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

References	percentage Ni	Co	P	ppm 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