Taenite and plessite cover about 50% by area; on the deep-etched section normal comb and net plessite and duplex dark-etching fields could be distinguished.

Schreibersite occurs as 1-2 mm cuneiform skeleton crystals, surrounded by 1 mm wide rims of swathing kamacite. It is also present as up to 100 μ wide, discontinuous grain boundary veinlets.

The limited access to material unfortunately makes Quesa a rather uninvestigated and, consequently, unknown meteorite. From the few observations I have compiled here, it appears that it is a somewhat anomalous medium octahedrite which may be related to, e.g., Carbo and Elbogen. It is recommended that it be subjected to thorough examination and that modern analytical work be appended.

Quillagua. See North Chile (Quillagua)

Quinn Canyon, Nevada, U.S.A.

Approximately 38°10′N, 115°45′W; 1,800 m

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Neumann bands. HV 180±15.

Group IIIA. 8.40% Ni, about 0.22% P, 20.9 ppm Ga, 41.5 ppm Ge, 0.58 ppm Ir.

Synonym Tonopah, see page 1004.

HISTORY

A mass of about 1,450 kg was discovered in August 1908 by a prospector looking for borax in the Quinn Canyon range, in Nye County. The mass was only partly embedded in the soil of a low hill of andesite and, resembling a large turtle, had the domed upper surface projecting above the ground. In 1909 the mass was hauled on a freight wagon with six horses the 90 miles to Tonapah, supervised by W.P. Jenney who also reported the details and circumstances of the finding (1909). He believed that the meteorite was the surviving nucleus of a violent fireball, observed and described in February 1894. This appears to be out of the question, however, since the corrosion indicates a higher terrestrial age than 14 years. In 1909 the whole mass was purchased by the Field Museum in Chicago and was described in detail by Farrington (1910a) who gave three photomacrographs of the exterior and two of small, etched sections. He concluded correctly that it was a medium octahedrite. This was disputed by Leonard (1944) with the result that it is now erroneously classified as a coarse octahedrite by Horback & Olsen (1965) and Hey (1966).

COLLECTIONS

Chicago (1,450 kg main mass), New York (13 g), Washington (11 g).

DESCRIPTION

The mass is shaped as an elongated low cone or shield, 110 cm long, 90 cm wide and 50 cm high. A visual inspection clearly reveals the "soil line" above which no significant weathering has occurred. The "soil line" has left about 30 cm of the thickness exposed to the atmosphere, and the regmaglypts here are well-preserved. They show a tendency to radiate away from the apex of the cone and are generally 4-7 cm in diameter. There is a large bowl-shaped depression in one place, 24 x 17 cm in aperture and 11 cm deep. Fusion crusts are present in numerous places. Where the corrosion is most progressive it has developed the Widmanstätten pattern as a delicate grid on the surface.

Below the "soil line" the morphology is radically different. Here, corrosion has modified the regmaglypts and produced numerous pits, 5-15 mm in diameter, with ragged edges. Locally, heavy caliche and ocher deposits are to be found under which the original surface may be preserved in a better way. On the average, several millimeters have been lost from the lower part of the meteorite by corrosion, while next to nothing has been lost from the top side.

A number of holes of almost cylindrical shape, 5-20 mm in diameter and up to 50 mm deep occur scattered irregularly over the surface. These cavities were undoubtedly produced by ablation of troilite nodules.

The specimen in the U.S. National Museum is a small fragment of 11 g, removed from the main mass with a chisel

Figure 1411. Quinn Canyon (Chicago). Close-up of a portion with well-preserved fusion crust, regmaglypts and cylindrical cavities from ablated troilite. Scale bar 2 cm. S.I. neg. M-71B.

QUINN CANYON – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	8.40								20.9	41.5	0.58	

and hammer. It confirms the general fresh appearance of the meteorite since both metallic fusion crusts and heat-affected α_2 zones are present. The fused metal forms 0.1-0.5 mm thick dendritic crusts and is, as usual, composed of numerous individual sheets, each about 50-100 μ thick. The columnar dendrites are oriented perpendicular to the unmelted substrate and form cells, typically 200 x 20 μ in size; the armspacing is 1-2 μ. The microhardness is 360±15. Scattered through the fused metal are tiny globules of oxides, generally 0.5-10 μ across. The exterior black oxidic fusion crust is not present on the specimen, having spalled off by the hammering.

The heat-affected α_2 zone is 2-3 mm thick. The α_2 forms serrated units 25-100 μ in diameter, with a hardness of 200±10, except right under the fusion crust where it increases to 250±10. Here, the structure is visibly moderated to bainitic-martensitic types evidently due to a slight carburization from the overlying melt. Hard, martensitic-bainitic zones are further systematically present along taenite and plessite fields. The zones are 20-50 μ wide and exhibit hardnesses of 340±25, again a result of carburization due to solid-state diffusion of carbon from the taenite to the kamacite, when the surface briefly was at 1100-1400° C.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 1.10±0.15 mm. The kamacite has subboundaries, decorated with 0.5-1 μ microrhabdites, and Neumann bands are well developed. The hardness is 180±15, but the determination is not fully reliable since it was taken on the only available material, rather close to the ablated and chiseled surface.

Taenite and plessite cover 35% by area, mostly as comb and net plessite. Taenite ribbons and wedges with transitional martensite zones (HV 410±25) and duplex black-etching interiors (HV 250±15) are quite common. The open-meshed plessite fields have hardnesses only slightly above those of the kamacite lamellae. The taenite rims are brown or tarnished yellow. These give way to a silvery-white color in the heat-affected α_2 zone where the martensitic-bainitic rim zones begin to occur simultaneously.

Schreibersite is present in the form of a few skeleton crystals, 1 x 0.3 mm found centrally in the kamacite lamellae, and as 20-60 μ wide grain boundary veins. Blebs, 5-50 μ across, occur in the plessite, and 10-20 μ thick blebs are frequently arranged as island arcs parallel to the taenite and plessite. A few 0.5 μ rhabdites occur in the kamacite. The bulk phosphorus content is estimated to be 0.22±0.03%.

No troilite was noted in the sections, but it is undoubtedly present as indicated by the cylindrical ablation holes on the surface.

Quinn Canyon is a medium octahedrite which is related to Lenarto, Orange River, Franceville, Thule and Carthage, to name a few undisputed medium octahedrites.

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

11 g chiseled and slightly hammered fragment (no. 893, 2 x 1.5 x 1 cm)

Quinn Canyon (Tonopah)

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm.

HISTORY

When F.C. Leonard published his paper on the meteorites of the western United States (1947) he included the so-called Tonopah octahedrite, of which he only knew of the 33 grams in the U.S. National Museum. I have examined this material. It consists of small fragments which have been chiseled off from a larger mass. It is partially covered with caliche, partially by fusion crust; and the heat-affected zone is well developed. In places the α_2 is up to 6 mm thick, but this is mainly due to the taper-sectioning.

An etched section displays a medium Widmanstätten structure with kamacite lamellae 1.10±0.15 mm wide. They are slightly distorted due to hammering. Taenite and plessite cover 35% by area and exhibit exactly the same variation as the fields in Quinn Canyon. Schreibersite is present as 1 x 0.3 mm skeleton crystals in the center of the kamacite and as 10-50 μ wide grain boundary precipitates. Only a few very small rhabdites are present.

The attached label reads "80 miles east of Tonopah" and the collector is named W.P. Jenny. A man named W.P. Jenney (1909) was supervisor when the Quinn Canyon iron was brought to Tonopah in 1909. From letters to Professor G.P. Merrill in the Smithsonian Archives, it may be seen that Jenney submitted a few fragments for examination in December 1908. Thus, the Tonopah meteorite which has come to be listed as an independent meteorite by Leonard (1947), Mason (1962a: 237) and Hey (1966: 486) is nothing more than early detached fragments of Quinn Canyon.

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

33 g chiseled and hammered fragments (no. 1789, approximately 3 x 2 x 1 cm)

Rafrüti, Canton Berne, Switzerland

47°0′N, 7°50′E; 1090 m

Ataxite, D. Equiaxial recrystallized kamacite grains, 0.02 mm in diameter, with dispersed taenite particles, 0.008 mm in diameter. HV 145±6.

Anomalous. 9.43% Ni, 0.6% Co, 0.06% P, 0.16 ppm Ga, 0.06 ppm Ge, 0.007 ppm Ir. Repeatedly artificially reheated to peak-temperatures about 400° C.

HISTORY

A mass of 18.20 kg was found in 1886 by a farmer, A. Zürcher, in the Emmenthaler Mountains, north of

Langnau and east of Wasen. The precise locality where the meteorite was found a foot deep in talus, was the lower Rafrüti, near the head of Mümpbach. It was acquired in 1900 by the Berne Museum, where Fellenberg (1900) gave a brief description with three photographs of the exterior. When Fellenberg sought more information, he was told that, in 1856, several people had witnessed a fireball and heard detonations, and that one of the witnesses had been knocked over by the blast. The meteorite burst into several pieces and, according to these people, one landed in Rafrüti. As discussed below, the Rafrüti material appears to be too weathered to have been an observed fall in 1856. What the people recorded must have been another event from which no material has been recovered.

Fellenberg noted that the Rafrüti mass was kept for 14 years on the farm, where several times during hard winters it had been heated on the hearth and then plumped into the cattle water to stop it from freezing. Occasionally, the 18 kg mass had been heated, then wrapped in blankets and used as a bed-warmer.

Cohen (1902b; 1905: 80) gave a description of the structure and an analysis. He classified it with Illinois Gulch, with which it has little in common, however. Berwerth (1918: 423) gave a photomicrograph and assumed that Rafrüti was originally a fine octahedrite which, by the repeated artificial reheatings, had been transformed to the present fine-grained ataxite structure.

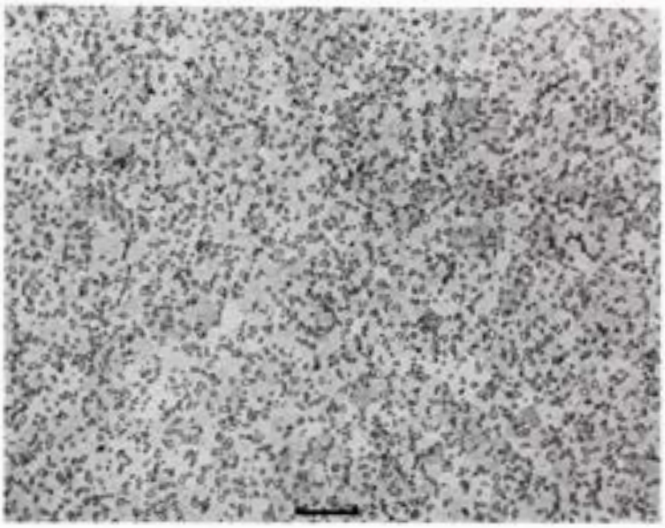

Figure 1412. Rafrüti (U.S.N.M. no. 251). Equiaxial recrystallized kamacite grains with irregular taenite particles mainly at grain boundaries. Etched. Scale bar 100 μ.

COLLECTIONS

Berne, Museum of Natural History (17.78 kg), Strasbourg (22 g), Washington (21 g), Vienna (13 g), Chicago (8 g), Berlin (2 g).

DESCRIPTION

The mass approximates an ellipsoid shape; however, while one half is rather smoothly rounded, the opposite half is angular-pyramidal. The mass measures 23 x 17 x 13 cm in three perpendicular directions and now (1970) weighs 17.78 kg; only a 420 g section has been removed from one end.

On the small sections examined by me a heat-affected α_2 zone, up to 2 mm wide, was irregularly preserved, but no fusion crust was present. The α_2 zone is penetrated in numerous places by millimeter-sized pits with sharp and rough ridges in between. In some places it is entirely removed by corrosion. Its hardness is low, 166±6, presumably due to the annealing recorded in the literature. Limonitic corrosion products, 0.1-0.5 mm thick, cover the surface erratically. The taenite particles survive for a while in the oxides.

The presence of an α_2 zone, albeit weathered, indicates that the overall shape of the present mass is not much changed since its fall. It is, on the other hand, not entirely clear whether the observed crust of terrestrial oxides formed by exposure to the atmosphere, before the meteorite was found, or whether the oxidation occurred mainly during the several reheatings. If the latter is the case, Rafrüti could have been an observed fall as maintained by Fellenberg's informers. I am, however, inclined to conclude

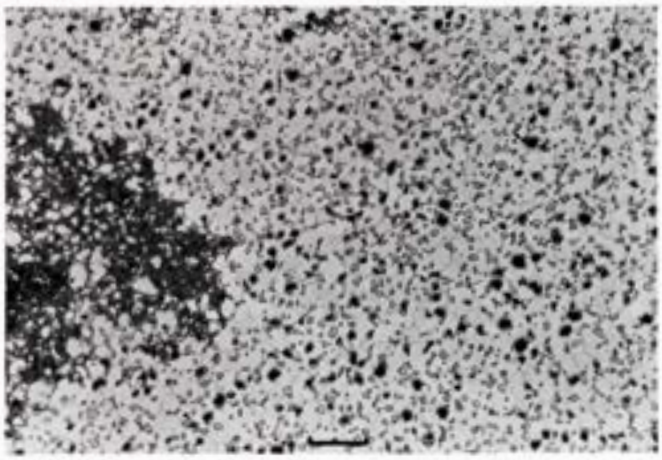

Figure 1413. Rafrüti (U.S.N.M. no. 251). A near-surface section showing selective conversion of kamacite to limonite (gray). Imperfect polishing has caused many particles to be torn out, leaving black pits. Etched. Scale bar 100 μ.

RAFRÜTI – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Cohen 1905	9.54	0.61	0.06	1800	1100	100	300					
Schaudy et al. 1972	9.32								0.159	0.055	0.007	

Ga and Ge are low, and Ir is the lowest recorded in any iron meteorite.

that Rafrüti was not observed to fall and that it weathered significantly before its discovery in 1886.

Etched sections are ataxitic with no structural elements visible to the naked eye. The metal is a polycrystalline aggregate of equiaxial kamacite grains, typically 10-30 μ across. Taenite covers 15-20% by area as irregular blebs, mainly located in the kamacite grain boundaries. No Widmanstätten pattern can be distinguished – at least not on small samples.

The kamacite is homogeneous; and the grain boundaries are equilibrated, indicating thorough annealing. Neumann bands were not seen, and deformation was not detected. The microhardness is correspondingly low, HV 145±6 (hardness curve type III). The structure and the low hardness suggest annealing temperatures of about 400° C.

The taenite blebs are typically 2 x 2 μ, 6 x 15 μ or 10 μ across, and correspond to the amoeba-like forms described in, e.g., Santiago Papasquiaro, Mejillones and Wathena. They occur with an average frequency of 1800 per mm^2, have irregular to concave outlines and often display 0.5-1.5 μ internal kamacite "windows."

Improper polishing and etching promote numerous 5-10 μ pits on the finished surfaces. They are artificial and can be removed by careful polishing with diamond paste, as discussed under Kopjes Vlei, Wathena and others. They evidently reflect the presence of a little understood unequilibrated metallic phase, which is easily attacked by both weathering and laboratory agents.

Phosphides were not detected. The 0.06% P recorded in an analysis is probably present in solid solution in the metallic phases. Sulfides were not present in the small sections examined. When identified, they will presumably be found to be of the shattered shock-melted variety.

Carbides, graphite and silicates are not present. The high carbon content reported by Cohen is puzzling and should be checked. Is it possible that the sample he analyzed came from the surface and included carburized zones from the reheating in the hearth?

The bulk structure of Rafrüti has only negligibly been influenced by the reheatings. It appears that kamacite grain boundary adjustments and recovery (effectively lowering the hardness) – and possibly slight changes of the α-γ interfaces – were all that occurred. The corrosion products were little influenced and high temperature (> 600° C) laceworks and oxidation did not develop. All structural effects indicate that the heat applied by the farmer did not exceed a temperature of about 400° C.

Rafrüti is an ataxite with a cosmic produced structure similar to those of Juromenha, Santiago Papasquiaro, Washington County and Wathena. It appears, however, that it is not chemically related to any of these nor to any other iron meteorite.

Specimen in the U.S. National Museum in Washington:
21 g part section (no. 251, 3 x 3 x 0.2 cm)

Ranchito. See Bacubirito

Rancho de la Pila, Durango, Mexico
24°7′N, 104°18′W

Medium octahedrite, Om. Bandwidth 1.05±0.15 mm. ϵ-structure. HV 300±15.

Group IIIA. 7.93% Ni, about 0.15% P, 20.8 ppm Ga, 42.1 ppm Ge, 0.70 ppm Ir.

HISTORY

A mass of 46.5 kg was plowed up in 1882 in a field belonging to Rafael Bracho at Rancho de la Pila, about 40 km east-northeast of Durango. The locality has the coordinates given above. The finder believed that the mass

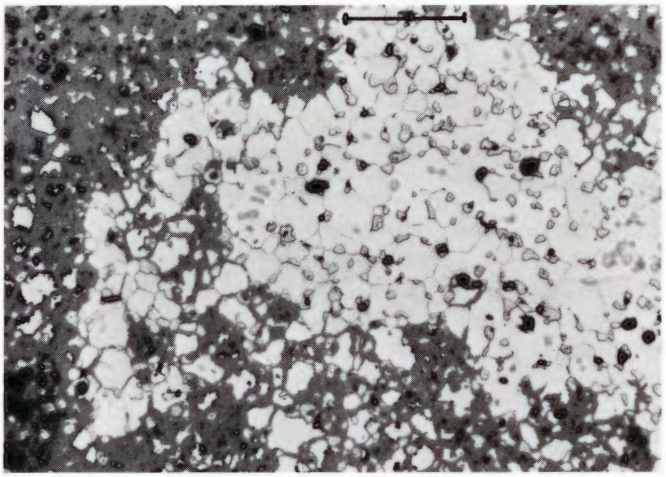

Figure 1414. Rafrüti (U.S.N.M. no. 251). Detail of corroded section. Limonite appears gray. Taenite forms irregular amoebae, mainly in the grain boundaries of recrystallized kamacite. Black dots are pits from torn out particles. Etched. Scale bar 100 μ.

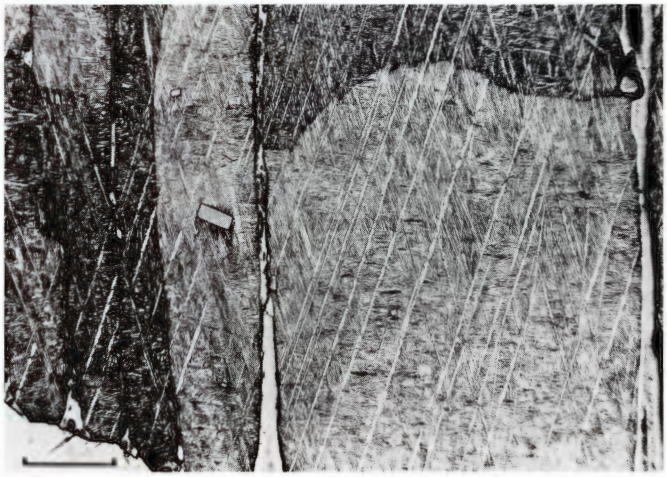

Figure 1415. Rancho de la Pila (Vienna no. D1490). Medium octahedrite of group IIIA. Shock-hatched kamacite in light and dark shades. Cloudy vertical taenite lamellae. Strongly etched. Scale bar 300 μ.

must have fallen since the last plowing of the field the year before, since, as it was only buried 25-30 centimeters, it could hardly have been overlooked in plowing. The mass was sent to Bremen, where it was described by Häpke (1884; 1886). Three casts were made before the mass was purchased by the British Museum in 1885. Farrington (1915: 364) has reviewed the history. Axon (1968b) recently briefly reexamined the material in London.

Unfortunately, a large number of meteorite fragments, labeled Rancho de la Pila but not originating from this mass, appear in many collections. Most of these erratic specimens were, before the 46 kg mass was found in 1882, labeled Durango or Karawinsky iron, but when Fletcher (1890a: 152) published his study of the Mexican meteorites, in which he concluded on purely historical basis that the Karawinsky material in Vienna (about 800 g), the Cacaria mass in Mexico City (41.4 kg) and unspecified Durango specimens all appeared to be identical to the newly found Rancho de la Pila mass, many labels, but not all, were rewritten with the result that considerable confusion arose. At this late date it is almost impossible to penetrate the maze of the numerous old specimens, which have been divided, exchanged and further subdivided, so it was here decided to describe authentic Cacaria and authentic Rancho de la Pila material separately, and further, under Durango, to treat the story of this controversial material.

COLLECTIONS

London (44.2 kg main mass and 1.4 kg pieces). Vienna (No. D1490, 209). Vienna (No. J4911, 7 g. Found mislabeled "Durango" in the Vienna Collection). Apparently very little has ever been cut and exchanged from this mass. Summation of so-called Rancho de la Pila material in other museums results in at least 3 kg slices and fragments which probably come from neither the Rancho de la Pila mass nor from the Cacaria mass, but from some third (and fourth ?) mass, divided and brought to Europe by various travelers in the first half of the nineteenth century, and generally designated Durango. Material, labeled Rancho de la Pila but chemically and structurally different from the authentic mass, has been found during this study in Copenhagen (No. 11 and No. 1862, 484), Washington (No. 3306), New York (No. 138) and Tübingen. Exactly what these are is difficult to decide, since many specimens appear to have been reheated artificially and even forged (e.g., U.S.N.M. No. 3306).

DESCRIPTION

The mass in London is of a prismatic shape with the average dimensions 30 x 23 x 18 cm. It is only cut in one place where about 2 kg has been removed, leaving a 15 x 10 cm sawed face. The mass is slightly corroded and is covered with a crust of terrestrial oxides 0.2 mm thick. There are several depressions, 2-4 cm in diameter, on the surface, apparently mainly regmaglypts from the atmospheric entry. Locally, the octahedral structure is clearly seen upon the surface because corrosion has preferentially attacked along the $\{111\}$ planes and partly detached small octahedral fragments.

The etched section is that of a medium octahedrite with straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 1.05±0.15 mm. The kamacite is of the hatched ϵ-type associated with shock intensities above 130 k bar, but the subgrain boundaries in the ferrite are easily seen as "barbed

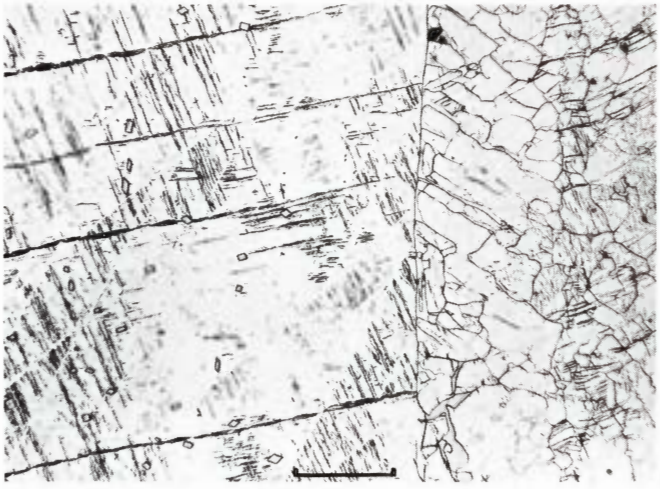

Figure 1416. Rancho de la Pila (Vienna no. D1490). Shock-hatched kamacite and, to the right, open-meshed net plessite. Etched. Scale bar 300 μ.

Figure 1417. Rancho de la Pila (Vienna no. D1490). A horizontal cloudy taenite lamella. On either side shock-hatched kamacite with prominent rhabdite prisms. Etched. Scale bar 300 μ.

RANCHO DE LA PILA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	7.93								20.8	42.4	0.70	

wire"on account of the numerous 1-2 μ phosphide precipitates. Locally, the boundaries have moved 10-30 μ away from their line of precipitates. The ϵ-structure has a hardness of 300±15, indicating significant shock hardening without annealing. Plessite occupies about 35% by area, mainly as net and comb plessite that repeat the directions of the gross Widmanstätten structure. Poorly resolvable, duplex $\alpha + \gamma$ mixtures are also common in the interior of triangular and rhombic plessite fields.

No large schreibersite crystals were seen, but 50-100 μ wide, monocrystalline grain boundary precipitates are fairly common. Rhabdite prisms are widespread and reach 50 μ in crosssection. In the interior of the plessite fields irregular schreibersite bodies occur in a wide range of sizes, up to about 200 x 100 μ. The large sizes of the rhabdites, as well as of the schreibersites inside the plessite fields, are rather unusual for octahedrites. The bulk phosphorus content is estimated to be 0.15±0.02%.

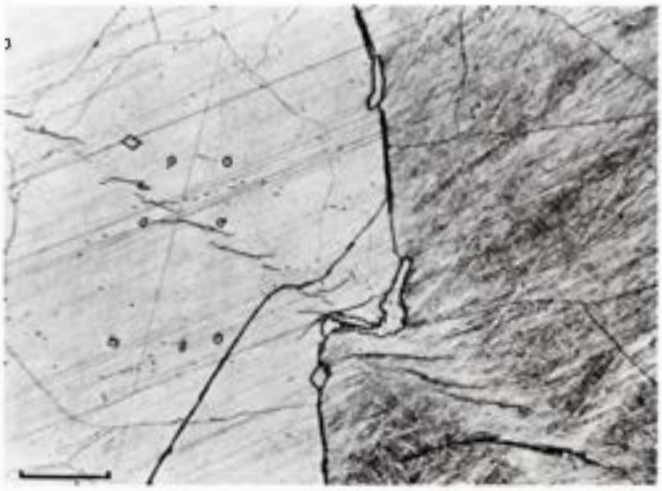

Figure 1418. Rancho de la Pila (Vienna no. J4911). A shear zone runs diagonally across two shock-hatched kamacite lamellae. In the grain boundary a violently shear-displaced schreibersite crystal. Numerous microfissures in the kamacite. Etched. Scale bar 300 μ.

Troilite is sparsely present as 0.5-10 mm nodules. In at least three places on the main mass they are removed by ablation melting, leaving cylindrical cavities, 7-20 mm across. A typical nodule, 1.2 x 0.7 mm in size, and surrounded by a 0.1 mm wide rim of swathing kamacite, consisted of troilite with multiple twinning and a few 5-30 μ wide daubreelite lamellae exsolved parallel to (0001) of the troilite.

There are numerous fine precipitates of the chromium nitride, carlsbergite, in the α-phase of the metal. They form oriented platelets, typically 20 x 2 x 0.5 μ in size. Small rhabdites are often precipitated upon them.

The kamacite shows several cubic cleavage fissures. They are usually only 1-10 μ wide, but up to 1 mm long, and are now filled with terrestrial limonite.

It has been claimed that Rancho de la Pila and Cacaria are paired falls. The structural analysis of the two irons does not support this idea. However, since Cacaria has been violently maltreated, the structural analysis alone is not quite sufficient. Therefore, it is important that the new main and trace-element analyses by Wasson clearly separate the two irons and thus support the conclusion based upon structures alone.

Rancho de la Pila is a shock-hardened medium octahedrite which is related to Samelia, Augusta County, Bagdad and Kyancutta. It is a typical member of the group IIIA irons.

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

45 g endpiece (no. 1018, 4 x 2 x 2 cm). Shepard Collection no. 13, labeled "Durango 1804."

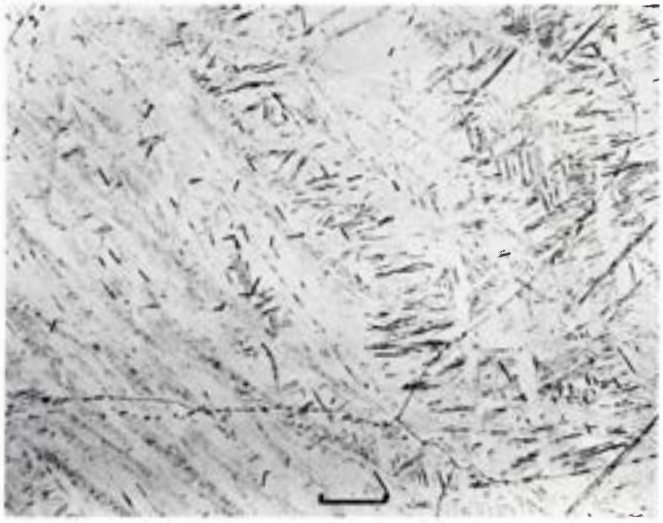

Figure 1419. Rancho de la Pila (Vienna no. D1490). Shock-hatched kamacite with subboundaries and numerous carlsbergite platelets. Etched. Scale bar 100 μ.

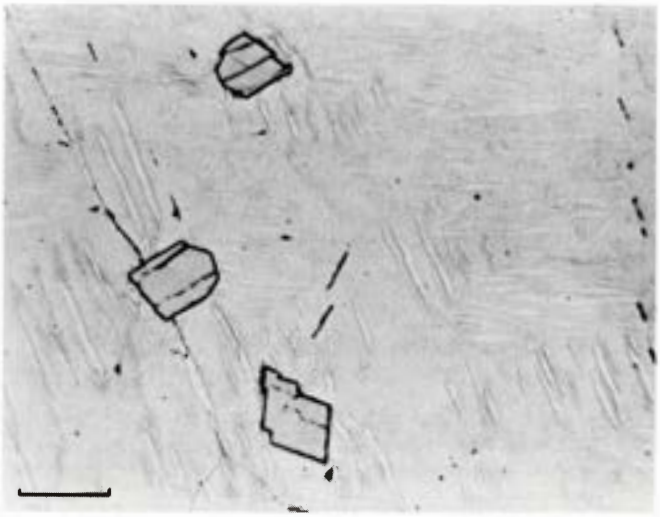

Figure 1420. Rancho de la Pila (Vienna no. D1490). Three shear-displaced rhabdite prisms and several slightly bent carlsbergite platelets. Lightly etched. Scale bar 40 μ.

Rasgata. See Santa Rosa.

Rateldraai, Cape Province, South Africa
28°50′S, 21°8′E

Medium octahedrite, Om. Bandwidth 0.90±0.15 mm. ε-structure. HV 280±25.

Group IIIA. 7.25% Ni, 0.50% Co, 0.08% P, 18.5 ppm Ga, 32.5 ppm Ge, 12 ppm Ir.

HISTORY

A mass of 1,210 pounds (550 kg) was found in 1909 near Rateldraai in the Kenhardt Division of the Cape Province (Prior 1926). It was acquired by the South African Museum in Cape Town and has been described as a coarse octahedrite (Hey 1966: 402). However, as the present study shows, Rateldraai is a normal medium octahedrite. A similar conclusion was reached during a cursory examination by Comerford et al. (1968).

COLLECTIONS

Cape Town (main mass of 550 kg), London (226 g).

DESCRIPTION

Rateldraai has an extremely rugged shape, see the photograph in the Supplement. It is elongated and flat, measuring 144 x 52 cm, with thicknesses that range from 45 to 10 cm. Apparently the meteorite was buried, except for two portions at either end that projected above the soil. These projecting parts corroded only slightly, while the rest became infested with many bowl-shaped depressions, e.g. 13 x 10 cm in aperture and 10 cm deep, and with ragged crests in between. The depressions were probably caused by a very long exposure to terrestrial corrosion, compare Willamette. The only sample available for metallographic examination came from one of the well-preserved ends, a 226 g slice measuring 5 x 5 x 1.5 cm (Brit. Mus. No. 1916,61).

Rateldraai displays a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 0.90±0.15 mm. The value of 1.7 mm (Hey 1966: 402) is in error. The kamacite is rich in subboundaries decorated with less than 1 μ phosphides, but they are somewhat obscured by an overlapping hatched ε-structure that, due to shock, developed later. Intensive shock hardening has occurred, to values of 280±25, and the included brittle minerals (phosphides, sulfides) are clearly shattered due to the shock-deformation.

Taenite and plessite cover about one-third by area. The comb and net plessite fields are degenerated so that the taenite component is almost resorbed. The plessite interiors are often just aggregates of kamacite grains with next to nothing left of the original taenite. This tallies well with the low bulk nickel content of 7.25%. The retained taenite is cloudy brown with the usual 1-2 μ wide yellow rim zones. A grid of densely spaced slipplanes, parallel to the bulk Widmanstätten structure, is clearly seen in the taenite lamellae. It indicates deformation plus slight annealing with submicroscopic precipitation; the hardness is 330±25. A few of the larger taenite lamellae are in the interior decomposed to martensitic or unresolvable duplex structures.

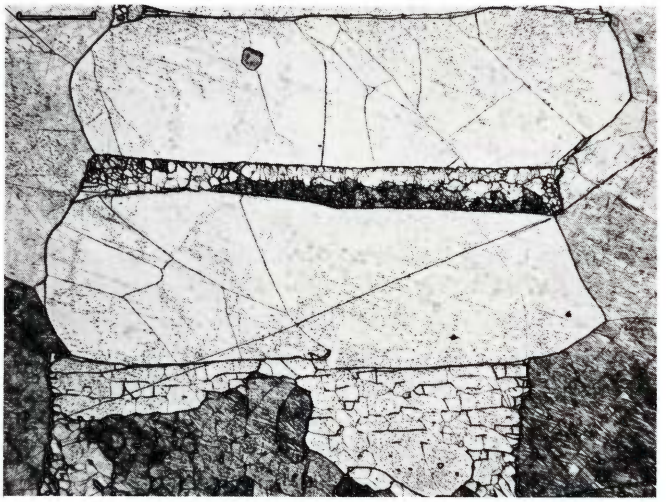

Figure 1421. Rateldraai (Brit. Mus. no. 1916, 61). Low-nickel medium octahedrite of group IIIA. Degenerated comb and net plessite, and shock-hatched kamacite. Neumann bands cross the entire field. Above, a lamellar troilite-daubreelite nodule. Etched. Scale bar 500 μ.

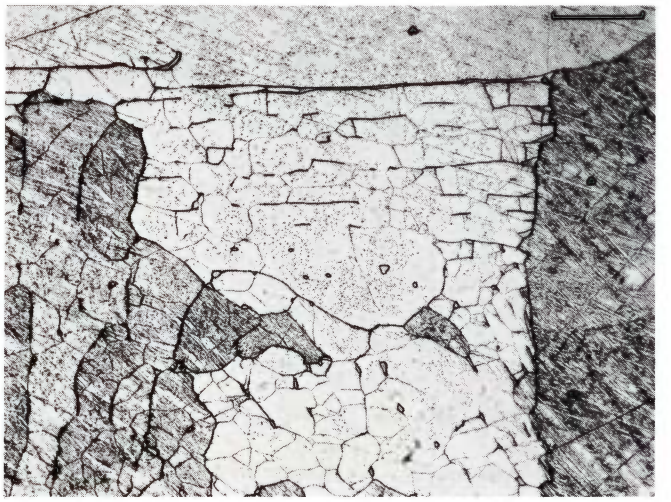

Figure 1422. Rateldraai. Detail of Figure 1421. The taenite edge of the plessite field is discontinuous and in the interior only insignificant taenite particles survive. Etched. Scale bar 300 μ.

RATELDRAAI – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Comerford et al. 1968	7.22	0.50	0.08									
Scott et al. 1973	7.28								18.5	32.5	12.0	

Rasgata. See Santa Rosa.

Rateldraai, Cape Province, South Africa
28°50′S, 21°8′E

Medium octahedrite, Om. Bandwidth 0.90±0.15 mm. ε-structure. HV 280±25.

Group IIIA. 7.25% Ni, 0.50% Co, 0.08% P, 18.5 ppm Ga, 32.5 ppm Ge, 12 ppm Ir.

HISTORY

A mass of 1,210 pounds (550 kg) was found in 1909 near Rateldraai in the Kenhardt Division of the Cape Province (Prior 1926). It was acquired by the South African Museum in Cape Town and has been described as a coarse octahedrite (Hey 1966: 402). However, as the present study shows, Rateldraai is a normal medium octahedrite. A similar conclusion was reached during a cursory examination by Comerford et al. (1968).

COLLECTIONS

Cape Town (main mass of 550 kg), London (226 g).

DESCRIPTION

Rateldraai has an extremely rugged shape, see the photograph in the Supplement. It is elongated and flat, measuring 144 x 52 cm, with thicknesses that range from 45 to 10 cm. Apparently the meteorite was buried, except for two portions at either end that projected above the soil. These projecting parts corroded only slightly, while the rest became infested with many bowl-shaped depressions, e.g. 13 x 10 cm in aperture and 10 cm deep, and with ragged crests in between. The depressions were probably caused by a very long exposure to terrestrial corrosion, compare Willamette. The only sample available for metallographic examination came from one of the well-preserved ends, a 226 g slice measuring 5 x 5 x 1.5 cm (Brit. Mus. No. 1916,61).

Rateldraai displays a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 0.90±0.15 mm. The value of 1.7 mm (Hey 1966: 402) is in error. The kamacite is rich in subboundaries decorated with less than 1 μ phosphides, but they are somewhat obscured by an overlapping hatched ε-structure that, due to shock, developed later. Intensive shock hardening has occurred, to values of 280±25, and the included brittle minerals (phosphides, sulfides) are clearly shattered due to the shock-deformation.

Taenite and plessite cover about one-third by area. The comb and net plessite fields are degenerated so that the taenite component is almost resorbed. The plessite interiors are often just aggregates of kamacite grains with next to nothing left of the original taenite. This tallies well with the low bulk nickel content of 7.25%. The retained taenite is cloudy brown with the usual 1-2 μ wide yellow rim zones. A grid of densely spaced slipplanes, parallel to the bulk Widmanstätten structure, is clearly seen in the taenite lamellae. It indicates deformation plus slight annealing with submicroscopic precipitation; the hardness is 330±25. A few of the larger taenite lamellae are in the interior decomposed to martensitic or unresolvable duplex structures.

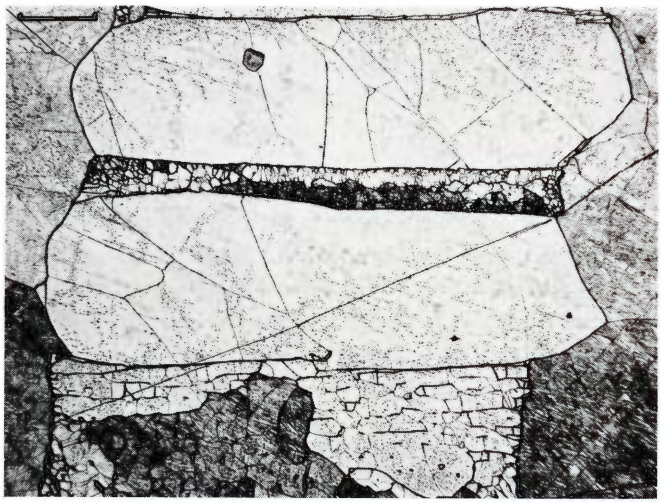

Figure 1421. Rateldraai (Brit. Mus. no. 1916, 61). Low-nickel medium octahedrite of group IIIA. Degenerated comb and net plessite, and shock-hatched kamacite. Neumann bands cross the entire field. Above, a lamellar troilite-daubreelite nodule. Etched. Scale bar 500 μ.

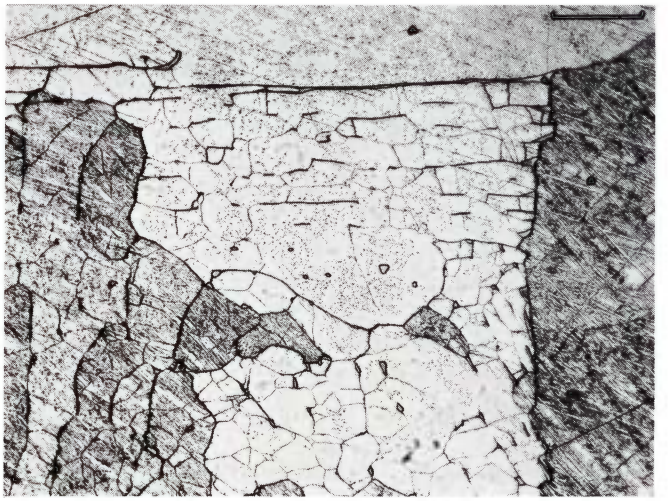

Figure 1422. Rateldraai. Detail of Figure 1421. The taenite edge of the plessite field is discontinuous and in the interior only insignificant taenite particles survive. Etched. Scale bar 300 μ.

RATELDRAAI – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Comerford et al. 1968	7.22	0.50	0.08									
Scott et al. 1973	7.28								18.5	32.5	12.0	

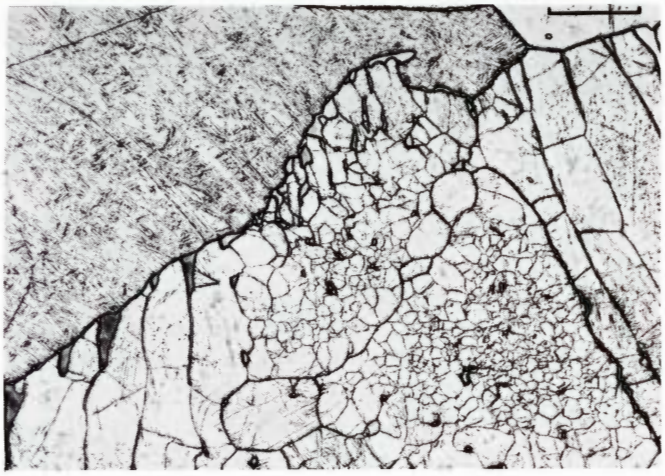

Figure 1423. Rateldraai (Brit. Mus. no. 1916, 61). Open-meshed net plessite field and shock-hatched kamacite in various shades. Etched. Scale bar 200 μ.

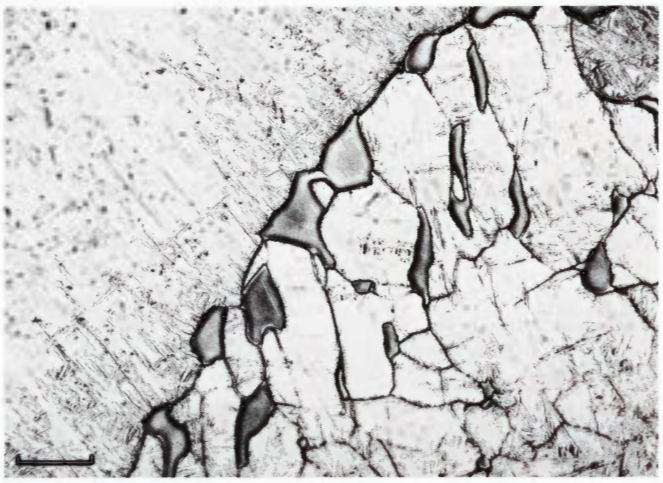

Figure 1424. Rateldraai. Detail of Figure 1423, showing cloudy taenite particles and subboundaries inside the plessite. Minute phosphide particles occur in the kamacite lamella (left). Etched. Scale bar 50 μ.

Schreibersite is rare. It occurs in some grain boundaries and in the plessite interiors as 5-10 μ wide particles. In some kamacite lamellae microrhabdites, less than 1 μ across are found. The bulk phosphorus content may be estimated to be 0.08±0.02%.

Troilite was seen, in one place only, as a 2 x 1 mm monocrystalline bar with a 0.2 mm wide daubreelite lamella inside. The troilite had nucleated a 1 mm wide rim of swathing kamacite. There are numerous subangular daubreelite particles scattered through the kamacite, ranging in size from 20 to 400 μ. Some of them include minute lamellae of troilite and kamacite in very characteristic aggregates similar to those described in, e.g., Cape York and Costilla Peak.

Graphite, carbides and silicates are absent. Carlsbergite is very common, both as oriented 20 x 1 μ platelets in the kamacite and as 10 x 2 μ irregular blebs on grain boundaries of the plessite fields. They are evidently quite ductile, since

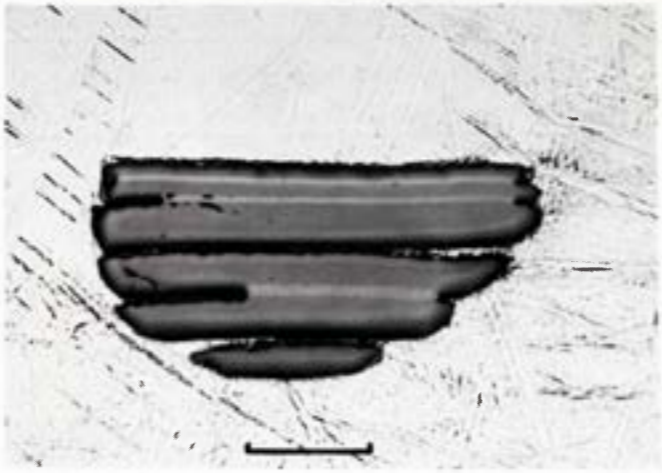

Figure 1425. Rateldraai (Brit. Mus. no. 1916, 61). A stack of parallel plates of troilite (light) and daubreelite (dark). Shock-hatched kamacite. Etched. Scale bar 40 μ.

they have been bent and distorted without fragmentation by the cosmic deformation that shattered the other minerals. Chromite occurs as lamellae, typically 1,000 x 100 x 2 μ in size. They have served as nuclei for the precipitation of minute phosphide particles, 1-5 μ thick.

Fusion crust was not detected, but 1-3 mm wide heat-affected zones of α_2 (HV 200±20) occur along a part of the exterior edges. The α_2 grains are serrated and unequilibrated, and they are small – 15-30 μ across – because they formed by transformation from shock-hardened ϵ-structures. The hardness gradient is of type I.

Rateldraai is a medium octahedrite of the nickel-poor and phosphorus-poor variety, related to Henbury, Schwetz, Wabar and Kalkaska, all of the resolved chemical group IIIA. Structurally, it is particularly closely related to Kalkaska, Haig, Norfolk, Kenton County and Costilla Peak. It is unrelated to the other South African meteorites found in the vicinity, such as Vaalbult, Kopjes Vlei and Orange River. Its exterior shape is one of the most fascinating to occur in iron meteorites, having been produced by ablation and subsequent remarkable corrosion.

Redfields. See the Supplement

Red River, Texas, U.S.A.

Approximately 33½°N, 99½°W

Medium octahedrite, Om. Bandwidth 1.05±0.15 mm. ϵ-structure. HV 262±12.

Group IIIA. 7.78% Ni, 0.49% Co, 0.12% P, 19.7 ppm Ga, 38.5 ppm Ge, 4.4 ppm Ir.

HISTORY

A mass of about 800 kg was discovered about 1800 by a Pawnee Indian between the Brazos River and the Red River, probably about 200 km west-northwest of the present city of Dallas. It was briefly mentioned by Bruce

(1810), who gave a sketch of the mass after it had been transported to New York. A colorful account of the events that led to the recovery of the mass – believed to be platinum by the discoverers – was given by an anonymous coeditor of Silliman's American Journal of Science (C.H., 1824: Volume 8: 218-225; cfr. footnotes pages 30 and 88 of the same volume). For a while the iron was the property of the mineral collector, Colonel George Gibbs, who had purchased it for $500 from the finders (Clark 1852: 59). After his death, it went on his bequest to Yale University (American Journal of Science 1835: Volume 27: 382) and an endpiece was cut from it. The iron was described and analyzed by Silliman & Hunt (1846), who also produced a successful self-imprint of an etched section. The deep-etched surface itself had been used as a mold for producing the typemetal block.

The meteorite was discussed on several occasions during the nineteenth century, sometimes under the synonym Cross Timbers. Various authors entertained ideas of a relationship with Wichita County, which in 1836 was transported to San Antonio from its supposed place of discovery in northwestern Texas. Relevant references may be found in Wülfing (1897: 93) and Farrington (1915: 366). More recently, King (1936), and O.E. Monnig (personal communication 1969) have examined the historical reports inorder to pinpoint the locality of discovery but so far with little success. However, one thing is certain: the locality often quoted 32°N, 95°W (e.g., Hey 1966: 403), must be very much in error since this point almost coincides with Nacogdoches, the village from which one party *started* and traveled many days in order to reach the mass in 1810. The approximate coordinates are rather 33½°N, 99½°W, in the present Knox or Baylor Counties. It is also certain that the two smaller masses of "platinum ore" which were hunted at the same time have nothing to do with the Red River meteorite. One was presumably Wichita County, of 150 kg, the other was perhaps Denton County, of 18 kg, which was finally procured in 1860. A thorough study of the notes referred to by Silliman & Hunt (1846), still preserved in the Archives of Yale University (Turekian, personal communication 1970), might perhaps yield a more precise locality for the Red River meteorite.

Nininger & Nininger (1950: plate 9) reproduced a photomacrograph of an etched section. Reed (1965a, b) examined the composition of the phosphides and the taenite with the microprobe and gave a photomicrograph.

COLLECTIONS

Yale (784.8 kg main mass, according to the most recent catalog (Turekian 1966: 10); previously the mass had been assumed to weigh about 1635 pounds, or 740 kg). Harvard (1,762 g), Bonn (1,509 g), Vienna (two pieces each of about 600 g; the one originally in the Kunz Collection may, in fact, be Russel Gulch and not Red River), Calcutta (559 g), Amherst (534 g), London (507 g), New York (248 g), Oslo (197 g), Paris (177 g), Moscow (145 g), Berlin (136 g), Budapest (124 g), Chicago (108 g), Rome (96 g), Tempe (95 g), Stockholm (85 g), Tübingen (84 g), Washington (78 g), Vatican (35 g), Strasbourg (25 g), Leningrad (16 g). The original mass must accordingly have weighed about 800 kg.

DESCRIPTION

The mass has the approximate maximum dimensions of 100 x 70 x 40 cm and has a cut surface about 20 cm in diameter, bearing an inscription in memory of the donor and of Colonel George Gibbs. The surface is weathered and no signs of fusion crust or heat-affected rim zones seem to be present. However, corrosion penetrates only a small distance below the surface, probably because the iron is rather massive, free from cracks and free from embrittling and electric potential-creating phosphides.

Etched sections display an indistinct Widmanstätten structure of straight, long ($\frac{L}{W} \sim 30$) kamacite lamellae with

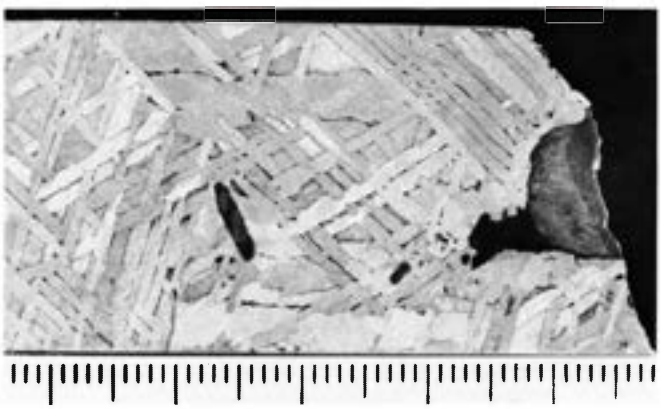

Figure 1426. Red River (Tempe no. 252a). Medium octahedrite of group IIIA. One large and several small troilite nodules with swathing kamacite. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

RED RIVER – SELECTED CHEMICAL ANALYSES

Small amounts of chlorine were detected near the surface by Silliman & Hunt (1846). The chlorine was no doubt introduced with the terrestrial ground water.

	percentage			ppm								
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Moore & Lewis 1968	7.86	0.49	0.12	310	40							
Scott et al. 1973	7.70								19.7	38.5	4.4	

a width of 1.05±0.15 mm. The kamacite has faint subboundaries decorated with a few 0.5 μ thick phosphides. It is shock-hardened (HV 262±12) and exhibits an acicular-hatched structure with no indications of annealing. On the specimen studied no hardness decrease could be detected when approaching the natural surface. It is, therefore, concluded that – at least here – a minimum of 5 mm has been lost by terrestrial corrosion, which means that Red River must have a significant terrestrial age.

Taenite and plessite cover about 35% by area, mostly as degenerated comb and net plessite fields with discontinuous taenite borders. Very hard, dark-etching plessite wedges and γ ribbons also occur. A large, typical field will display a stained taenite rim (HV 330±25) followed by a narrow martensitic-bainitic transition zone. Next come martensitic zones with acicular α phase (1 μ thick) and/or duplex unresolvable α + γ mixtures (HV 360±25). Finally, come easily resolvable comb or net plessite which display the same hardnesses as the adjacent kamacite lamellae.

Schreibersite is only present as fine precipitates. Grain boundary veinlets, 5-40 μ wide, are common; and 2-50 μ irregular blebs substitute for gamma grains of similar sizes in the plessite fields. The microhardness is 700±30, which is about 100 units less than for the coarse schreibersite lamellae in, e.g., São Julião. The schreibersite of São Julião contains 15% Ni (Cohen 1900b), while that of Red River contains 34-37% Ni (Reed 1965a). Indications are that the hardness of schreibersite decreases with increasing nickel content, which may prove to be a rather useful observation when detecting and interpreting the precipitation sequence of phosphides.

In the matrix, numerous hard, oriented platelets of carlsbergite, the chromium nitride so common in group IIIA, are to be found; they are typically 20 x 2 x 1 μ.

Troilite occurs as scattered lenticular, rhombic or globular blebs, ranging from 0.5 to 12 mm in size. Daubreelite is present as scarce 10-50 μ blebs. At least the smaller troilite nodules, which could be examined in polished sections, have been shock-melted and now appear as spongy intergrowths of metal and sulfide on the 1-2 μ scale. Chromite crystals, typically as 300 x 50 μ bars, occur relatively frequently in the kamacite, where they often have nucleated some troilite and schreibersite.

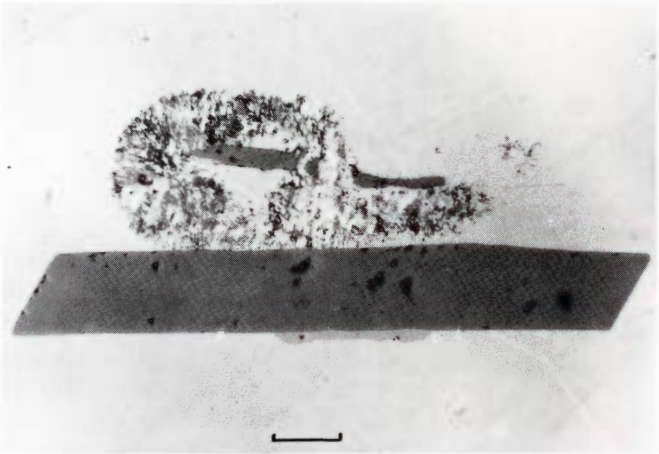

Figure 1427. Red River (Copenhagen). One large and one small chromite bar which have nucleated troilite (above) and schreibersite (below). When the meteorite was at some time exposed to shock, the troilite melted and solidified to fine-grained structures. Polished. Crossed polars. Scale bar 50 μ.

Red River, for a long time the largest meteorite in the possession of man, is a typical, shock-hardened medium octahedrite, related to Glasgow, Rowton, Iron Creek and Merceditas . Chemically, it belongs to group IIIA.

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

14 g hammered and chiseled fragments (no. 95)
53 g part slices (no. 1008)

Red Willow, Nebraska, U.S.A.

About 40°15′N, 100°30′W

A mass of 2 3/4 kg was found about 1899 at an indefinite locality in Red Willow County and was described by Barbour (1903). According to this report, the mass was a beautiful monolith, somewhat similar to Bushman Land; structurally, it was classified as a medium octahedrite. Unfortunately, the present repository is unknown.

Reed City, Michigan, U.S.A.

43°54′N, 85°31′W; 300 m

Anomalous coarse octahedrite. Bandwidth 1.8±0.3 mm. Shocked and altered. HV 185±8.

Anomalous. 7.48% Ni, 0.50% Co, about 0.45% P, 22.5 ppm Ga, 55.5 ppm Ge, 54 ppm Ir.

HISTORY

A mass of 19.8 kg was plowed up in 1895 by Ernest Rupperst on his farm in Osceola County, near Reed City. A piece of less than a pound was broken off by the finder in an effort to discover what made the "stone" so heavy, but the main mass was acquired for the Michigan State Agricultural College (the present Michigan State University) by Professor Barrows. It was partly cut by Ward in 1902, and was described with a photograph and a photomacrograph by Preston (1903). Cohen (1905: 27, 399) mentioned it briefly and included it with Hammond and Cacaria in the "Hammond-group" of altered octahedrites. Berwerth (1914: 1080) believed that Reed City had been artificially reheated, and Buchwald (quoted in Hey 1966: 404) suggested that part of the mass had been heated and forged. This seems, however, to apply only to the lost, pound-sized specimen, while all other material is undamaged. Maringer and Manning (1962: 135) observed that the gross structure indicated some comparatively severe reheating prior to the entry into the atmosphere, since the original structure along the edge was overlapped by a genuine, ablation-heated rim

zone. Axon et al. (1968: 593) gave two photomicrographs which corroborated the view that Reed City had been subjected to cosmic recrystallization. Axon (1964) found the main mass free of Neumann bands, but in regions near the surface a few were found and ascribed to the impact with the atmosphere.

COLLECTIONS

Michigan State University (about 10 kg half mass), Chicago (2,968 g), Washington (1,838 g), Ann Arbor (862 g), London (810 g), Ottawa (600 g), Harvard (490 g), Amherst (314 g), New York (296 g), Paris (203 g), Tempe (193 g), Berlin (169 g), Tübingen (154 g), Bonn (92 g), Copenhagen (75 g), Calcutta (56 g), Strasbourg (19 g).

DESCRIPTION

The average dimensions of the somewhat turtle-shaped mass were 26 x 21 x 10 cm before cutting. One side was smoothly domed, while the opposite side was irregular, mostly flat, but with three larger (3 cm in diameter) and numerous smaller pittings (Preston 1903). While the exterior appearance of the meteorite suggests considerable weathering, with locally 0.5-2 mm thick terrestrial iron oxide deposits, sections through the mass clearly indicate that the corrosion has not removed all of the heat-affected α_2 zones, and a significant amount of fusion crust is also preserved. Reed City must have penetrated the atmosphere in an oriented, stabilized way. The domed side displays 1-3 mm thick α_2 zones and no fusion crust. The opposite side has, in addition to a 1-3 mm thick α_2 zone, numerous small craters, generally 1-5 mm deep, and thus penetrating the α_2 zone. The craters are irregularly filled with dendritic, metallic melts that have been swept from the front side and deposited here on the rear side. Close to the geometric center of the rear side is a large crater, 3 cm across, and 2 cm deep, but filled one half with metallic melts. Micromelted phosphides are present in the exterior 50% of the α_2 zones. The α_2 zone has a hardness of 205±10. Just inside the α_2 zone is a recovered transition zone with hardnesses as low as 145±5. Then follows, at a depth of 5-10 mm, the unaffected interior with hardnesses of 185±8 (hardness curve type II). The general appearance and arrangement of the ablation deposits closely correspond to those of Costilla Peak; very similar deposits are found on Jamestown, Carlton, Seneca Township, Wood's Mountain, Arlington and many other irons.

Etched sections display a blurred, irregular Widmanstätten pattern of stubby, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.80±30 mm. The kamacite of the lamellae is subdivided in polygonal cells, that are 10-50 μ across, and uniformly oriented within the same original α-lamellae. This is indicated by the uniformly oriented sheen, the Neumann bands, and the uniform orientation of the etch pits which, upon prolonged etching, appear as 5-10 μ triangular, square or hexagonal cavities. It is, thus, not a recrystallized or normalized ferrite in the normal metallurgical sense, since such an array would be composed of grains of varying orientations. In the cell boundaries rounded blebs of taenite, 2-5 μ thick, occur, covering about 5% by area. The etch pits occur with a frequency and have a form and size that indicate their close association with former

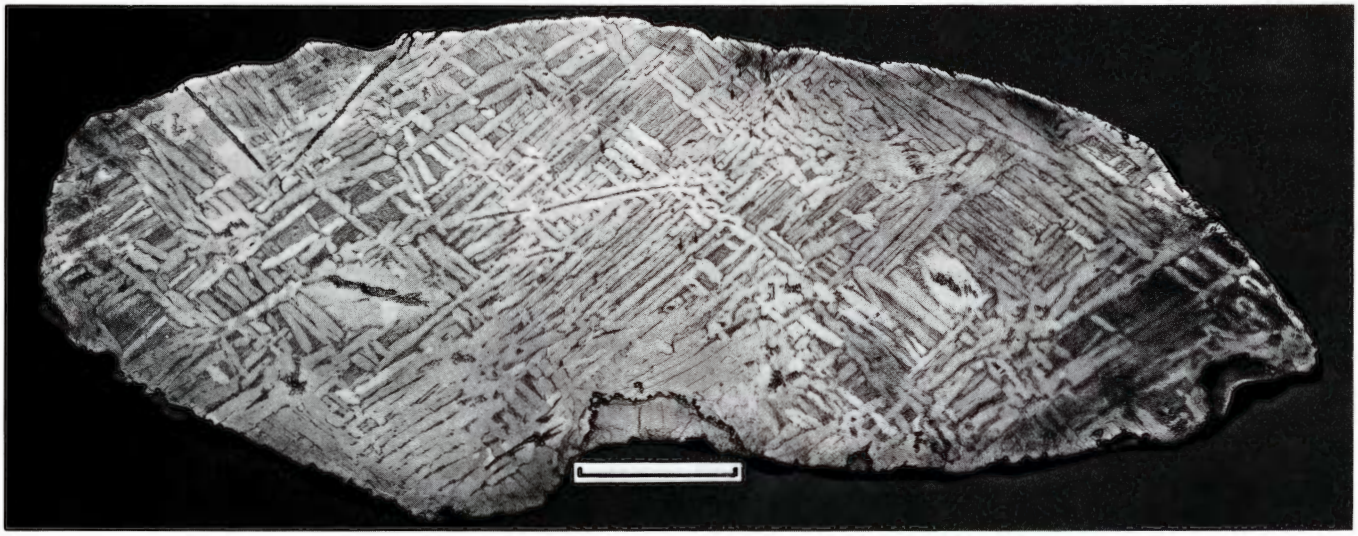

Figure 1428. Reed City (U.S.N.M. no. 1380). Full slice through an anomalous coarse octahedrite. The heat-affected α_2 zone is well-preserved, and fusion crust is present in many places, for instance, as intricate whirlpool basins above the scale bar and at right end. Deep-etched. Scale bar 3 cm. S.I. neg. 36084A.

REED CITY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	7.62	0.50	0.25	135	220		140					
Scott et al. 1973	7.35								22.5	55.5	54	

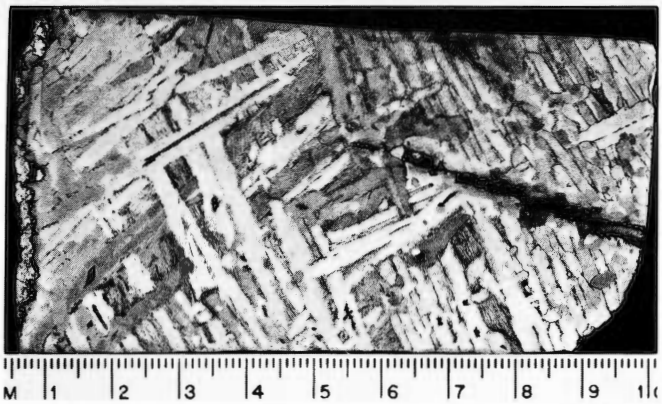

Figure 1429. Reed City (Tempe no. 154a). Fusion crust to the right. The blurred structure resembles that of Seneca Falls and Hammond and is due to shock and associated annealing. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

rhabdites. Apparently the rhabdites were dissolved and the phosphorus reprecipitated in situ in a process which only remotely approached equilibrium conditions. The resulting fine-grained structures are, therefore, very sensitive to corrosion, to plucking by polishing and to laboratory etching reagents. The kamacite phase has a hardness of 185±8.

Taenite ribbons and plessite fields cover about one-third by area, but already a visual inspection shows that the interphase boundaries are very diffuse. At high magnification (10-45x objective) it is seen that the taenite, whether in individual ribbons or in plessite fields, is completely altered. A typical ribbon is decomposed to a 3:1 mixture of kamacite and taenite with a hardness of 175±6. The kamacite grains are 5-10 μ across, and the rounded taenite blebs slightly smaller. The taenite and plessite fields were originally quite rich in 2-50 μ phosphide blebs. A superstructure, comprising hundreds of individual α- and γ-grains, suggests a dendritic arrangement caused by the solidification of a melt occupying the volume of the original taenite ribbon. It is surprising to see how strongly the selective corrosion has attacked the altered taenite and plessite. It appears that the attack mainly follows the ultra fine-grained Fe-Ni-P eutectics, giving rise to characteristic limonitic deposits with concave outlines. Several fine fissures along these phosphide-filled zones have assisted in the transport of terrestrial water deep into the meteorite.

Schreibersite is a rather dominating mineral, occurring as Brezina lamellae and as skeleton crystals up to 40 x 8 x 1 mm in size. It is monocrystalline (HV 885±25) and enveloped in 2-5 mm swathing kamacite. It also occurs as 50-200 μ wide grain boundary precipitates. From point counting, it is estimated that the total phosphorus content is 0.45±0.05%. While the smaller grain boundary crystals have been completely altered to fine-grained mixtures of kamacite, taenite and phosphide, the larger crystals have preserved a nucleus with scalloped edges, surrounded by a 50-200 μ wide fine-grained zone of the same sort as above. This zone is developed in a way that suggests rapid melting and solidification in the same way as the taenite ribbons – except that the phosphide blebs now constitute a significant part of the mixture. The unmelted, remaining schreibersite plates are heavily faulted, and the individual segments are irregularly displaced and separated by a fine-grained ($< 1\ \mu$) material that easily corrodes and may represent some relatively low-melting eutectic. At least locally, it is sulfide-rich.

A 200 μ chromite crystal was observed in the middle of a schreibersite rosette.

Troilite occurs sparsely as 1-20 mm nodules, enveloped in 0.5-1 mm thick schreibersite rims. The troilite is shock-melted and solidified to 2 μ eutectic iron-sulfide mixtures. From some of the troilite melts 1-7 μ wide veinlets have been injected into the surrounding, fissured schreibersite.

Reed City is structurally very unusual. It appears that the original single austenite crystal first underwent a continuous, "normal" cooling period, whereby the Brezina lamellae – and later the coarse Widmanstätten lamellae – developed. The nickel content and the bandwidth would indicate a cooling rate similar to the group I irons. The high phosphorus and low carbon content, and the Ga-Ge-Ir values show, however, that Reed City is anomalous, and, even if it happened to have the same cooling rate as group I, it probably originated in a different place.

A cosmic event, which may have been a shock plus the relaxation heat from the shock compression, altered the troilite and the taenite extensively while the kamacite and the schreibersite were influenced to a lesser extent.

While entering the atmosphere, well developed fusion crusts were deposited upon the protected leeward side.

Individual features of Reed City may be seen in Hammond, Holland's Store, Seneca Falls, Juromenha and others, but as a whole Reed City is unique.

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

251 g part slice (no. 316, 8.5 x 7 x 0.7 cm)
785 g slice (no. 1380, 24.5 x 9 x 0.4 cm)
713 g slice (no. 1380, 23 x 8 x 0.5 cm)
89 g part slice (no. 3012, 5 x 3 x 0.7 cm)

Rembang, Java
6°44′S, 111°22′E

A mass of 10 kg fell near Rembang on August 30, 1919, according to Bedford (1938). He noted that it was a normal octahedrite with heat-affected rim zones; but, unfortunately, a thorough examination has not been published. Reed (1972a) found 8.7% Ni and suggested that Rembang belongs to group IVA. The main mass is possibly in Djakarta; 275 g is in Canberra.

Repeev Khutor, Astrakhan Region, USSR
48°36′N, 45°42′E

Plessitic octahedrite, Opl. Spindle width 0.21±0.05 mm.

Group unknown, but probably anomalous. About 14% Ni and 0.3% P (?).

HISTORY

Since the early reports concerning this fall are, in major respects, conflicting (see references in Hey 1966: 405), I have based the following note on the late, but well-informed, descriptions published by Zavaritskij & Kvasha (1952: 68-70, figures 58-61), Zavaritskij (1954: 68, figures 5 and 6), and Krinov (1960a: figures 79, 80, 106).

A mass of 12.35 kg was observed to fall on August 8, 1933, at about 10 p.m. near Repeev Khutor. The locality lies near Kapustin Yar at the lower Volga, about 100 km east by south of Stalingrad, and has the coordinates given above. Eyewitness observations and examinations of the main mass indicated that the meteorite rotated in its flight and burst into two fragments (Krinov 1960a). However, only one fragment was recovered, and the evidence regarding the second fragment is perhaps not entirely convincing.

COLLECTIONS

The whole mass is in the Academy of Sciences, Moscow; it only displays a minor cut surface.

ANALYSIS

The material has evidently only been subjected to a preliminary analysis; this gave about 10% Ni (Zavaritskij & Kvasha 1952: 70) which is rather low. From the cursory examination below I would expect 14±1% Ni and 0.3±0.1% P.

DESCRIPTION

Repeev Khutor is a beautiful conical mass with a height of 12 cm and a base of 17 x 13 cm. The conical part is very smooth and terminates in a rather acute point which, presumably, was the apex during an oriented flight. The cone is not fully symmetrical, but slightly flattened – as indicated by the dimensions of the base. The base itself must have been the rear surface during flight and now appears as a flat, or slightly concave surface covered with shallow regmaglypts 2.5-5 cm across. The conical surfaces are apparently somewhat folded in over the rear face, but a closer examination indicates that the curved transitional rim must be due to ablational smoothing and not to mechanical deformation by air-drag. In shape and sculptural details Repeev Khutor displays, en miniature, the same as Morito (page 838) and Willamette (page 1311), forms suggesting that these forms are of aerodynamical significance and not just accidental shapes produced by tumbling and fragmentation.

The black fusion crust, with its wrinkles and warts, has been described by Zavaritskij & Kvasha (1952).

A brief examination of the etched section in Moscow indicates that Repeev Khutor is an octahedrite of the rather unusual plessitic type. Discontinuous kamacite lamellae ($\frac{L}{W} \sim 40$) with a width of 0.21±0.05 mm cover about 10% of the section. The lamellae are subdivided into cells by subboundaries and contain a large number of 0.1-0.15 mm wide schreibersite blebs, normally arranged along the central parts of the lamellae.

The matrix between the primary lamellae constitutes a dense plessitic felt, where pointed kamacite spindles, 30-60 μ wide, occur in profusion in the Widmanstätten directions. Numerous, 5-50 μ wide irregular schreibersite

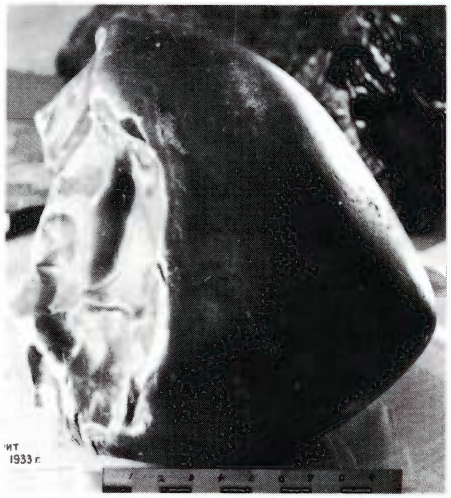

Figure 1430. Repeev Khutor (Moscow). An eminent cone-shaped mass displaying irregular angular regmaglypts on the posterior surface. Ruler is 10 cm.

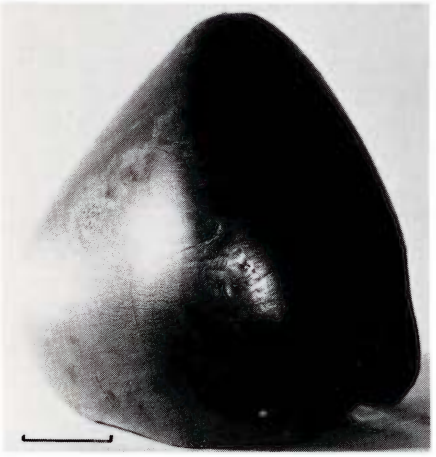

Figure 1431. Repeev Khutor (Moscow). The same as Figure 1430 seen from the apex. Scale bar 3 cm. (Courtesy E.L. Krinov.)

Figure 1432. Repeev Khutor (Moscow). The same as Figure 1430 seen from the regmaglypt-covered surface. The cut and etched surface (top) suggests that Repeev Khutor is a plessitic octahedrite of a rare type. Scale bar 3 cm. (Courtesy E.L. Krinov.)

particles are intercalated in the plessitic felt. On the small deep-etched section no other minerals or details could be disclosed.

Repeev Khutor may provisionally be classified as a plessitic octahedrite. Its basic structure is reminiscent of Carlton, Victoria West and Laurens County, but a reexamination of somewhat larger polished sections than presently available and a full analysis will be required before Repeev Khutor may be considered to be classified and understood. Since it is a rare type and an authentic fall, it is recommended that the mass be restudied.

Rhine Villa, Adelaide, South Australia
34°20′S, 139°10′E

Coarse octahedrite, Og. Bandwidth 1.40±0.25 mm. Neumann bands. HV 207±15.

Group IIIE. 8.61 Ni, 0.54% Co, 0.29% P, 19 ppm Ga, 37 ppm Ge, 0.12 ppm Ir.

HISTORY

A mass of 3,325 g was found in 1900 by H.W. Payne near Rhine Villa. It was discovered on the surface partly covered by soil. It was described by Goyder (1901) who also gave a photograph of the exterior shape and of an etched section. According to Anderson (1913: 64) the locality of find is Rhine Villa about 50 miles northeast of Adelaide, in Hundred of Angas. He stated that the main mass was sent to Germany. Hodge-Smith (1939: 24) noted that the present name of the locality is Cambrai.

The specimens in Washington, Copenhagen, Berlin and Vienna were all purchased from the mineral dealer F. Krantz in Bonn in 1902. These specimens, and most others known to the author, are parallel, full slices through the small mass, and they have in common an undulating, striated surface as if the sections were cut with a wire saw, a technique which was applied in Krantz's workshop. Therefore, there are heavy indications that Krantz acquired the main mass shortly after it had been described by Goyder and that he cut and distributed the whole mass.

COLLECTIONS

Bonn (218 g), London (185 g), Vienna (183 g), Budapest (181 g), Paris (175 g), Chicago (155 g), Prague (131 g), Copenhagen (125 g), Berlin (123 g), Washington (115 g), Adelaide (85 g), Vatican (67 g), Strasbourg (28 g). These specimens add up to 1.70 kg. If we allow for a loss of about 15%, or 500 g, in cutting and analyzing, there should still remain about 1 kg specimens in "unregistered" collections, probably in Germany.

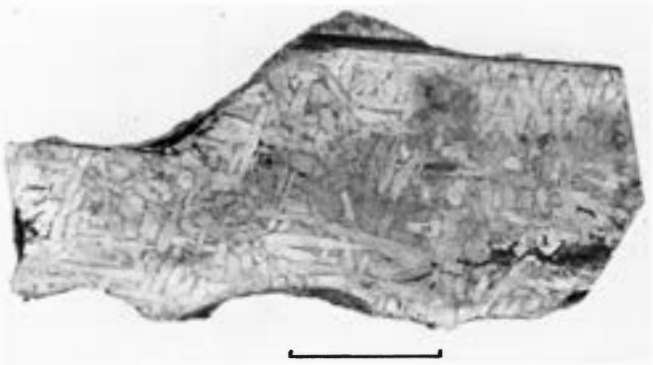

Figure 1433. Rhine Villa (Copenhagen no. 1902, 1060). A coarse octahedrite with bulky kamacite lamellae belonging to group IIIE. Deep-etched. Scale bar 20 mm.

DESCRIPTION

The mass had the shape of a rectangular box with the average dimensions 12 x 10 x 5 cm. The cut specimens exhibit a weathered surface, covered with 0.1 mm thick, terrestrial oxides, and locally marred by heavy hammer and chisel blows. No artificial reheating has taken place, however. The fusion crust and the heat-affected α_2 zone have been removed by a long terrestrial exposure.

Etched sections display a coarse Widmanstätten structure of swollen, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.40±0.25 mm. The kamacite has conspicuous subboundaries decorated with 1-10 μ phosphides which often assume rhabdite shapes. Neumann bands are common. The hardness is 207±15; it varies particularly with the number and size of the phosphide precipitates present in the kamacite.

Taenite and plessite cover about 25% by area, especially as an acicular plessite type with 1-5 μ wide α-needles. A typical, complete plessite field will have a narrow, 10 μ

Figure 1434. Rhine Villa (Copenhagen no. 1902, 1060). The swollen kamacite lamellae are well displayed in this figure. Several skeleton crystals of schreibersite appear black. Etched. Scale bar 3 mm.

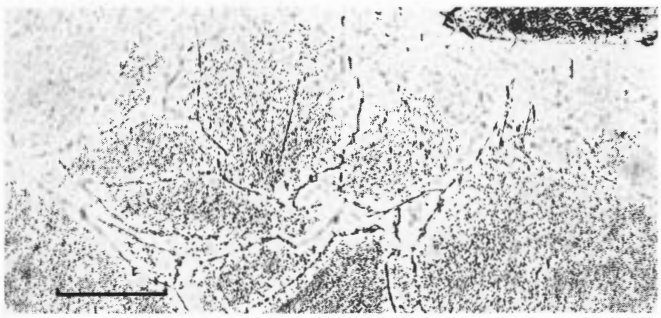

Figure 1435. Rhine Villa (Copenhagen no. 1902, 1060). The kamacite is rich in subboundaries decorated with fine phosphides. Etched. Scale bar 300 μ.

wide rim of yellow taenite (HV 300±20), followed by a light-etching, martensitic zone (HV 425±25). Then comes a brown-etching martensite (HV 350±25) which merges with duplex $\alpha + \gamma$ regions and with the acicular plessite (HV 235±25).

About one-third of the plessite fields display irregular, palmate carbide crystals similar to the carbide roses described in, e.g., Staunton, Carlton, Colfax and Coopertown. The carbide roses are 100-800 μ across and contain minute inclusions of taenite, kamacite and schreibersite. The hardness is 890-975; this is lower than the hardness of massive cohenite found in group I irons, the reason partly being the small size and the impurity of the crystals, also, partly a higher nickel content of the carbide in Rhine Villa. The carbide roses are isotropic and identical to the $M_{23}C_6$-carbide, haxonite, recently described by Scott (1971).

Schreibersite is present as scattered skeleton crystals, about 0.5-2 mm in size. They are enveloped by 0.8-1.5 mm wide rims of swathing kamacite. An unusually large number of the schreibersite crystals have nucleated and grown upon preexisting troilite, daubreelite and chromite cyrstals, generally 50-500 μ across. Schreibersite is further common as 25-100 μ wide grain boundary veinlets and as 2-20 μ blebs inside the plessite. Rhabdites, 1-3 μ across, are common. The hardness of the schreibersite is 925±25.

Troilite is present as nodules that range in size from 30 μ to 1 mm and display segregated, parallel daubreelite bars. Common is an extremely fine exsolution product of alternating, 1 μ thick lamellae of troilite and daubreelite. While these lamellated textures have not responded to shock, the more massive troilite nodules have been shock-melted and solidified to 1-10 μ aggregates. Part of the surrounding metal has been dissolved and incorporated in fine-grained sulfide-metal eutectics, and the daubreelite and schreibersite have been partly shattered and dispersed in the melt as 1-10 μ fragments.

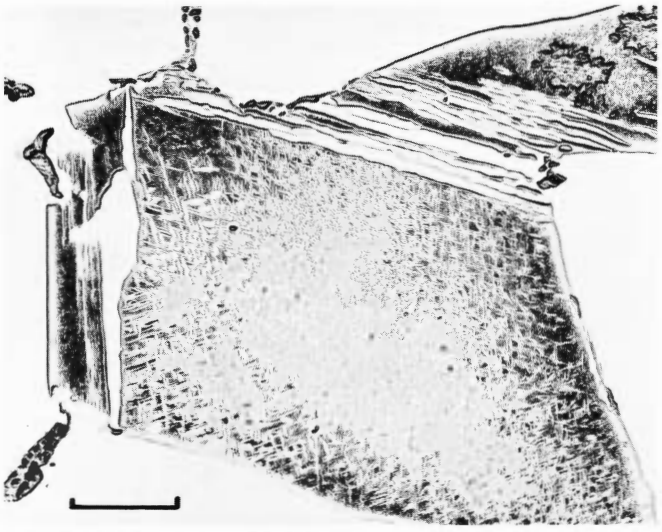

Figure 1436. Rhine Villa. Detail of Figure 1434. Acicular plessite field with schreibersite bodies along left edge and with haxonite (in relief) in the interior (top right). Etched. Scale bar 500 μ.

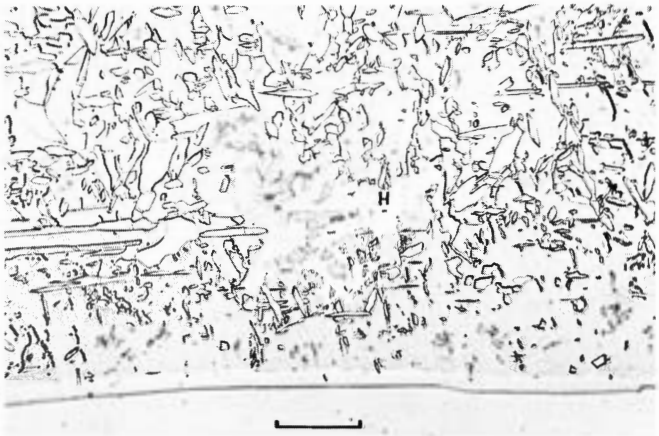

Figure 1437. Rhine Villa. Detail of Figure 1436. Haxonite (H) inside an acicular plessite field. Etched. Scale bar 30 μ.

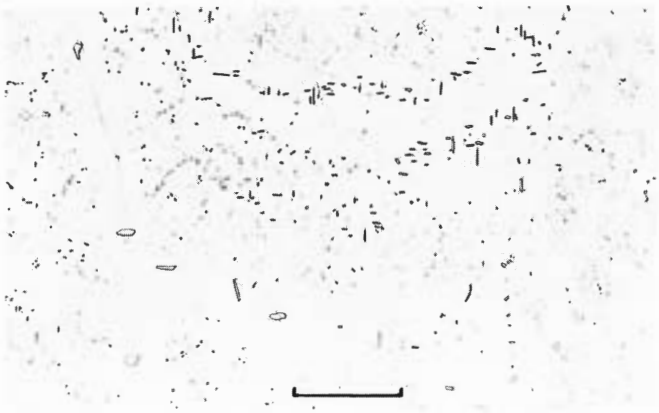

Figure 1438. Rhine Villa (Copenhagen no. 1902, 1060). Grain boundary to the left with irregular phosphides. Several subboundaries with minute oriented phosphide precipitates. Etched. Scale bar 100 μ.

Chromite is present as euhedric crystals, 0.1-1 mm in size, normally enveloped in troilite-daubreelite and/or schreibersite. Its hardness is above 1000, but could not be measured precisely because it fractured under a 100 g load.

RHINE VILLA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Smales et al. 1967						63	120	1	19.1	38		
Buchwald 1967, unpubl.	8.58	0.54	0.29				140					
Scott et al. 1973	8.63								18.8	36.3	0.12	

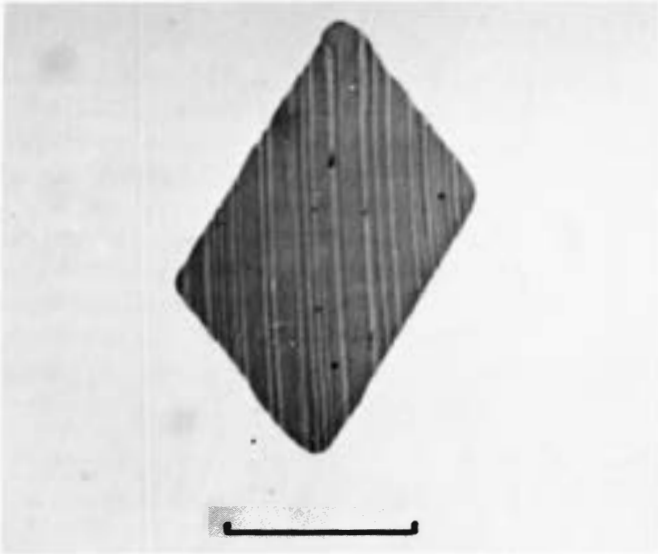

Figure 1439. Rhine Villa (Copenhagen no. 1902, 1060). A rhomboid sulfide inclusion composed of alternating troilite (light) and daubreelite lamellae. Slightly bent. Polished. Oil immersion. Scale bar 20 μ.

Rhine Villa is an unusual coarse octahedrite. It is unrelated to Toluca and other group I irons of this bandwidth (1.4 mm), but related to Willow Creek, Paneth's Iron, Staunton, Coopertown and similar group IIIE meteorites. A particular noteworthy feature which Staunton, Coopertown, and Rhine Villa have in common is the carbide constituent of the plessite fields, and the short, spindle-shaped kamacite lamellae.

Specimen in the U.S. National Museum in Washington:
114 g slice (no. 272, 8 x 4 x 0.5 cm)

Richa, Nigeria

Approximately 10°N, 9°E

Medium octahedrite, Om. Bandwidth 0.55±0.08 mm. Neumann bands. HV 200±25.

Anomalous. 9.4% Ni, 0.66% Co, about 0.3% P, 78 ppm Ga, 82 ppm Ge, 17 ppm Ir.

HISTORY

According to Hey (1966: 406), this mass of approximately 1.5 kg was found before 1960 near the Daudy mining camp. This was situated between Bargesh and Richa in the southwestern corner of the Jos plateau, but the coordinates could not be given with more precision than quoted above. The mass was acquired by the Geological Survey of Nigeria, and a 390 g endpiece was presented to the British Museum in 1966. This was briefly described and analyzed by Easton, who classified it as a medium octahedrite, anomalous with respect to the Ni-Ga-Ge ratios (Hey 1966).

COLLECTIONS

Geological Survey of Nigeria, Kaduna (about 1 kg), London (390 g).

DESCRIPTION

The mass appears to have been of an ovoidal shape with the approximate dimensions of 10 x 7.5 x 5 cm and a weight of 1.5 kg. The sample in London is a 36 mm high endpiece with a cut section of 72 x 46 mm. It has undergone a peculiar oxidative weathering, resulting in the prominent standing out of the kamacite plates of the structure – surprisingly enough not the taenite – over the whole surface. Fusion crust and heat-affected α_2 zones are not preserved.

Etched sections reveal a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.55±0.08 mm. There are numerous subboundaries decorated with 0.5 μ phosphides, and Neumann bands are common. The kamacite has a rather variable hardness, 200±25, evidently due to small variations in the degree of cosmic deformation of the metal.

Taenite and plessite cover about 40% by area. The larger fields show comb and net plessitic development of the interiors, while the smaller, massive wedges display martensitic-bainitic and unresolvable duplex interiors. A typical field will show a tarnished taenite rim (HV 310±20) followed by a transition zone, etching indistinctly martensitic (HV 370±30). Next comes a brown-etching martensitic-bainitic zone, with individual platelets parallel to the bulk Widmanstätten structure (HV 340±30), followed by duplex, unresolvable $\alpha + \gamma$ structures (HV 290±20). The central portions are easily resolvable $\alpha + \gamma$ structures with 2-10 μ γ-particles and hardnesses only slightly above those of the adjacent kamacite lamellae. Annealing effects are not present.

Schreibersite occurs as cuneiform skeleton crystals in sizes up to 6 x 0.5 mm. More typical are the 1.5 x 0.5 mm bodies, normally aligned centrally in some of the kamacite lamellae. The schreibersite is monocrystalline but brecciated, and individual segments may be shear-displaced 5-10 μ. Schreibersite is also common as 10-30 μ grain boundary precipitates and as 2-20 μ particles substituting

Figure 1440. Richa (Brit. Mus. no. 1966, 55). Medium octahedrite of group IID. The mass is severely weathered, and the duplex plessite fields and grain boundaries are particularly attacked (black). The kamacite lamellae, therefore, protrude above the general surface in a most peculiar way. Etched. Scale bar 3 mm.