in all details are identical to Tamarugal, Tarapaca (Om) must represent a small fragment of the main mass. It is not known whether the fragment was detached from the main mass by the discoverers.

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

18.5 g corner (no. 3088, 3 x 2 x 1 cm)

Tambo Quemado, Ayacucho, Peru
14°33′S, 74°30′W

Medium octahedrite, Om. Bandwidth 0.75±0.10 mm. Artificial α_2. HV 200±15.

Group IIIB. 9.9% Ni, 0.62% Co, 0.83% P, 17.6 ppm Ga, 31.0 ppm Ge, 0.02 ppm Ir.

The specimens in the United States, and probably the whole mass, have been artificially reheated to about 1000° C.

HISTORY

A mass of 141 kg was brought to Lima in 1950, where it was briefly described by Freyre (1950) who also presented two figures of the exterior. From the files of Dr. H.H. Nininger and Dr. C.B. Moore, which I was kindly permitted to examine, I add the following information. The mass, estimated to weigh 130 kg, was discovered – or rather was reported – in 1949 by J. Ernesto Lañas del Castillo as being in a remote part of the Andes Mountains. The location is given as near the village of Tambo Quemado, in the district of Leoncio Prado which has the coordinates given above. The discoverer made arrangements to remove the mass but could accomplish little himself, partly because of local native superstitutions and partly due to interference from government authorities. As it turned out, after considerable wrangling and to the full dissatisfaction of the discoverer, the whole mass – except for a 108 g slice, and later a 1.36 kg wedge, which were forwarded to Dr. Nininger – ended up in the Geological Museum in Lima. A part of the wedge came in 1955 to the U.S. National Museum. Jain & Lipschutz (1969) gave a photomicrograph and interpreted the structure as being the result of a cosmic event, a shock wave with a minimum pressure of 1.4 megabars. The present author disagreed with this (Buchwald 1968d), pointing out that several structural elements suggested an artificial reheating.

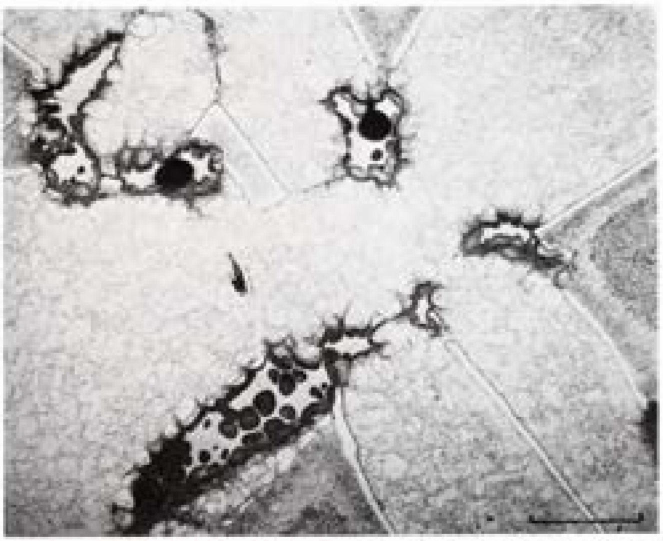

Figure 1705. Tambo Quemado (U.S.N.M. no. 1572). The schreibersite crystals melted during the artificial reheating and solidified in fine dendritic structures with gasholes (black). Etched. Scale bar 40 μ. (Perry 1950: volume 9.)

COLLECTIONS

Division de Geologia del Instituto Nacional de Investigación y Fomento Mineros, Lima (main mass of about 140 kg), Washington (970 g), Tempe (103 g), Harvard (70 g), Yale (42 g).

DESCRIPTION

From the photographs given by Freyre (1950), it appears that the mass is very irregular with the average dimensions of 48 x 25 x 25 cm. It is deeply indented by marked regmaglypts, 3-10 cm in diameter, and in one place a 10 cm deep, V-shaped indentation is found. Whether or not this was caused by a tool can only be determined by an examination of the mass proper. If it was formed by a tool, the mass must have been made malleable and ductile by warming to a red heat, at least.

Figure 1704. Tambo Quemado (U.S.N.M. no. 1572). An artificially reheated medium octahedrite of group IIIB. The schreibersite skeleton crystals (black) are enveloped in swathing kamacite. Deep-etched. Scale bar 20 mm.

The following is based upon an examination of the specimens in Washington, Tempe, Harvard and Yale. The surface is corroded and covered by 0.1-0.5 mm thick oxide crusts; corrosion has also penetrated some distance along the schreibersite lamellae; but the overall appearance is that of a well-preserved iron which has lost less than 1 mm, on the average, of its surface.

Etched sections display a medium Widmanstätten structure of straight, somewhat irregular ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 0.75±0.10 mm. No Neumann bands are present; instead the kamacite is decomposed by the $\alpha \rightarrow \gamma \rightarrow \alpha_2$ transformation to a polycrystalline mosaic of serrated α_2 grains, each 25-100 μ across. Depending on the actual nickel content the α_2 grains vary from almost equiaxial to much-frayed, martensitic-bainitic units. The hardness ranges from 180 to 215.

TAMBO QUEMADO – SELECTED CHEMICAL ANALYSES

The carbon value appears high for the structure. The phosphorus value only records what is present as small grain boundary inclusions and in solid solution in the metallic phases.

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson 1955, pers. comm.	9.89	0.62	0.13	1350	100							
Wasson & Kimberlin 1967	10.1±0.3								17.6	31.0	0.02	

Taenite and plessite cover 35-40% by area, mostly as dense fields which reach sizes of 3 x 4 mm. The phase boundaries are indistinct as the result of high temperature diffusion, and the interiors are decomposed to polycrystalline mosaics of austenite grains, which have independently formed the α_2 structure. The hardness ranges from 340 in the light-etching taenite rims to 230 in the interior.

Schreibersite is – or rather was – present in significant amounts. It formed oriented Brezina lamellae, typically 25 x 15 x 1 mm in size, which were enveloped in 1-1.5 mm wide rims of swathing kamacite. Schreibersite is also common as 20-100 μ wide grain boundary veins. Point counting of 22 cm^2 indicated 5.1 volume %, corresponding to 0.70 weight %. If we add Henderson's value for inclusion-free material, 0.13%, we obtain as a bulk phosphorus value 0.83% P.

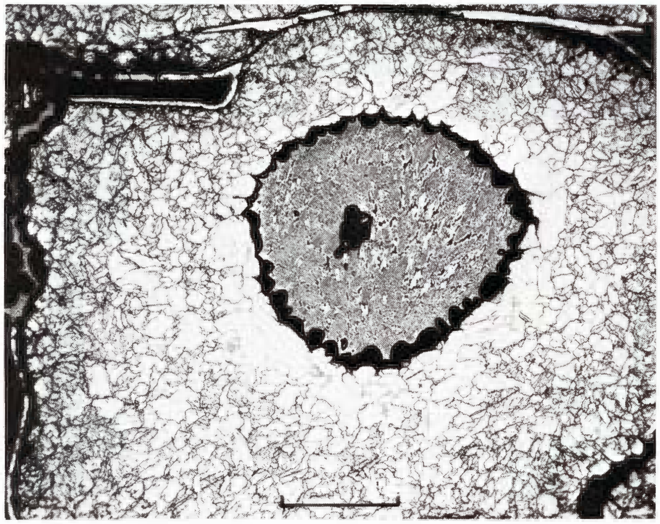

Figure 1706. Tambo Quemado (U.S.N.M. no. 1572). A fused schreibersite crystal (center) surrounded by kamacite that transformed by artificial reheating to unequilibrated α_2 grains. Etched. Scale bar 40 μ. (Perry 1950: volume 9.)

All phosphides have been micromelted, and many of the larger ones have sweated out and now partly cover the corroded surface with 1-2 mm thick "fusion crusts." Upon resolidification, the pure phosphides of the interior have formed fine-grained eutectics with a hardness of 700±25. They are surrounded by dark-etching metal rims which appear to be supersaturated with respect to phosphorus and have a hardness of 360±20. The phosphides which were associated with terrestrial corrosion products have formed complex reaction mixtures, often with many gasholes. Some of the cavities have, after the phosphides had partially disappeared, been refilled with glassy slags and dendritic metal and sulfides. The possibility that some phosphate minerals were originally present, but now are altered, can not be excluded.

The corrosion products frequently contain an abundance of 0.5-1 μ thick metal globules, and they also form 10-50 μ wide, coarse-grained laceworks. Interestingly enough the early corrosion products which have reacted in the high temperature stage are superimposed with a thin, but distinct, layer of secondary corrosion products which have not been reheated.

The various structural alterations indicate that the meteorite has been reheated to about 1000° C for a period of an hour or so, enough for some diffusion to take place, for the schreibersite to melt and sweat out and for the cavities to be partially refilled with slags. Since the corrosion products participated in the high temperature reactions, the reheating must have been artificial.

In this connection the original reporter, J.E. Lañas, has a comment which supports my conclusion, "I have found a metallic aerolite, apparently like iron, with a scarce quality, since when reaching high temperature instead of melting it becomes feeble . . . ." It is not entirely clear whether Lañas was the one who reheated the mass. Various small notes seem to indicate that the Indians had known the iron for a

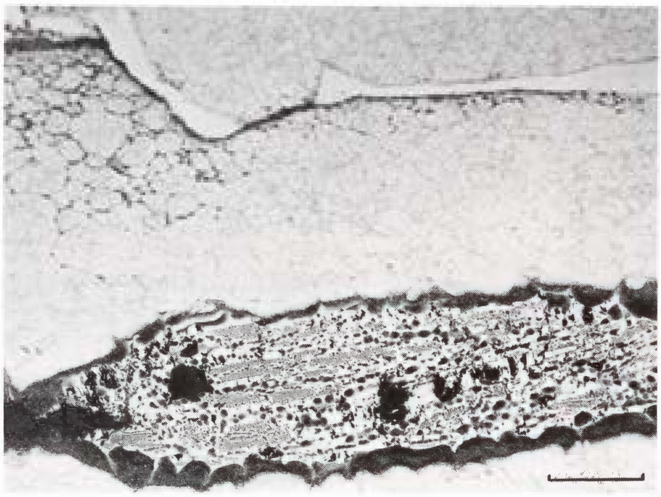

Figure 1707. Tambo Quemado (U.S.N.M. no. 1572). A fused schreibersite lamella (below) and high temperature intercrystalline oxidation in the kamacite. Diffuse taenite lamellae. Etched. Scale bar 200 μ. (Perry 1950: volume 9.)

Figure 1708. Tambo Quemado (U.S.N.M. no. 1572). A phosphide which was associated with terrestrial oxidation products and upon artificial reheating formed complex melts. Etched. Scale bar 40 μ. (Perry 1950: volume 9)

long time and had unsuccessfully tried to heat and utilize it. The observation that some corrosion has taken place after the artificial reheating was accomplished indicates that the reheating had occurred some time ago, but was still remembered by the Indians. When Lañas came from outside their community they evidently considered the meteorite their property and demanded a remuneration for it, which they got – in the form of a quantity of cement for their public school (letters in the files of Dr. C.B. Moore).

Before the artificial reheating Tambo Quemado was a rather normal medium octahedrite related to, e.g., Bella Roca, Mount Edith and Sams Valley. It is a typical group IIIB meteorite, according to the analyses by Wasson. Its reheated structure corresponds in many respects to Rodeo, but Tambo Quemado reached a higher temperature.

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

831 g wedge-shaped slice (no. 1572, 9 x 6 x 4 cm)
121 g part slice (no. 1572, 7.5 x 4 x 0.6 cm; cut from above)
20 g part slice (no. 1677, 3.5 x 2.5 x 0.3 cm; cut from above)

Tamentit, Touat, Algeria

Approximately 27°45′N, 0°10′W; 300 m

Medium octahedrite, Om. Bandwidth 1.20±0.15 mm. ε-structure. HV 330±20.

Group IIIA. 8.31% Ni, 0.21% P, 20.3 ppm Ga, 42.7 ppm Ge, 2.5 ppm Ir.

HISTORY

A large mass, about ½ m in diameter, was reported by Rohlf (1865) to be lying in the Tamentit Oasis in the district of Touat. Rohlf's description clearly indicated that the mass was an unusually well-preserved meteorite, so it was briefly mentioned on numerous later occasions (e.g., Buchner 1869: 602; Wülfing 1897: 406). However, samples of the mass could not be procured, because the Arabs regarded it with veneration and considered it their talisman.

When the development of the Algerian Sahara improved after the first World War, interest in the meteorite renewed. Lacroix (1927a, b) has given a detailed description of the efforts that eventually, in 1927, resulted in the arrival of the 510 kg mass in Paris. It has since attracted attention as perhaps the most beautiful sample in the meteorite collection of the Muséum National d'Histoire Naturelle.

According to Lacroix, Arab manuscripts and word of mouth maintain that a block of gold was observed to fall between Noum en Nas and Tittaf. When the adjacent tribes assembled on the spot a heated dispute over the right of possession arose so Allah (God) in anger transformed the mass into silver. As still no agreement could be reached, the mass was transformed into iron. The nomads then lost interest for a while, but later Shaykh 'Amr, ordered the meteorite to be transported to Tamentit and placed in front of the mosque.

From the names of the tribes and the shaykh involved in the legend, Lacroix was able to date the fall to the fourteenth century, probably close to 1400. The Tamentit is thus the oldest iron meteorite fall on record which is still preserved in its entirety.

The site of fall, between Noum en Nas and Tittaf, has the coordinates given above. Tamentit is a small Oasis about 40 km north-northwest of Tittaf, a village which is shown on modern maps. In Tamentit, the meteorite was to be found buried in the middle of a crossing made by two narrow, winding streets and only 40 cm of the domed

Figure 1709A. Tamentit (Paris no. 1577). The main mass of about 500 kg is a domed shield with soft regmaglypts. Below, above the scale bar, a wedge-shaped section has been removed with a blowtorch. (Photo courtesy Professor J. Fabriès.)

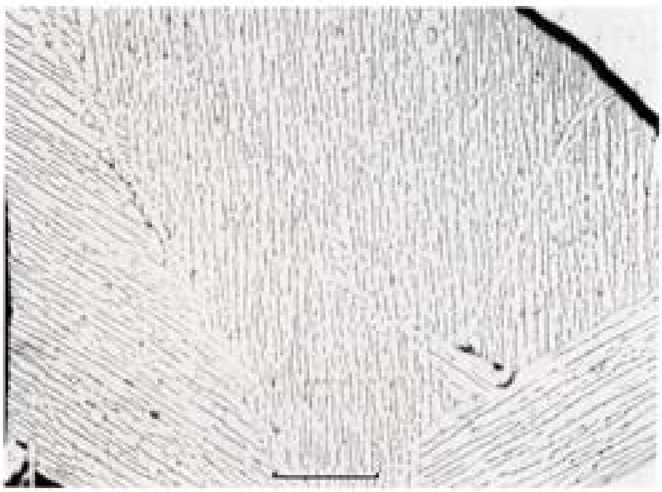

Figure 1709B. Tamentit (Copenhagen no. 1972, 1686). The comb plessite fields of the group IIIA meteorites often reach large dimensions. Small schreibersite particles stand in high relief (dark). Cloudy taenite rims. Etched. Scale bar 700 μ.

shield emerged; people always passed close to it but were allegedly careful not to damage it.

Lacroix (1927b) had a 10 kg sample cut from the mass with a blowtorch; he then discussed the observed damage and the preferential oxidation and burning of iron by the torch. A very brief and somewhat inappropriate description of etched sections led to the classification of Tamentit as a coarse octahedrite, an erroneous conclusion still held in modern catalogs (Hey 1966: 472).

For a possible relationship with another small iron the reader is referred to Dellys.

COLLECTIONS

Paris (main mass of 500 kg and slices, totaling 50 kg), Copenhagen (747 g), Vatican (576 g), Chicago (534 g), London (341 g), Rome (167 g), Calcutta (138 g).

DESCRIPTION

Tamentit is shield-shaped. It presents an anterior domed, almost hemispherical surface, and a posterior concave surface. Its maximum thickness is 44 cm, while the somewhat square shield measures 77 x 80 cm in two perpendicular directions.

The hemispherical dome is covered with well developed regmaglypts, generally 5-9 cm across and with smoothly rounded ridges in between. The opposite concave surface is covered with still larger regmaglypts, some of which are inconspicuous and shallow, while others are deep and bowl-shaped. Fusion crusts are present, except in places where the domed surface was exposed to contact by human beings and animals while partly buried in the streets of Tamentit.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 30$) kamacite lamellae with a width of 1.20±0.15. Subboundaries decorated with $< 1\ \mu$ phosphides are common but somewhat obscured by secondary shock structures. Shock pressures above 130 k bar have produced a mixture of indistinct Neumann bands and hatched ϵ-structures which is very hard, HV 330±20. The kamacite lamellae adjacent to black wedges of taenite-plessite are often dark-etching; high magnification reveals copious amounts of minute precipitates ($< 0.5\ \mu$), which apparently are situated on the slipplanes of the kamacite. Similar patterns are discussed under Thule, Welland and others.

Taenite and plessite cover 30-40% by area. Comb and net plessite, duplex unresolvable, and duplex resolvable $\alpha + \gamma$ structures occur in profusion. A typical large field, 5 x 4 mm, will exhibit a tarnished taenite rim (HV 430±20), followed by yellowish martensitic zones (HV 490±20). Next come martensitic-bainitic transition zones (HV 360±20) and duplex $\alpha + \gamma$ textures, of which the easily resolvable ones with 1-2 μ γ-particles, display hardnesses similar to, or somewhat lower than, the adjacent kamacite lamellae (290-340).

Schreibersite is present as angular inclusions, measuring 5 x 0.5, 2 x 0.2, 0.8 x 0.5 mm, centrally in the kamacite lamellae. It is also common as 20-100 μ wide grain boundary veinlets and as 5-50 μ irregular bodies substituting for γ in the plessite fields. Rhabdites were not

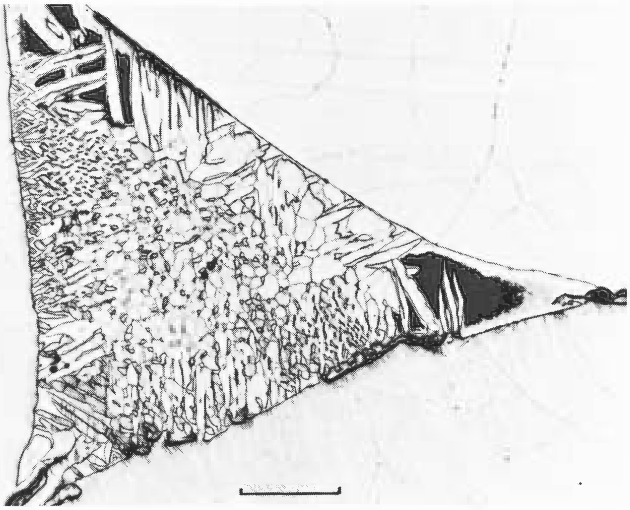

Figure 1710. Tamentit (Copenhagen no. 1972, 1686). A triangular plessite field with black taenite patches. Subboundaries are visible in the shock-hatched kamacite. Etched. Scale bar 400 μ.

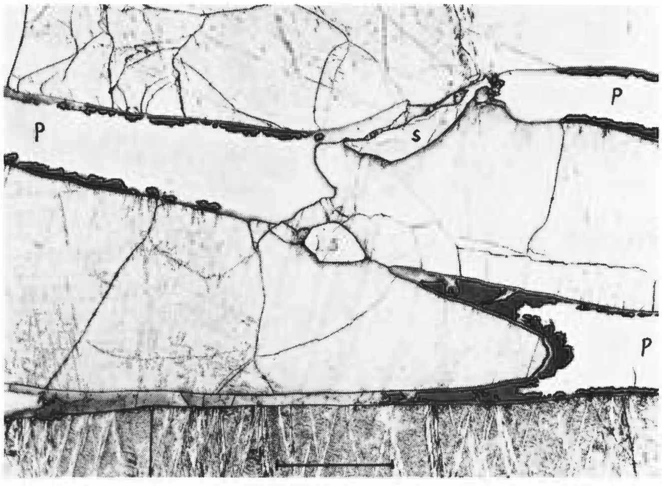

Figure 1711. Tamentit (Copenhagen no. 1972, 1686). Shock-hatched kamacite lamellae of various shades. Plessite fields (P) with cloudy taenite rims. Brecciated schreibersite crystals (S). Etched. Scale bar 200 μ. See also Figure 108.

TAMENTIT – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lacroix 1927b	8.25	0.38	0.21	650	100							
Scott et al. 1973	8.37								20.3	42.7	2.5	

The cobalt determination appears somewhat low.

detected. Most of the schreibersite crystals are brecciated; they may be shear-displaced in 1-5 μ steps, presumably as a result of the same shock that deformed the metallic phases.

Troilite occurs as up to 1 cm nodules, enveloped in 0.2 mm discontinuous rims of schreibersite, which again are surrounded by 1 mm wide rims of swathing kamacite. Troilite was not present in the polished sections; therefore, its details could not be examined.

The fusion crust and a 1.5-2.5 mm wide heat-affected α_2 zone are well-preserved. However, corrosion penetrates to a depth of several centimeters along preexisting fissures in the α - γ grain boundaries and the schreibersite crystals. These are now recemented by limonitic corrosion products. The state of corrosion is probably what can be expected from 500 years of exposure to Sahara's environment, so it appears plausible that Tamentit really was observed to fall about the year 1400.

Tamentit is a shock-hardened medium octahedrite related to Tamarugal, Aggie Creek, Trenton and Thule. It is a normal member of group IIIA and is particularly interesting because of its beautiful shield-shape and its rather well documented history.

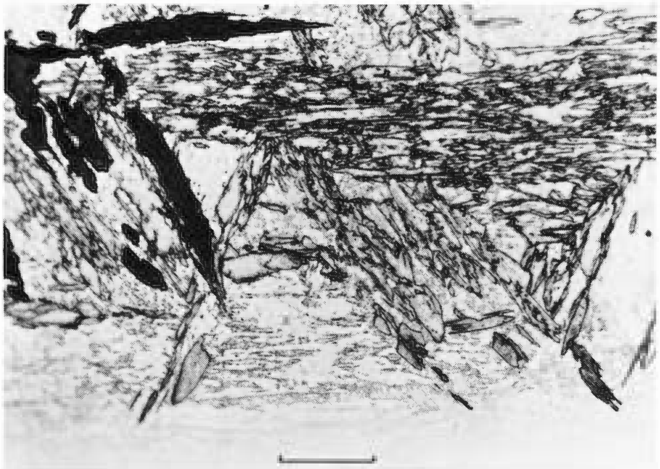

Figure 1712. Tamentit (Copenhagen no. 1972, 1686). The martensitic-bainitic transition zone of a plessite field showing platelets parallel to the bulk Widmanstätten pattern. Etched. Oil immersion. Scale bar 20 μ.

Tanakami Mountain, Honshu, Japan

34°55'N, 135°58'E

Coarse octahedrite, Og. Bandwidth 1.50±0.30 mm. Neumann bands. HV 258±12.

Group IIIE. 8.75% Ni, 0.4% P, 18.2 ppm Ga, 34.6 ppm Ge, 0.22 ppm Ir.

HISTORY

A mass of 174 kg was found about 1885 by a farmer on the slopes of the mountain Tanakami. The exact location is unknown; the coordinates above are those of the summit of the low mountain. The meteorite, the largest in Japan, was purchased in 1899 by the Imperial Museum in Tokyo, where it was described by Otsuki (1900); an English summary appeared later (Jimbo 1906: 42). Very little has been cut and distributed from this iron (Murayama 1960: 46-48, 51, figures on pages 48 and 51). Murayama (1953: cover photograph) also produced a photomacrograph.

COLLECTIONS

National Science Museum, Tokyo (170 kg), London (178 g), Chicago (162 g), Washington (90 g), Albuquerque (10 g).

DESCRIPTION

The mass is turtle-shaped with the average dimensions of 49 x 43 x 24 cm. The original regmaglypts are modified by weathering and, in places, the surface is weathered sufficiently to exfoliate along octahedral planes. The terrestrial age appears to be rather high.

The specimens in the Smithsonian Institution are weathered, near-surface fragments. The polished section already displays the coarse Widmanstätten structure because veins of limonite penetrate abundantly along the grain boundaries. The kamacite lamellae are straight and swollen, spindle-shaped ($\frac{L}{W} \sim 10$) and have a width of 1.50±0.30 mm. Hey (1966: 472) gave a bandwidth of 0.75 mm, but this determination must be on atypical material. The kamacite has numerous subboundaries, decorated with conspicuous 1-4 μ wide rhabdites. Neumann bands are present but somewhat indistinct; the hardness of 258±12 indicates considerable cold working of the matrix.

Taenite and plessite cover about 25% by area, mostly as acicular fields where bayonet-shaped alpha lamellae, 2-10 μ wide, form a dense feltwork on a background of poorly resolvable, duplex $\alpha + \gamma$ mixtures. Comb and net plessite are present, but only in very modest quantities. The alpha phase of the plessite fields is selectively corroded to an extreme degree in the examined specimen, which also shows a 2-3 mm thick crust of terrestrial oxides. No fusion crust and no heat-affected α_2 zones were detected.

The shape of the kamacite lamellae and, therefore, of the retained taenite and plessite, is anomalous, being more spindle- or barrel-shaped than usually is the case. Also, the acicular fields exhibit a significant number of carbide roses: about every third field shows hard, white patches,

TANAKAMI MOUNTAIN – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Jimbo 1906	8.56	0.62	0.43									
Scott et al. 1973	8.94								18.2	34.6	0.22	

0.1-0.4 mm across, which, on high magnification, turn out to be oriented intergrowths of carbide with minor amounts of kamacite, taenite and schreibersite. The inclusions are generally 2-10 μ across; depending upon the exact morphology and quantity of carbide, the hardness ranges from 1025 to 650. The carbide is isotropic and identical to the new mineral haxonite, $(Fe,Ni)_{23}C_6$ described by Scott (1971).

Schreibersite occurs as scattered lamellae, typically 3 x 0.5 mm in size, as 20-100 μ grain boundary veinlets, and as 2-20 μ thick blebs in the plessite fields. Rhabdites are common on the α-subboundaries, and are locally abundant as 0.5-2 μ precipitates in the α-lamellae.

In the examined specimen, troilite occurs as 0.1-0.6 mm monocrystalline nodules, associated with and often completely embedded in the large schreibersite crystals. Daubreelite forms 1-100 μ wide, parallel lamellae in the troilite. Rhythmic intergrowths of alternating, 1-5 μ wide troilite and daubreelite lamellae are common. The smaller the nodule the higher the percentage of daubreelite, up to about 50%. The troilite is severely altered to pentlandite due to terrestrial corrosion.

Chromite occurs as 0.1-0.2 mm euhedric crystals, either alone in the kamacite or associated and in direct contact with daubreelite and troilite.

Although small, the examined specimen clearly indicates that Tanakami is a somewhat unusual coarse octahedrite, with its anomalous kamacite morphology and the significant amount of carbide roses. It appears to be very closely related to the small 3.3 kg iron, Rhine Villa, and to Staunton. It is less closely related to Kokstad and Willow Creek.

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

78 g three weathered fragments (no. 1431, about 4 x 2 x 1 cm each)
12 g weathered fragment (no. 1456, 3 x 2 x 0.5 cm)

Figure 1713. Tanakami Mountains (Tokyo). A coarse octahedrite of group IIIE, a group related to IIIA-B. Note the swollen kamacite lamallae. The sample is weathered and shows small corrosion blisters that formed after finishing the polished section. Deep-etched. Scale bar 5 mm. (Courtesy Sadao Murayama.)

Tandil, Buenos Aires, Argentina

Approximately 37°22′S, 59°20′W

Previously known as a hexahedrite fall in 1916; here shown to be a pseudometeorite.

HISTORY

A mass of 1.1 kg was discovered by a farmer before 1916 in the vicinity of Tandil. It was in use as a gate stop at his house 15 km (three Argentinean leagues) west of Tandil when it was acquired by a Dr. Ronco between 1916 and 1919. He, in turn, donated the mass to the Museum in La Plata in 1929. A preliminary description by Fossa-Mancini appeared in 1948; Radice (1959: 126) gave curatorial information.

COLLECTIONS

Museo de La Plata (977 g), Harvard (65 g).

ANALYSES

No analytical work has been reported.

DESCRIPTION

According to Fossa-Mancini (1948), the fist-sized mass was observed to fall between 1916 and 1919. A deep-etched section made it possible for him to classify Tandil as a normal hexahedrite. In spite of the fall date, the meteorite allegedly had a limonitic crust and weathered inclusions.

During a brief visit to the La Plata Museum in March 1973, I critically reexamined the mass. It measures about 9 x 7 x 6 cm and weighs 977 g. Its specific gravity may be estimated to be 5-6, far below that expected for an iron meteorite (7.5-8.0). There are no meteoritic sculpture, no regmaglypts and no meteoritic minerals. The mass is nonmagnetic. One face, of 6 x 5 cm, is covered by substantial ochre-laminae which, to the uninitiated, may suggest weathered meteoritic elements. In my opinion, the ochre is rather part of the mass itself. The only section made, of 2 x 1 cm, reenforces this impression.

Conclusion: the Tandil mass is a terrestrial rock, probably an ochre-limonite concretion.

Tarapaca. See Tamarugal (Tarapaca), and La Primitiva

Tawallah Valley, Northern Territory, Australia

15°42′S, 135°40′E

Nickel-rich ataxite, D. α-spindles 8±4 μ wide. Rich in phosphides. HV 205±10.

Group IVB. 17.6% Ni, 0.69% Co, about 0.10% P, 0.25 ppm Ga, 0.07 ppm Ge, 16 ppm Ir.