continuous taenite lamellae are now subdivided into segments, each 50-400 μ across, and thus each comprising a large number of α and γ units. The same texture is present in, e.g., Reed City, but the reason for it is not clear. It seems, however, to be another indication of severe shock-reheating.

Schreibersite occurs as imperfect Brezina lamellae parallel to $(110)_\gamma$ and attains sizes of 12 x 0.5 mm (HV 870±20). Small crystals, e.g., 2 x 0.3 mm in size, are common centrally in some kamacite lamellae. Schreibersite also occurs as 20-100 μ wide grain boundary veinlets and as 5-50 μ blebs inside the plessite fields, but it is often difficult to identify because of the alterations. Almost all schreibersite is severely brecciated and has apparently been on the verge of remelting. The rims are scalloped, and one or two rows of amoebae-like 5-10 μ taenite particles and angular phosphide particles are situated in a 10-50 μ wide zone around them. The schreibersite interiors display fine ($< 1\ \mu$) exsolution products along fracture lines, and incipient recrystallization to 5-15 μ grains has occurred adjacent to shock-melted troilite.

Troilite was seen on the section in Yale as a large nodule, 17 mm in diameter, with a 0.1 mm schreibersite rim. Troilite also occurs as 0.1-1 mm blebs associated with the schreibersite lamellae. It is shock-melted and has penetrated into the fissured neighbor crystals as 5-15 μ wide veins which are now severely corroded. The shock-melted pools are fine eutectic aggregates of 1-5 μ metal (now often corroded) and sulfides in which phosphide particles are dispersed. These are rounded globules, 5-10 μ across, indicating that the reheating was more severe than in many other meteorites which display only angular fragments of schreibersite.

Shepard (1853b) reported "two very brilliant, black octahedral crystals, whose weight together was only 0.005 of a grain" (i.e., 0.3 milligram). He had isolated them from the insoluble matter in a wet chemical analysis and identified them as chromite.

Silicates, graphite and carbides were not detected.

As noted above, the corrosion of the surface is only slight. However, due to severe cosmic alteration the mass was evidently extensively fissured on a microscale. Later when the mass became exposed to the terrestrial environment, ground waters penetrated the microcracked schreibersite crystals and along Widmanstätten boundaries. In addition, the α-phase became selectively converted to limonite in many duplex structures, and the cell boundaries of the taenite lamellae and the grain boundaries of the recrystallized kamacite were attacked.

Seneca Falls is a medium octahedrite of a normal type, such as Lenarto, which, as the result of severe shock and associated (?) reheating, recrystallized and spheroidized to a peculiar structure. Somewhat similar structures are present in Maria Elena, Reed City and Hammond.

Chemically, it appears that the mass belongs to group IIIA. If so, the meteorites Bartlett, Lenarto, Ruff's Mountain, Seneca Falls and Juromenha – which are genetically related – display a series of irons with increasing stages of secondary metamorphosis due to cosmic events.

[J.T. Wasson (personal communication 1973): Group IIIA with about 8.25% Ni, 21.1 ppm Ga, 42.8 ppm Ge and 0.25 ppm Ir].

Seneca Township, Michigan, U.S.A.

41°48′N, 84°11′W; 240 m

Fine octahedrite, Of. Bandwidth 0.28±0.05 mm. Annealed ϵ-structure. HV 210±10.

Group IVA. 8.52% Ni, about 0.08% P, 2.17 ppm Ga, 0.124 ppm Ge, 1.8 ppm Ir.

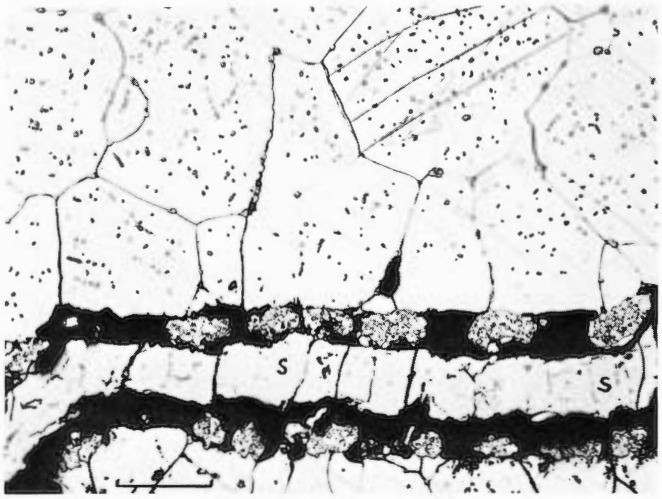

Figure 1586. Seneca Falls (Chicago no. 60). Schreibersite lamella (S) with decomposed duplex rims from cosmic annealing. The aggregates are extremely vulnerable to terrestrial corrosion and difficult to polish without pitting (black). Neumann bands in one of the recrystallized grains above. Etched. Scale bar 100 μ.

Figure 1587. Seneca Township (U.S.N.M. no. 1325). The rear side of the 11.5 kg meteorite. Although the turtle-shaped mass appears severely weathered, the exterior form is in almost every respect a result of ablative sculpturing and not a result of subsequent corrosion. Scale bar approximately 4 cm. S.I. neg. 9464B.

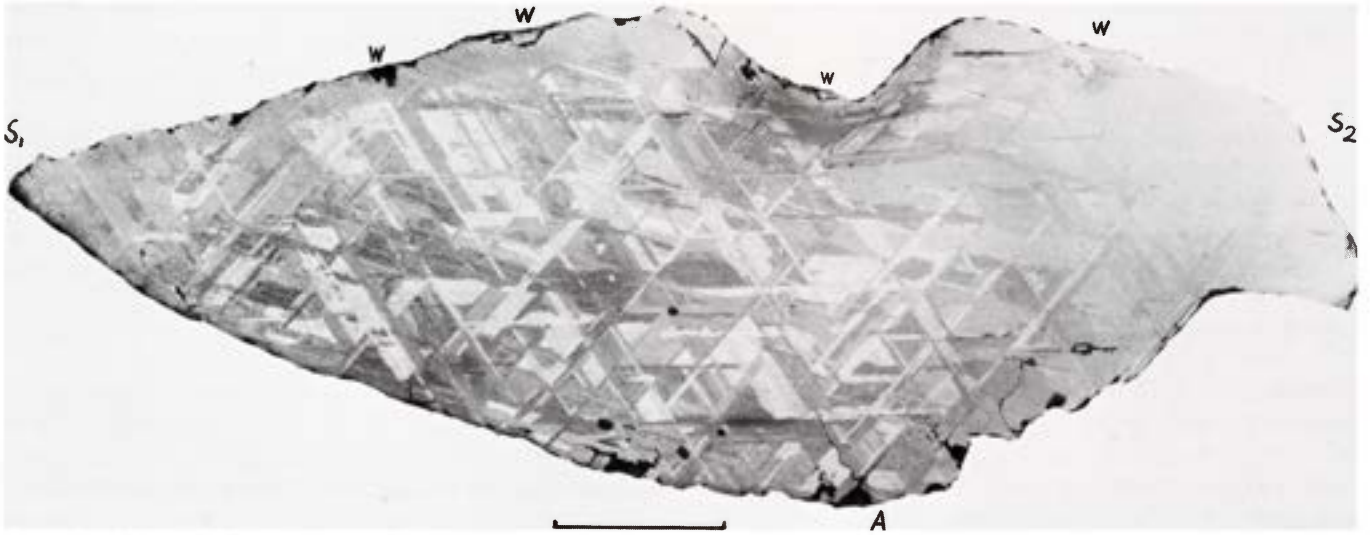

Figure 1588. Seneca Township. Section S_1-S_2 through Figure 1587 including the bowl-shaped cavity. A wide heat-affected α_2 zone is visible along the top side; a narrow one, along the opposite side. Apex during flight approximately at A. At W, whirlpool melts. Deep-etched. Scale bar 30 mm. See also Figure 60.

HISTORY

A mass of 11.5 kg was found by L.A. Robin in 1923 while he was cultivating corn. The locality is in Section 4, Seneca Township, Lenawee County, and it has the coordinates given above. The mass was briefly mentioned by Merrill (1927b) who presented a photograph of the exterior. Perry, who had acquired the mass in 1923, later published a thorough description (1939d) in which he showed numerous, interesting photomicrographs of the fusion crust. Some of these figures were reprinted by Perry (1944) in his monograph on meteorites. He firmly believed that the mass had been observed to fall in 1903, and he quoted an eyewitness in support. As discussed below, a recent fall date is really out of the question considering the significant corrosion present. Perry donated the mass to the Smithsonian Institution in 1939.

COLLECTIONS

Washington (9.33 kg), New York (190 g), Ann Arbor (184 g), Chicago (181 g), Harvard (165 g), Tempe (121 g), London (85 g).

DESCRIPTION

The mass is roughly turtle-shaped with the average dimensions of 24 x 18 x 8 cm. Several sections through the mass suggest an aerodynamic wing profile as it is still better seen upon, e.g., Jamestown and Wood's Mountain. One side of the mass has no regmaglypts and no whirlpool structures, and the heat-affected α_2 zone is 1.8-2.2 mm thick. The opposite side exhibits several regmaglypts, 10-20 mm in diameter and 2-6 mm deep. It also shows a bowl-shaped depression, 6 x 5 cm in aperture and 2 cm deep. In numerous places the surface on this side is indented with melted pools of metal, which are typically 2-5 mm in diameter and penetrate to a similar depth. Finally, the heat-affected α_2 zone under this surface is anywhere from 4-10 mm thick, reaching the highest values under the most convex parts of the surface. These observations all indicate that Seneca Township was pretty well stabilized during the atmospheric flight, having the highest ablation rates upon the slanting, forward-oriented, flat surface. Although it is difficult to prove, it is suggested that the bowl-shaped

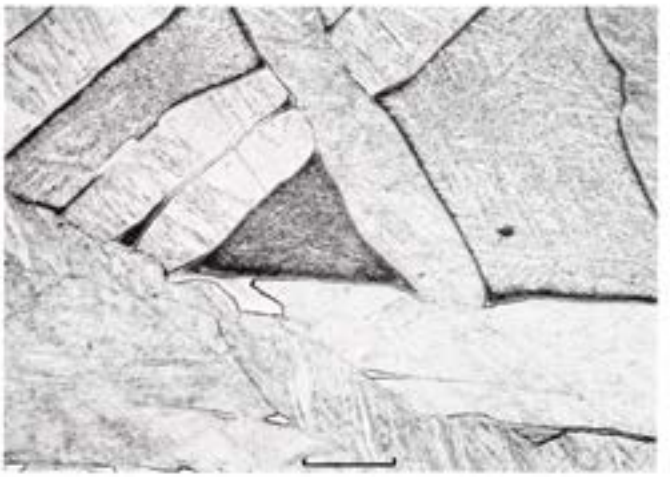

Figure 1589. Seneca Township (U.S.N.M. no. 1325). An annealed fine octahedrite of group IVA. Etched. Scale bar 200 μ. (Perry 1950: volume 4.)

SENECA TOWNSHIP – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson & Kimberlin 1967	8.52								2.17	0.124	1.8	

cavity was initiated in the high atmosphere as a result of a rupture on the rear side of the meteorite which detached a fragment along fissured Widmanstätten planes. Later ablation smoothed the walls of the cavity.

Another possibility is that the cavity was gouged out opposite the apex by turbulent eddies during the atmospheric flight. Compare Sacramento Mountains, Tamentit and others.

The whirlpools consist of rapidly solidified, dendritic metal with an armspacing of about 8 μ. They frequently display concentric or distorted concentric structures, and they often form coalescing aggregates of droplets. The microhardness is 260±25. It is interesting to note that the unmelted, meteoritic matrix below the whirlpools may be severely compressed; a possible explanation is that the fused droplets hit the rear face with a considerable force and were able to plastically deform the metal. It must be remembered that the rim layer, at the time of deposition, had been heated to above 800° C; and the metal may be readily deformed at these temperatures.

The mass is weathered so much that it is difficult to distinguish the original fusion crust; all of the black magnetite-wüstite crust has disappeared, and terrestrial oxides have also modified the whirlpool melts. Generally the surface is covered with 0.1-1 mm thick layers of limonite. It is estimated that, on the average, 0.4 mm has been lost during terrestrial exposure; and such a loss requires considerably more time than the 20 years between the alleged date of fall and the recovery in 1923. Consequently, the terrestrial age is probably thousands of years.

Etched sections display a fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 30$) kamacite bands with a width of 0.28±0.05 mm. The kamacite is markedly hatched at low magnification and appears to be a shock-hardened ϵ-structure; high magnification reveals, however, that the structure is two-phased with numerous fine taenite beads, about 0.5 μ across, lining the ragged structures. The microhardness is 210±10, which is a very low value for the ϵ-structure. It may best be explained as a shocked and partially annealed structure.

Taenite and plessite cover about 50% by area, especially in the shape of open-meshed, comb and net plessite. The typical group IVA plessite fields of finger and cellular forms are also common. A well developed field will have a narrow, yellow taenite rim (HV 265) followed by a martensitic transition zone (HV 365±35). Then follow duplex, poorly resolvable $\alpha + \gamma$ areas (HV 250±25) and finally open-meshed finger plessite (HV 210±10).

Schreibersite is absent, except for a rare 2-5 μ bleb in a grain boundary. There is, however, a significant amount of phosphorus in solid solution in several of the taenite ribbons along the plessite fields. This may be readily seen in the heat-affected α_2 zone where the phosphorus-enriched

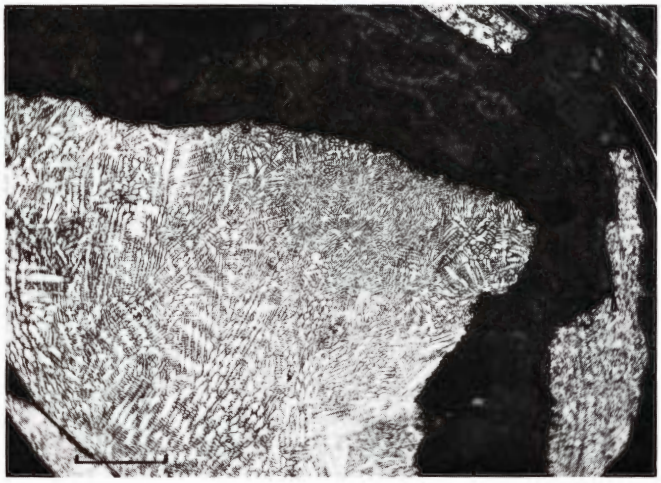

Figure 1591. Seneca Township (U.S.N.M. no. 1325). Detail of one of the whirlpool structures, W, in Figure 1588. Fused oxides alternate with fused metal, and terrestrial corrosion has further oxidized the confusing structures. Etched. Scale bar 200 μ. (Perry 1944: plate 70.)

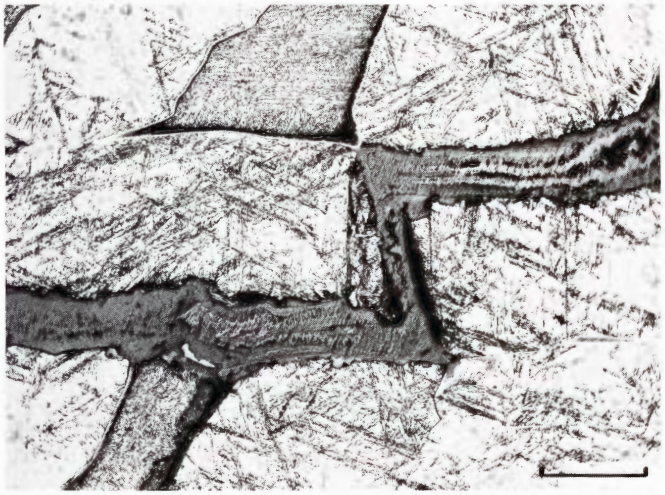

Figure 1590. Seneca Township (U.S.N.M. no. 1325). Shock-hatched and annealed kamacite. Deep fissures which are recemented by terrestrial limonite. Etched. Scale bar 200 μ. (Perry 1950: volume 4.)

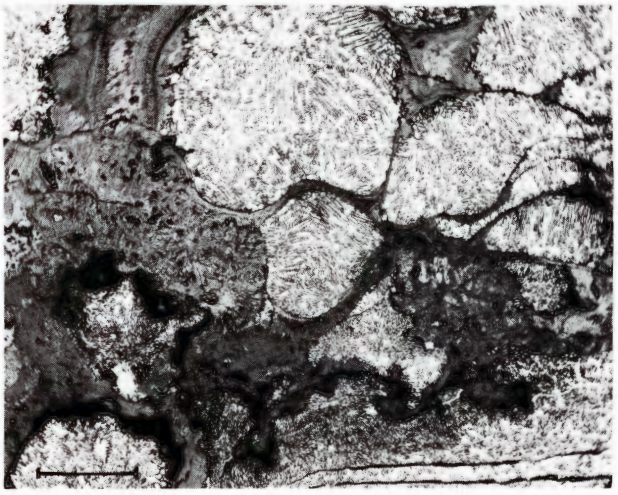

Figure 1592. Seneca Township (U.S.N.M. no. 1325). Detail of Figure 60. Dendritic droplets of metal are separated by fused oxides and terrestrial corrosion products. Etched. Scale bar 200 μ. (Perry 1944: plate 70.)

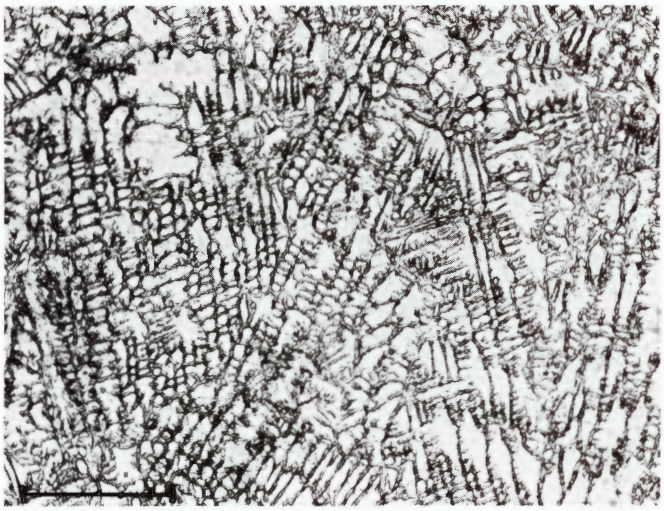

Figure 1593. Seneca Township (U.S.N.M. no. 1325). Detail of Figure 1591 showing the dendritic metal. The dendrites have, upon cooling, transformed to unequilibrated fine-grained α_2. Etched. Scale bar 100 μ. (Perry 1944: plate 70.)

parts are the first to melt. The bulk phosphorus content is estimated to be 0.05-0.1%.

Troilite is present as scattered, lenticular to rhombic inclusions, which normally are 0.1-2 mm in size. They are shock-melted and solidified to fine-grained eutectics which include metal. Fragmented daubreelite particles are dispersed through the melts. The melts are frequently injected many millimeters, perhaps centimeters, into the adjacent, fissured metallic matrix. The fissures particularly follow the Widmanstätten planes; and considerable plastic deformation is present along them; and they frequently taper out and continue as narrow shear-deformed zones. The deformation and the fissures probably date from a preatmospheric shock event. Since the cracks were only partly filled with melts, they were readily available to terrestrial ground water which explains why corrosion products may be found in the deep interior of the mass, while the α_2 zone is still well-preserved. Corrosion has unfortunately destroyed many of the details.

Seneca Township is a shocked and annealed, fine octahedrite which is closely related to Muonionalusta, Bristol, Altonah and Jamestown, all belonging to the phosphorus-poor end of the group IVA meteorites.

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

8,895 g main mass (no. 1325, 19 x 14 x 8 cm with cut at both ends)
337 g endpiece (no. 1325, 11 x 4.5 x 3 cm)
72 g part slice (no. 1325, 7 x 4 x 0.5 cm)
28 g part slices (no. 786, small sections)

Senegal. See Siratik

Serrania de Varas, Antofagasta, Chile
24°33′S, 69°4′W

Fine Octahedrite, Of. Bandwidth 0.31±0.04 mm. Recrystallized. HV 167±10.

Group IVA. 8.00% Ni, 0.05% P, 2.16 ppm Ga, 0.13 ppm Ge, 1.8 ppm Ir.

HISTORY

A mass weighing 1.5 kg was found about 1875 by a miner while he was searching for minerals near Serrania de Varas. It was acquired by George Hicks, one of the earliest explorers of the northern Atacama Desert, from whom it was purchased in 1879 by the British Museum. The spot was marked by Mr. Hicks on his map corresponding to the coordinates given above (Fletcher 1889: 230, 258). Fletcher gave a description of the mass and an analysis. Brezina (1896: 269) added that the heat-affected zone was broad and well developed, a fact which was later illustrated and discussed by Brezina & Cohen (1886-1906: plate 39). Cohen (1905: 365) gave a review under the entry "Varas", a synonym which has been used to a certain extent.

Figure 1594. Serrania de Varas (Brit. Mus. no. 53323). A recrystallized fine octahedrite of group IVA. To the right, the heat-affected α_2 zone which stands in sharp contrast to the unaffected interior. Prominent cracks, e.g., vertically to the left, follow the Widmanstätten grain boundaries. Etched. Scale bar 3 mm.

SERRANIA DE VARAS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Fletcher 1889	8.00	0.44	0.05				trace					
Schaudy et al. 1972	8.00								2.16	0.13	1.8	

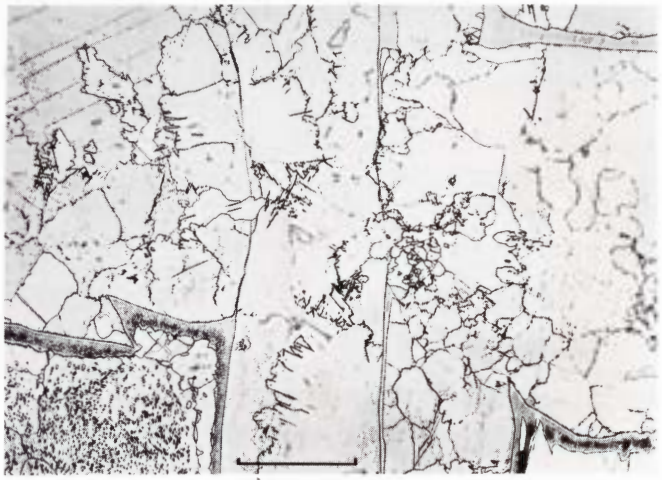

Figure 1595. Serrania de Varas (Brit. Mus. no. 53323). Kamacite lamellae showing irregular and imperfect recrystallization. Indistinct remnant Neumann bands in several places. Etched. Scale bar 200 μ.

jagged boundary

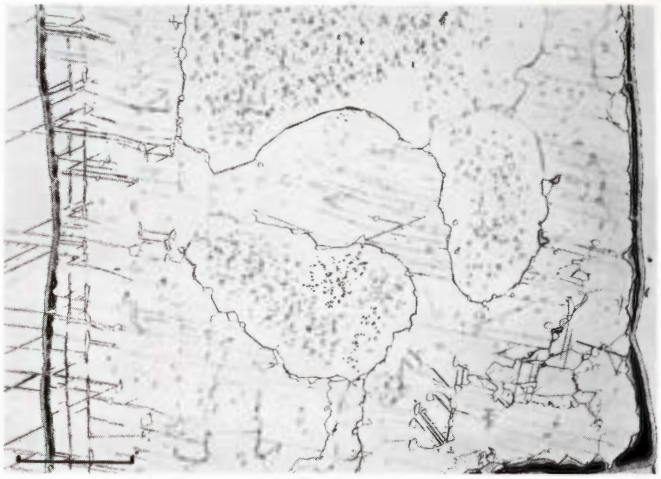

Figure 1596. Serrania de Varas (Brit. Mus. no. 53323). An annealed cellular plessite field with slightly spheroidized taenite particles. Phosphides are absent. Etched. Scale bar 200 μ.

COLLECTIONS

London (1,474 g), Vienna (14 g), Chicago (10 g). In this study, the Chicago specimen No. 950 of 31 g, labeled Serrania de Varas (Farrington 1916: 297; Horback & Olsen 1965: 294), was found to be a primitive, heterogeneous cast iron with ledeburite. The origin of the sample is uncertain.

DESCRIPTION

According to Fletcher (1889), the mass is an entire monolith (9 x 8 x 5 cm), one side being only slightly convex while the other is nearly an obtuse cone.

> "The base of the cone has an average diameter of 90 mm and approximates to a triangle with convex sides and rounded corners. The conical side is covered with shallow pittings of small diameter; the other side is more smooth. None of the original crust was found to be present, and the rust coating is thin. No enclosures were passed through in making the section, which is bounded by an ellipse with axes of 57 mm and 30 mm in length."

In the present study, a full slice through one end of the mass was kindly placed at my disposal by the British Museum (No. 53323, 57 x 30 x 1.5 mm, 24 g). The etched section shows that Serrania de Varas is a fine octahedrite with straight, long ($\frac{L}{W} \sim 40$) kamacite lamellae with a width of 0.31±0.04 mm. The kamacite is of a rather heterogeneous development. About half is normal, with a few indistinct subboundaries and numerous narrow, somewhat decorated Neumann bands (HV 165±8). The other half, irregularly intergrown with the normal kamacite, is recrystallized to grain aggregates with serrated boundaries, heavily decorated with less than 0.5 μ precipitates (HV 170±8). The unequilibrated recrystallized grains, which are independently oriented, may be anywhere from 5 μ to 300 μ in diameter, but it is characteristic that their boundaries are jagged and very distinct from the recrystallized grains in the related meteorite, Social Circle.

The recrystallized grains contain two generations of Neumann bands. The first generation is identical to the Neumann bands of the normal kamacite; these bands ought to have disappeared by the recrystallization, but they persist as ghost-lines because they were already decorated with small precipitates. The second generation of Neumann bands is late and probably associated with the atmospheric deceleration and fissuring, as described below.

Taenite and plessite cover 40 to 50% by area. Net plessite and cellular plessite are common, often as 2 x 1 mm fields, while the smaller fields display finger plessite or duplex, black-etching interiors. The taenite rims and lamellae stain cloudy-brown upon etching; their relatively low hardness (HV 255±15) suggests that they have become somewhat annealed by reheating. The same is indicated by the absence of clear martensitic-bainitic zones; they are annealed and transformed to almost unresolvable duplex $\alpha + \gamma$ structures.

Schreibersite and rhabdites were not observed in any form, which is in line with the low bulk phosphorus content. Troilite was not detected but may be present in other sections – possibly as shock-melted aggregates.

A few 20-60 μ subhedral daubreelite grains occur scattered in the kamacite. Other meteoritic minerals were not present.

Locally, heavy shear-displacements are visible. The taenite and plessite fields are faulted, and corresponding parts are displaced 10-50 μ relative to each other. Along the 10-100 μ wide displacement zones, which can be followed for several centimeters, recrystallization has led to very fine-grained kamacite only about 10 μ across. In other places the association between shear-deformation and recrystallization is less evident but nevertheless perceptible. Wherever the deformation strain was large, the resulting grain size decreased upon recrystallization, and vice versa. Where the deformation strain remained below the critical

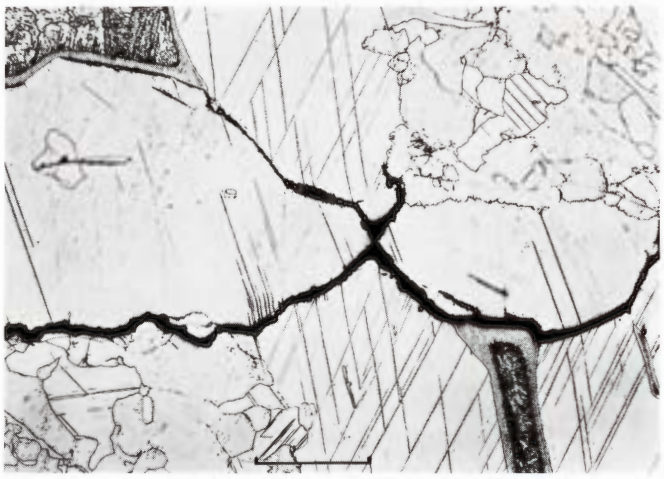

Figure 1597. Serrania de Varas (Brit. Mus. no. 53323). The cracks follow the Widmanstätten and the recrystallized grain boundaries indicating that they are of post-recrystallization age. Etched. Scale bar 200 μ.

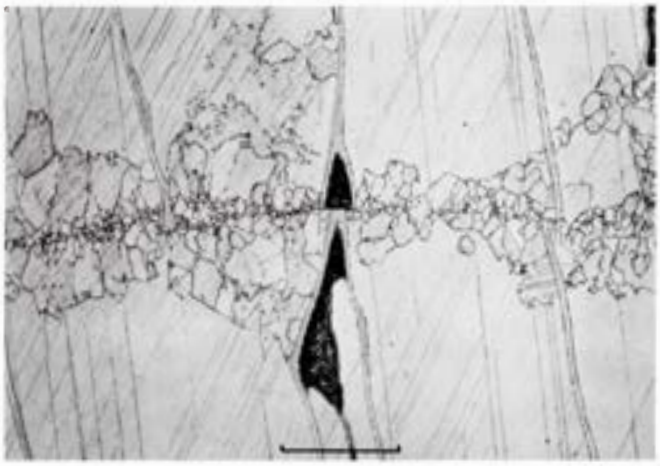

Figure 1598. Serrania de Varas (Brit. Mus. no. 53323). A narrow but distinct shear zone offsets kamacite and taenite. Imperfect recrystallization has occurred along the shear plane, producing finest grains where the strain was highest. Etched. Scale bar 200 μ.

limit, no recrystallization occurred; however, recovery led to hardnesses of the same low level as in the recrystallized areas.

Along the periphery of the mass there is a well developed α_2 zone from the atmospheric flight. Its width varies from less than 0.1 mm to about 5 mm, the larger widths occurring at the acute ends of the ellipse. The α_2 crystallites are 10-50 μ across and etch in softer contours than the recrystallized, decorated grains of the interior. Since the outlines of many of the recrystallized grains and many of the Neumann bands still survive in the α_2 zone, due to the presence of grain boundary precipitates, it takes more than a casual examination to determine exactly the limit of the α_2 zone. Its hardness is 185±15 (hardness curve type II).

Quite locally, remnants of the metallic fusion crust may be detected as successive layers of metallic sheets up to 300 μ in total thickness. The dendrites are 5-15 μ thick and have rapidly grown perpendicular to the cold substrate. No fused oxide layers are present any more; instead, limonitic shales cover the exterior irregularly as 0.1-0.5 mm thick layers. On the average Serrania de Varas has lost less than 0.5 mm by corrosion and is thus relatively well-preserved.

No indications of artificial reheating or hammering are present so the observed recrystallization and low hardness values must be genuinely cosmic in origin.

Five conspicuous cracks are to be seen on the section, all following some α - γ Widmanstätten boundary. The longest extend to the inner edge of the heat-affected α_2 zone but only occasionally continue to the surface. The fissures are narrow, 1-15 μ, and now are partially filled with terrestrial corrosion products. They normally progress through the unrecrystallized kamacite; but when they meet recrystallized portions, they branch and follow the grain boundaries. They are thus of post-recrystallization age.

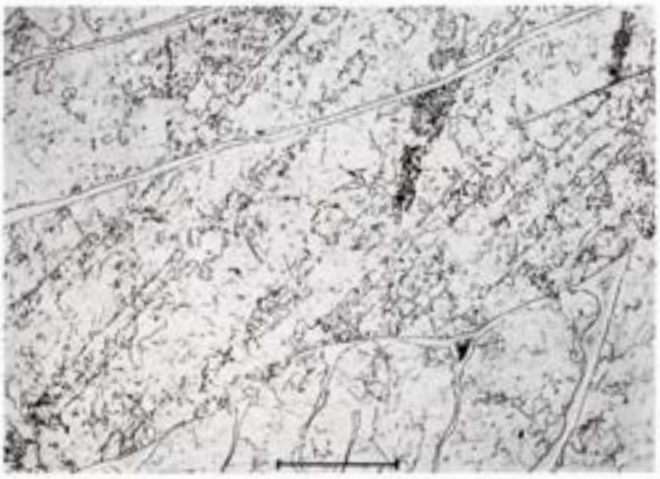

Figure 1599. Serrania de Varas (Brit. Mus. no. 53323). The heat-affected α_2 zone. Traces of Neumann bands remain, probably because the bands were decorated with very fine taenite particles. Etched. Scale bar 200 μ.

The presence of fissures which are confined to an interior zone below the α_2 zone indicates late development that is associated with the atmospheric flight. The most plausible explanation is that the fissures are due to tension in the interior which is caused by tensile forces set up in the exterior part of the mass. Such a situation may be assumed to be quite normal for an iron meteorite penetrating the atmosphere. It will, however, only have a chance to lead to fissuring when the rim zone constitutes a significant proportion of the whole mass, as is the case of Serrania de Varas.

The transformation from α to γ and back to unequilibrated α_2 in a 1-5 mm thick outer shell was associated with a volume increase. Consequently, the interior nucleus, 25-50 mm across, became subjected to triaxial tension during the latter part of the flight. The tensile stress caused fractures in the weakest part of the interior, i.e., in

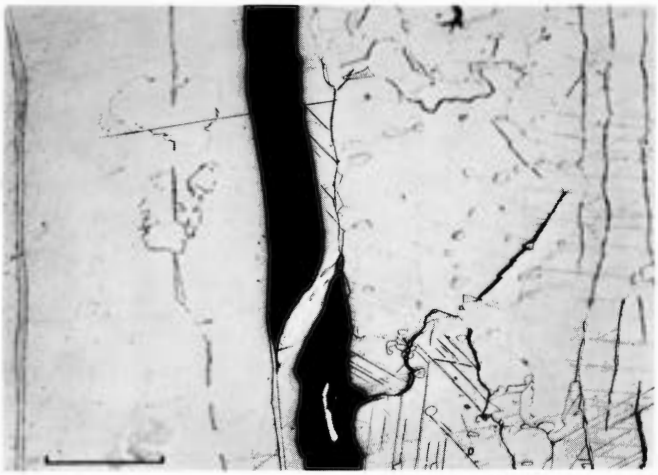

Figure 1600. Serrania de Varas (Brit. Mus. no. 53323). A fissure that follows a kamacite-plessite boundary but also branches into the plessite field where it partially follows cubic cleavage planes in the kamacite. Etched. Scale bar 200 μ.

the unrecrystallized kamacite along α - γ boundaries, where segregated phosphorus atoms had probably further decreased the coherency. Simultaneously, new Neumann bands and a few cubic cracks developed in the kamacite. Serrania is an eminent example of how the delicate balance between transformation in the shell and the ratio between shell and untransformed nucleus may significantly influence the final structure of an iron meteorite during the penetration of the atmosphere. Further, the present case is a fine example of the behavior of a pure iron-nickel Widmanstätten structure, in which phosphide and sulfide inclusions are virtually absent.

If the description above appears confusing, it is because this meteorite does possess many features, the association and sequence of which is not altogether clear to a casual observer. Summarizing, Serrania de Varas first – on primary homogeneous cooling – developed a normal fine octahedrite structure, like, e.g., Bishop Canyon. Next followed a Neumann band-producing shock, and slight reheating sufficed to decorate these bands. Then, severe shear forces displaced the kamacite and taenite, and associated (?) reheating recrystallized the kamacite and recovered the taenite and other parts of the kamacite. This part of the structural development may have been due to a severe shock. Finally, part of the mass was lost by ablational melting in the atmosphere. The surviving part transformed – in a rim zone, several millimeters thick, – into α_2, and the resulting tension forces cracked the weaker and colder interior.

Serrania de Varas is a fine octahedrite with an interesting history. In its primary structure and chemistry it is closely related to Gibeon, Bishop Canyon, Charlotte and Social Circle; while in its secondary recrystallization textures it is mostly related to the last mentioned.

Seymchan, Magadan Region, USSR

About 63°40′N, 150°0′E

A mass too large to move was discovered by the geologist F.A. Mednikov during field work in June 1967. It was situated in the stream bed of a small unnamed tributary of the Yasachnaya River, which itself is a left tributary of the Kolyma River. While the locality has the approximate coordinates given above, the mass was named after the town of Seymchan, situated about 150 km southeast of the locality of discovery.

An expedition was sent to examine the locality and recover the meteorite. This turned out to be a roughly triangular prism, measuring 60 x 45 x 40 cm with pronounced regmaglypts and an estimated weight of 300 kg. (According to a note in Meteoritical Bulletin, No. 43, 1968: 272.3 kg).

The river bed and the adjacent slopes were searched with a mine detector with the result that another fragment, of 51 kg, was discovered about 20 m downstream from the first find.

No analytical or structural work has yet been reported. The large mass is in the Academy of Sciences, Moscow, the small one, in the Museum of the Northeastern Geological Survey (in Magadan ?).

The information above is from a report by Tsvetkov (1969; in Russian).

[J.T. Wasson (personal communication 1974): Group IIE with about 9.15% Ni, 24.6 ppm Ga, 68.3 ppm Ge and 0.55 ppm Ir].

Seymour, Missouri, U.S.A.

37°14′15″N, 92°47′13″W; 450 m

Coarse octahedrite, Og. Bandwidth 2.2±0.5 mm. Neumann bands. HV 210±15.

Group I. 6.9% Ni, about 0.2% P, 89 ppm Ga, 382 ppm Ge, 1.7 ppm Ir.

HISTORY

A mass of 57 pounds (26 kg) was plowed up about 1940 by Claude Dickson 10 km north-northwest of Seymour, in Webster County. The exact locality was furnished by Read (1964b) who purchased the mass in 1964 and described it with photographs of the exterior and an etched slice. Drake (1969; 1970; personal communication) examined the composition of the schreibersite and cohenite precipitates with the electron microprobe.

SEYMOUR – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Drake 1969	7.2											
Wasson 1970a	6.54								89.0	382	1.7	

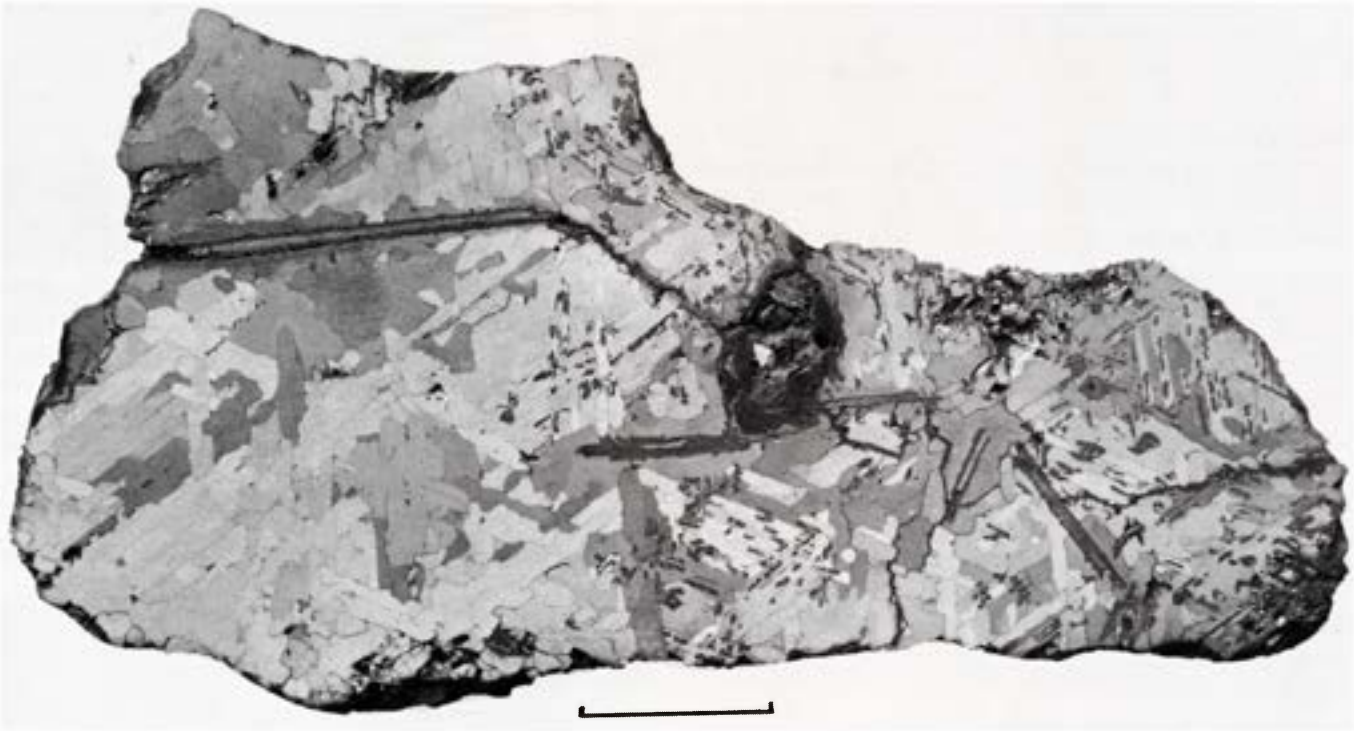

Figure 1601. Seymour (U.S.N.M. no. 4518, the 625 g slice). A typical coarse octahedrite of group I. Centrally, a troilite-graphite nodule. Large plates of schreibersite with cohenite rims. Elongated rounded cohenite crystals in the kamacite lamellae are as usual irregularly distributed. Deep-etched. Scale bar 30 mm. S.I. neg. 1265.

The detailed study by Drake provided the following analytical data for the various phosphide and carbide types. For comparison I have added my microhardness results (Vickers, 100 g load), omitting, however, the most nickel-rich schreibersite veins and the rhabdites which were too small for a reliable measurement. Both the chemical data and the hardness values are very typical for a large number of iron meteorites of group I, e.g., Magura, Gladstone, Smithville, Cranbourne, Canyon Diablo, Odessa, Leeds and Toluca.

	% Ni	Microhardness $^{kg}/mm^2$
Schreibersite, Brezina lamellae	13.1 - 14.6	840 - 950
Schreibersite, rims upon troilite	19.1 - 23.2	910 - 950
Schreibersite, blebs in cohenite	33.8 - 37.5	780 - 830
Schreibersite, grain boundary veins	35.2 - 48.9	720 - 830
Rhabdites, 5-15 μ across	38.0 - 47.8	–
Cohenite, rims upon Brezina lamellae	0.7 - 1.7	1050 - 1100
Cohenite, rims upon troilite/schreibersite	1.2 - 1.7	1050 - 1125
Cohenite, centrally in kamacite	1.4 - 1.6	1100 - 1140
Haxonite roses in pearlitic plessite	about 4	650 - 1000

Drake also noted that the schreibersite rims in the immediate neighborhood (~ 100 μ) of troilite increased steeply to 27% Ni. From the table it may be seen that (i) the hardness of the phosphides drops from about 950 to about 720 with increasing nickel content, (ii) that no significant composition or hardness differences were registered in the three cohenite varieties, (iii) that the haxonite roses are richer in nickel (my determination) and significantly lower in hardness, (iv) that it is typical throughout that schreibersite is always softer than 1000 and cohenite always harder than 1000. What may not be seen from the table is the fact that cohenite is the more metallic phase of the two and is ductile enough to carry a Vickers 100 g pyramid load without splintering. Schreibersite is considerably more brittle so that generally 50% of all determinations have to be rejected because of splintering. This is fully in line with the observation that schreibersite is always the easier mineral to brecciate in cosmic deformation events and to be plucked out during laboratory grinding and polishing operations.

COLLECTIONS

Harvard (about 22 kg), Washington (1,320 g), Chicago (495 g).

DESCRIPTION

The meteorite is a somewhat flattened "hexagonal" mass with the average dimensions of 22 x 21 x 12 cm. One side is rather smooth and flat and may be a fracture surface from splitting in the atmosphere. The remaining surface is covered with shallow regmaglypts and depressions which in places are severely modified by terrestrial corrosion. Limonitic crusts, 0.1-2 mm thick, cover much of the surface. Sections perpendicular to the surface reveal, however, that the heat-affected α_2 zone is preserved over significant areas as a 0.1-1.2 mm thick rim zone. In one place even the fusion crust is preserved, albeit in a somewhat corroded form. A 100 μ thick magnetite-wüstite layer is underlain by a dendritic, 100 μ thick metallic layer. Where the fusion crust happens to cut a cohenite crystal, the fused layer is so carbon-rich that it is solidified to a fine-grained ledeburite. It is estimated that on the average no more than 2 mm is lost by weathering.

Etched sections display a coarse Widmanstätten structure of irregular, bulky ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.2±0.5 mm. The narrowest lamellae of this range are always associated with the cohenite-rich parts, while the cohenite-poor sections frequently exhibit patches of almost equiaxial kamacite grains, 5-10 mm across, as a result of late grain growth. Neumann bands are common. Subboundaries are also present and are sparsely decorated with 1-2 μ rhabdites. The hardness of the kamacite ranges from 190 in grains rich in 5-15 μ rhabdites to 230 in grains with galaxies of very fine (< 0.5 μ) rhabdite precipitates. The hardness reaches a minimum of 160±5 in the annealed transition zone, and increases again to 210±10 in the heat-transformed α_2 zone below the fusion crust (hardness curve type II).

Taenite and plessite cover 3-5% by area, mostly as comb and net plessite fields that are closely associated with the cohenite blebs centrally in the kamacite lamellae. The wider taenite ribbons are decomposed to pearlitic, spherulitic or martensitic structures near the cohenite crystals. The pearlite has 0.5-2 μ wide taenite lamellae and a hardness of 235±15; in its oxidized form it increases to 480±25. The spheroidized plessite has 2-20 μ thick taenite globules and merges with the pearlitic variety. The martensite is of the high-nickel, high-carbon acicular type with a hardness ranging from 400 to 450. Dark-stained patches in between are rather soft (330±20) and appear to be retained austenite, that is on the verge of decomposing to submicroscopic $\alpha + \gamma$ particles.

Schreibersite occurs as Brezina lamellae and skeleton crystals, typically 60 x 10 x 1 mm or 5 x 3 x 2 mm in size. It is further common as 25-150 μ wide grain boundary precipitates, and as 5-20 μ blebs inside the plessite fields. Rhabdites are common, both as 5-15 μ prisms and as galaxies of 0.5-2 μ thick blebs in the kamacite matrix. The composition and hardness of the phosphides are listed page 1111.

Troilite occurs as rather pure monocrystalline nodules, 10-25 mm across, and as 1:1 spongy mixtures with graphite. The two varieties often merge gradually with a tendency for the graphite-rich part to be located along the rim. The troilite (HV 290±15) contains about 5% daubreelite which forms parallel, 5-25 μ wide lamellae. The graphite forms sheaves, flakes and chips, generally 5-50 μ across. The larger aggregates near the troilite rim assume cliftonitic shapes, but perfect crystals were not observed.

Schreibersite rims, 0.3-0.6 mm wide, cover the troilite nodules; and cohenite rims of a similar variable thickness are precipitated upon the schreibersite. Cohenite further occurs as 300 μ thick rims around the Brezina lamellae, and as elongated, rounded blebs centrally in the kamacite lamellae. The cohenite crystals range in size from 2 x 1 x

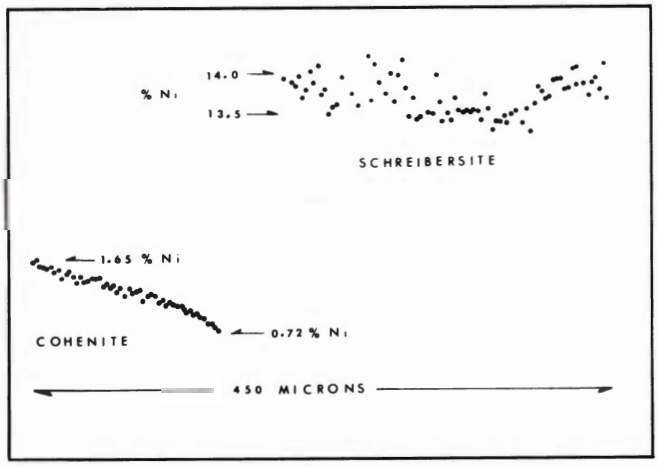

Figure 1602. Seymour. Nickel profile from the center of a schreibersite lamella (extreme right) to a cohenite-kamacite boundary (extreme left). Constructed by analyzing points at two micron intervals on the electron microprobe. (From Drake 1970.)

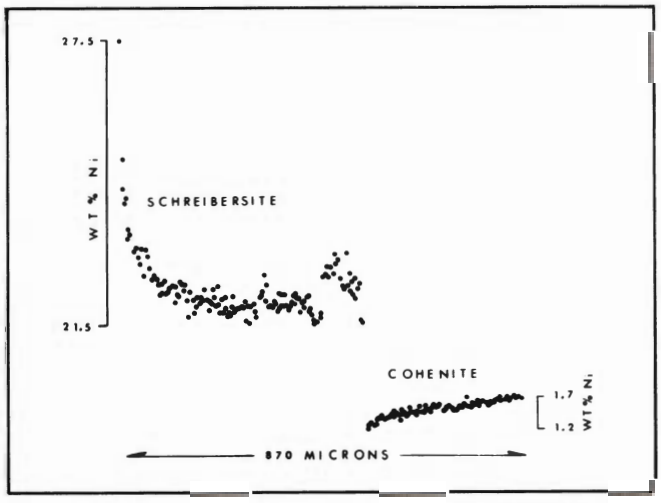

Figure 1603. Seymour. Nickel profile across swathing schreibersite and swathing cohenite from troilite-schreibersite boundary (extreme left) to cohenite-kamacite boundary (extreme right). Constructed by analyzing points at two micron intervals. (From Drake 1970.)

0.5 mm to 10 x 1.5 x 0.8 mm, and include – as is usual – 10-50 μ wide kamacite, taenite and schreibersite windows. No decomposition to graphite has occurred. Quite locally in the pearlitic plessite there occur haxonite roses, 100-300 μ across. They are branched, intricate intergrowths on the micron scale of haxonite, kamacite, taenite and schreibersite.

Seymour exhibits quite a few corroded grain boundaries. It appears that microcracks were already present when the meteorite landed, created during atmospheric breakup or possibly before. The troilite contains pentlandite veinlets, and the schreibersite and cohenite crystals are brecciated and filled with limonitic veinlets. Polished specimens continue to corrode under normal, dry museum conditions, probably due to chlorine introduced by terrestrial ground water.

From the above description it will be seen that Seymour is a perfectly normal, inclusion-rich coarse octahedrite closely related to, e.g., Cranbourne, Smithville, Yardymly and Jenkins. The resemblance to the latter is remarkable; all structural and chemical details and the state of corrosion are identical within the normal range encountered in coarse octahedrites. Moreover, both masses seem to possess one late fracture surface from atmospheric splitting. The well documented localities are rather distant from each other – 90 km, a distance beyond what is normally expected as the spread by bursting during entry. It can, however, not be completely ruled out that Seymour and Jenkins are a paired fall.

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

548 g slice (no. 4518, 15 x 9 x 0.6 cm)
625 g slice (no. 4518, 19 x 7 x 0.9 cm)
82 g part slice (no. 4518, 7 x 3 x 0.6 cm)

Shingle Springs, California, U.S.A.

38°40′N, 120°56′W; 300 m

Nickel-rich ataxite, D. α-spindles 15±10 μ wide. Rich in phosphides. HV 278±15.

Anomalous. 16.95% Ni, 0.63% Co, 0.33% P, 2.1 ppm Ga, 0.13 ppm Ge, 2.6 ppm Ir.

HISTORY

A mass of about 85 pounds (38.5 kg) was found in 1869 or 1870 in a field about half a mile from Shingle Springs, El Dorado County. Today the village is called Shingle; it has the coordinates given above. The mass was taken to the blacksmith's shop where it was soon found to be an unmanageable subject for working (Shepard 1872b; Jackson 1872). It was acquired for the collection of W.H.V. Cronise, of San Francisco, and while there it was examined and described by Silliman (1873) who also presented a photograph of the entire mass. Later, the main mass fell into the hands of boys and was lost (H.A. Ward in Farrington 1915:415). It appears that about 2 kg had been cut from the meteorite before it disappeared. Many specimens were distributed in the 1870s; a large specimen, of 932 g, in Yale (Dana 1886: 4) was later subdivided and distributed, so that now only 433 g remains in Yale (Turekian 1966: 11). The second largest piece extant, a 254 g specimen, described and pictured by Horn (1912: 16, plate 2), is almost certainly a mislabeled specimen – perhaps a Canyon Diablo fragment. Brezina (1896: 294) gave a brief description and a photomacrograph. Cohen (1899: 477; 1905: 156) gave a thorough summary of the history, a description and a new analysis. In more recent times Perry (1944) has presented three photomicrographs.

COLLECTIONS

Yale (433 g), Chicago (117 g), New York (106 g), Vienna (99 g), London (75 g), Paris (71 g), Berlin (61 g), Bonn (34 g), Washington (31 g), Harvard (30 g), Strasbourg (18 g), Rome (12 g), Vatican (12 g), Ottawa (10 g). Budapest (71 g, lost, according to the newest catalog by Ravasz (1969)).

DESCRIPTION

According to Silliman (1873), the mass was flattened on one side and domed on the opposite. His figure indicates that remnants of regmaglypts, 2-4 cm across, may have been present on part of the surface. The largest dimensions were 29 and 24 cm; the third dimension is not given but appears to have been about 24 cm. Silliman observed a slight relief along the margin on the machined sections and interpreted this as a 4-5 mm thick, hardened crust. On the specimens I have examined no such effect is present; the hardness (100 g load) remains constant on 278±15 from the interior towards the corroded edge. No fusion crust and no heat-affected α_2 zones are preserved; terrestrial corrosion has removed at least 3-4 mm from the portions examined in this study.

SHINGLE SPRINGS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Cairns in Silliman 1873	17.17	0.60	0.31	700	100	200						
Sjöström in Cohen 1899	16.69	0.65	0.34	300	500	200	200					
Schaudy et al. 1972	16.95								2.06	0.13	2.6	

Figure 1604. Shingle Springs (U.S.N.M. no. 103). An anomalous nickel-rich ataxite with a streaky matrix and numerous kamacite spindles (black). Etched. Scale bar 2 mm. S.I. neg. 1409.

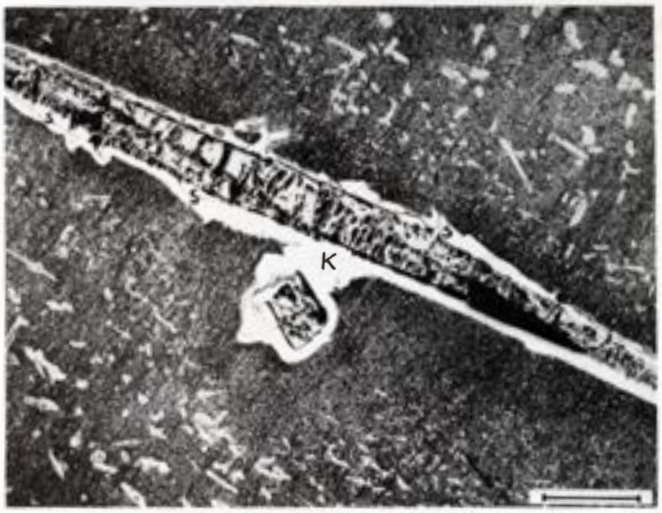

Figure 1606. Shingle Springs (U.S.N.M. no. 103). Troilite with daubreelite lamellae. Minute schreibersite crystals (S) along the interface with kamacite (K). Etched. Scale bar 400 μ. (Perry 1944: plate 51, figure 4.)

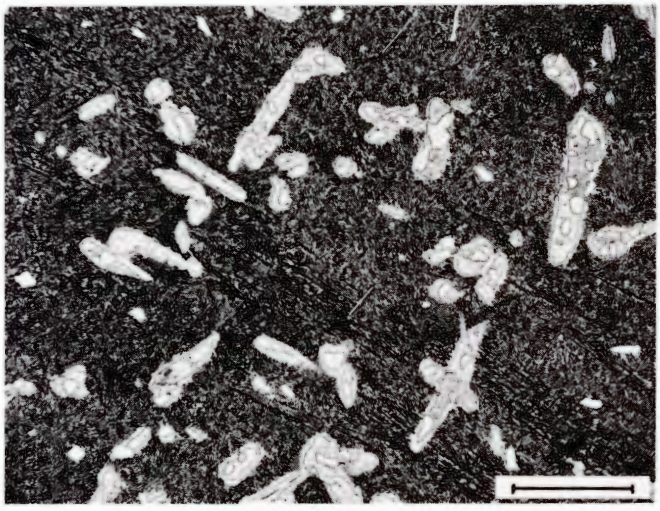

Figure 1605. Shingle Springs (U.S.N.M. no. 103). Fine schreibersite crystals (white) occur in profusion in the meteorite, usually having served as nuclei for kamacite grains (gray). Etched. Scale bar 200 μ. (Perry 1944: plate 25.)

Etched sections display an ataxitic structure broken only by scattered, nonmetallic inclusions, generally less than 1 mm across, but occasionally rising to 2-5 mm in size. The metal shows no Widmanstätten structure but only an indistinct striping and staining. At high magnification the metal displays an extremely fine-grained, duplex structure, somewhat resembling hard pearlite in steel. It appears that the matrix is decomposed into α plus γ but that the individual lamellar units are less than 0.5 μ thick. Depending upon the exact orientation of the lamellar packets, the etched surface alternates between light and dark patches and gives, at a low magnification, a martensitic appearance. The hardness is 278±15; the high hardness is mainly due to the high proportion and fine distribution of the hard, high-nickel taenite component. In the matrix are a few (one per mm^2) α-spindles, 10-20 μ thick and 50-200 μ long. They have a hardness of 175±8.

Schreibersite occurs evenly scattered throughout the matrix with a frequency of 30-40 per mm^2. The schreibersite forms irregular blebs, 5-25 μ wide, which are surrounded by 10-40 μ wide zones of swathing kamacite. Frequently several schreibersite grains are enveloped by the same kamacite grain. Fine platelets of schreibersite, typically 100-200 μ in diameter and 1-2 μ thick, are also common. The high population density of the phosphides is in accordance with the rather high (for an ataxite) phosphorus content of 0.33%.

Troilite and daubreelite occur with a frequency of about one per cm^2, mostly as complex intergrowths. One inclusion, 2 x 0.2 mm in size, was composed of alternating, 100-200 μ wide lamellae of troilite (75%) and daubreelite. Another, 200 x 200 μ in size, consisted of equal amounts of troilite and daubreelite intergrown in dovetailed units. The troilite is monocrystalline and shows a few twins from mild, plastic deformation. Normally, 10-20 μ wide schreibersite crystals are deposited on the nodules, and 10-50 μ wide kamacite rims separate the minerals from the matrix. Perry (1944: plate 51, figure 4) showed a photomicrograph of the troilite-daubreelite intergrowths but erroneously stated in the text that they were schreibersite.

Shingle Springs is a nickel-rich ataxite which structurally and chemically resembles Piñon. It also resembles some of the ataxites of group IVB, such as, Tawallah Valley and Weaver Mountains, and it would be difficult on the basis of structural observations alone to separate it from these last mentioned meteorites. The preserved specimens appear to have escaped damage in the blacksmith's shop.

Specimen in the U.S. National Museum in Washington:
31 g part slice (no. 103, 6 x 1.5 x 0.5 cm). From Yale in 1887.

Shirahagi, Honshu, Japan

36°42′N, 137°22′E

A mass of 22.7 kg was found in 1890 near Shirahagi in the Kamiichikawa river bed (Jimbo 1906). It was described as a fine octahedrite by Murayama (1953), who also attached photographs of the exterior and of etched sections. In 1895 the iron meteorite was bought by Viscount Takeaki Enomoto, and a few years later he gave permission for about one-fifth of the iron to be cut away and forged into two or three sword blades. These swords were called the "Meteor Swords" and one of them was offered to the Crown Prince. The remaining main mass (about 18.2 kg) was presented to the National Science Museum in Tokyo. Presently, 91 g is in Tempe and 12 g in Albuquerque.

Another mass of 10.88 kg was found in 1890 near Saotome which appears to be close to Shirahagi. Hey (1966: 432) listed some references and noted that the mass must now be considered lost. This was confirmed in a personal communication (1970) from Dr. S. Murayama; Japanese scientists were convinced, however, that Saotome had not been an independent meteorite but was another specimen of the Shirahagi fall.

The 91 g sample in Tempe (No. 685.1) is an endpiece, measuring 3 x 3 x 3 cm. No fusion crust and no heat-affected α_2 zone were disclosed on the section.

The etched section exhibits a fine Widmanstätten structure of severely distorted, long ($\frac{l}{W} \sim 25$) kamacite lamellae with a width of 0.30±0.05 mm. It appears that the deformation is due to tensional and torsional forces that have produced necking and, finally, a fracture. Considering that two specimens were actually found, it may be assumed that the tensile fracture occurred when a somewhat larger mass burst in the atmosphere and produced a small shower. On the other hand, the deformations are so extensive that they must be due to very violent forces similar to those that produced the Gibeon shower. However, this is inconsistent with the small masses actually found, and, therefore, it is preferred to believe that the bulk of the deformations are due to a cosmic shock event.

Shirahagi appears to be a fine octahedrite of group IVA with about 8.0% Ni and less than 0.1% P.

[J.T. Wasson (personal communication 1974): Group IVA with 7.86% Ni, 2.19 ppm Ga, 0.12 ppm Ge and 2.32 ppm Ir].

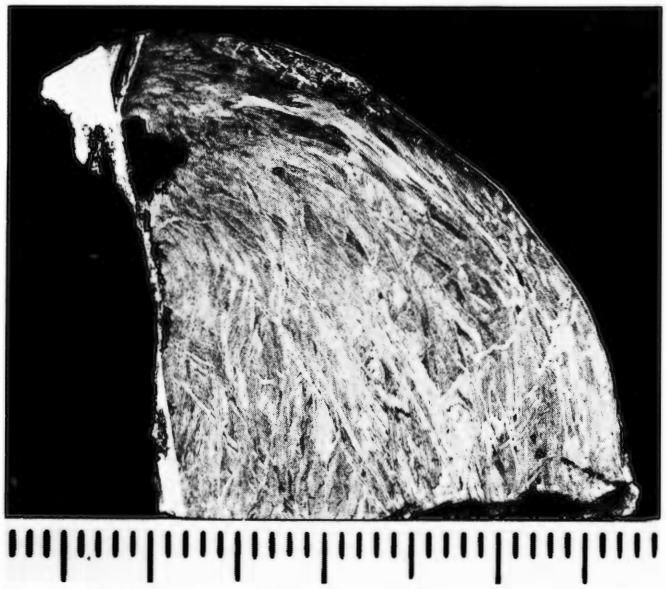

Figure 1607. Shirahagi (Tempe no. 685.1). Apparently a fine octahedrite of group IVA. Extremely distorted Widmanstätten structure of uncertain origin. Deep-etched. Divisions on scale bar in mm. Courtesy C.B. Moore.)

Shohaku, Heian-nan-do, Korea

40°19′N, 126°55′E

One mass of 101 g was found before 1938. It appears to be a medium octahedrite (Hey 1966: 466), but whether it can be upheld as an independent meteorite only a modern examination can determine.

Shrewsbury, Pennsylvania, U.S.A.

39°52′N, 76°40′W; about 250 m

Medium octahedrite, Om. Bandwidth 1.15±0.15 mm. Annealed Neumann bands. HV 162±7.

Group I: 8.42% Ni, about 0.29% P, 61 ppm Ga, 204 ppm Ge, 2.6 ppm Ir.

HISTORY

A mass of 24 pounds was plowed up in 1907 on a farm about seven miles north of Shrewsbury, York County. It was shown by the finder to F.J. Grugan in 1909 and Grugan, recognizing the meteoritic character, instituted a search for further specimens. Several more fragments, totaling three pounds, were recovered. It appears, however, that these fragments had been detached from the main mass at an earlier date and subsequently distributed as curiosities by the finder, but the original report is not quite clear on this point (Farrington 1910b). The report describes, with photographs of the exterior and of an etched slice, the structure and composition of the mass. Stone & Starr (1967) reprinted the original description and added two photographs of etched slices.

COLLECTIONS

London (934 g), Philadelphia (850 g), Paris (691 g), New York (563 g), Harvard (507 g), Washington (395 g), Rome (208 g), Budapest 1956 (175 g), Chicago (103 g), Hamburg (90 g), Yale (90 g), Copenhagen (67 g), Tempe (23 g).

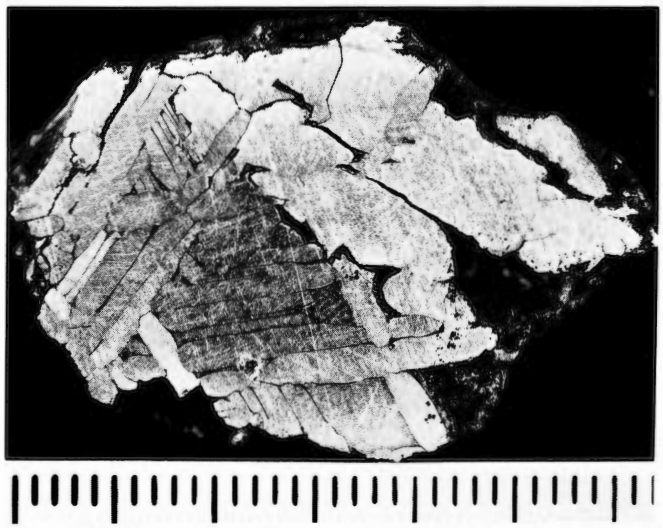

Figure 1608. Shrewsbury (Tempe no. 233a). Medium octahedrite of group I related to Toluca and Mazapil. Deep-etched. Divisions on scale bar in mm. (Courtesy C.B. Moore.)

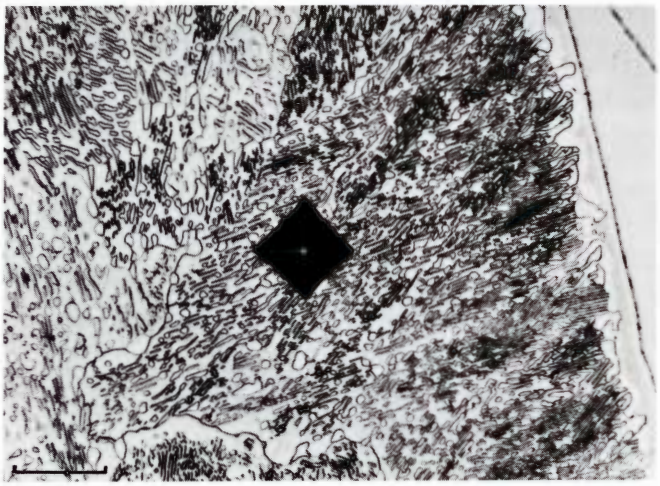

Figure 1609. Shrewsbury (Copenhagen no. 1910, 301). Pearlitic plessite field with cloudy taenite rim. A Vickers hardness impression. Etched. Scale bar 30 μ.

DESCRIPTION

According to Farrington (1910b), the meteorite, as restored by adding the later recovered fragments, was of irregular rhombohedral shape, measuring about 15 x 15 x 15 cm, and weighing 12.2 kg. It was weathered, and the original surface of the meteorite remained on only half the mass. On the other half, the surface showed a jagged fractured appearance with typical octahedral parting. Although Farrington believed that this surface could have been produced by splitting in the air – like Glorieta Mountain – it is much more likely that the jagged surface is the result of the finder's chisel when he was distributing curiosities to his friends.

This view is corroborated by examination of the slices in Philadelphia, London, Washington, Harvard, Tempe and Copenhagen. (The original mass has apparently been completely sliced up into 1 cm thick sections and distributed). The fusion crust and the heat-affected α_2 zone have disappeared so it is estimated that at least 3-4 mm of the surface has been lost by weathering. It may well be more, since octahedral parting is occurring along a major part of the surface where corrosion has attacked along the phosphide-lined Widmanstätten boundaries. Since the jagged surfaces are relatively uncorroded, they must be of recent date and caused by artificial chiseling.

Corrosion selectively attacks the α-phase of the pearlitic fields, the nickel-depleted zones around schreibersite and rhabdites, and the α-phase of the decomposed cohenite. It is also well developed along the decorated Neumann bands and in the grain and subgrain boundaries. Below a depth of about 3 cm, the corrosion is less severe.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 1.15±0.15 mm. The kamacite is rich in subboundaries decorated with $< 1\ \mu$ rhabdites. Neumann bands were once abundant, but as a result of the late cosmic annealing they are partially annihilated, or they have been locked in position by decoration with $< 1\ \mu$ rhabdites. The kamacite is apparently very rich in a densely spaced network of subgrains, each 1-10 μ across, and arranged in subparallel cells, almost as in Uwet and Providence. It may be the result of recovery plus polygonization, the incipient stages of recrystallization. Properly recrystallized units, 5-10 μ across, are only present in Neumann band intersections and near some schreibersite crystals. The microhardness of 162±7 tallies very well with the structural observations.

Taenite and plessite occupy 15-20% of the sections. Comb and net plessite are common and pearlitic plessite is very well developed (HV 168±5, of fields with 1-2 μ thick austenite lamellae). A typical plessite field will show a tarnished outer layer of taenite with widely spaced parallel slipbands (HV 230±10). Then follows annealed martensitic-bainitic transition zones (HV 275±10) and finally duplex $\alpha + \gamma$ textures. All the structures are about 100 hardness points softer than corresponding structures in the related Toluca and Mazapil meteorites.

Schreibersite is common as rosette-shaped or square crystals, typically 16 x 4, 30 x 10, 6 x 1 or 2 x 2 mm in size. They were once enveloped in 0.1-0.3 mm wide rims of cohenite, but this has decomposed to ferrite (HV 98±5) and graphite during the same gentle reheating that altered the

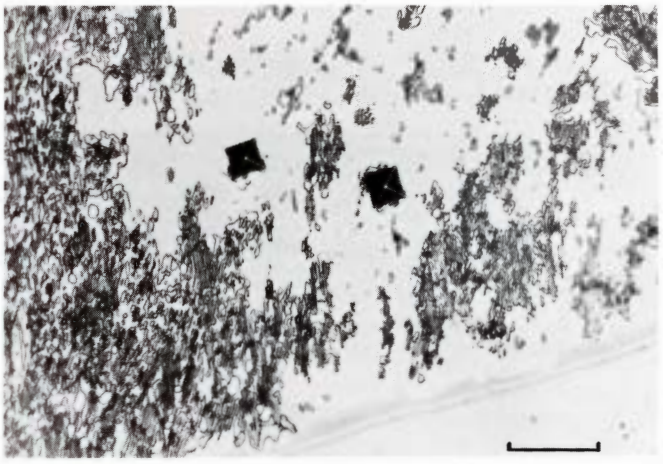

Figure 1610. Shrewsbury (Copenhagen no. 1910, 301). Another pearlitic plessite field, this one having served as a recipient for significant haxonite precipitates (white). The Vickers hardness impressions are carried by the carbide, indicating that it is hard *and* ductile. Etched. Scale bar 30 μ. See also Figure 143.

SHREWSBURY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Zn**	**Ga**	**Ge**	**Ir**	**Pt**
Wasson 1970a	8.42								61.4	204	2.6	

In the old, otherwise insufficient, analysis published in Farrington (1910b), phosphorus was reported as 0.29%.

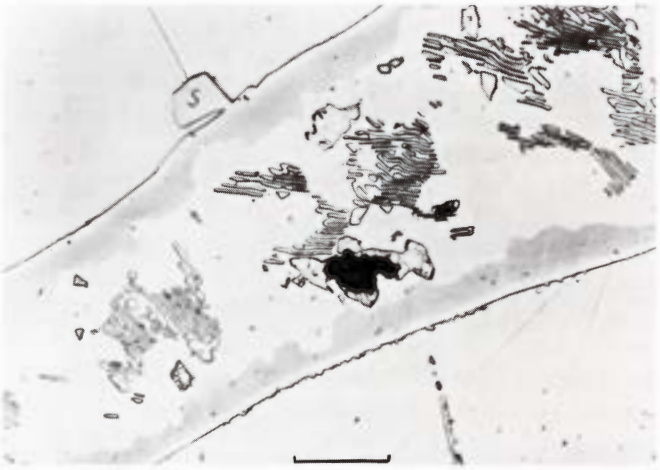

Figure 1611. Shrewsbury (Copenhagen no. 1910, 301). A taenite lamella with an exterior high nickel rim followed by cloudy taenite, and an interior with haxonite-taenite intergrowths (white, in shades). A graphite plume in center and a schreibersite crystal above (S). Etched. Oil immersion. Scale bar 20 μ.

Figure 1612. Shrewsbury (Copenhagen no. 1910, 301). Cosmic annealing has decomposed a cohenite crystal. Its previous outline is indicated by the decomposition products: granulated ferrite and lamellar graphite. Annealed and decorated Neumann bands are also seen. Etched. Scale bar 40 μ.

kamacite. Terrestrial corrosion has, unfortunately, frequently converted the ferrite phase to various oxides, but the microcrystalline (1 μ) graphite is easily detected as 200 x 20 μ plumose aggregates. Schreibersite occurs, in addition, as 20-80 μ wide grain boundary folia, and as 1-50 μ blebs inside the comb plessite. Rhabdites are common as 2-15 μ tetragonal prisms.

Troilite-silicate-graphite nodules occur locally as 5-30 mm aggregates with rims of schreibersite, cohenite and 1-2 mm swathing kamacite. The silicates consist of rounded 50-500 μ grains of olivine and plagioclase with 1-50 μ inclusions of troilite and kamacite. They have nucleated rims of crystalline graphite, which locally is developed as cliftonite units, 20-50 μ across. The troilite was once monocrystalline, but has been shock-melted and solidified to 1 μ eutectics of iron and sulfur. The shock shattered the silicates, cliftonite and schreibersite, so fragments of these may be identified as dispersed blebs in the troilite melt. At a later date, the cohenite decomposed to ferrite and graphite by low-temperature diffusion; the resulting microcrystalline graphite precipitated upon preexisting cliftonite or in the kamacite and is easily distinguished from the primary more coarse-grained graphite.

Small amounts of carlsbergite occur in the kamacite as 10 x 1 μ platelets. Haxonite is present in many of the pearlitic plessite fields, where it forms isotropic, massive areas 0.3 x 0.1 mm in size with a microhardness of 810±60. Small (5-50 μ), elliptic, bluish inclusions were observed in many of the larger schreibersite crystals but were not identified. They resemble phosphates, such as sarcopside and graftonite.

Shrewsbury is a medium octahedrite of group I related to Mazapil, Balfour Downs, Deport, Leeds, Misteca and Toluca. It is particularly interesting in its unambiguous signs of cosmic annealing, probably caused by gentle reheating to 300-400° C. The detailed morphology of many plessite fields resembles that which is present in, e.g., Anoka. The low microhardness of all metallic phases is in agreement with an interpretation of late cosmic annealing.

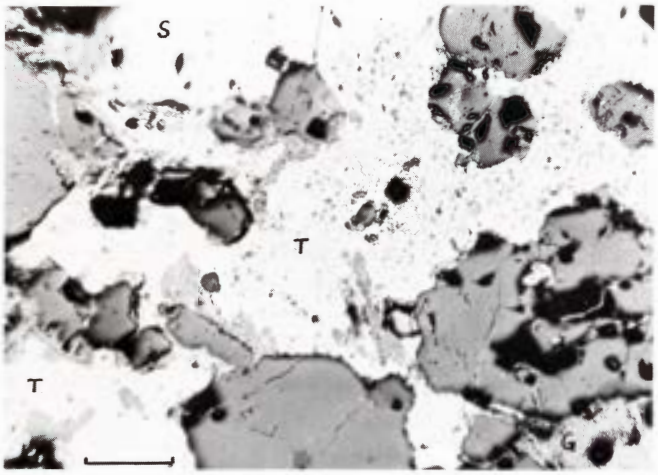

Figure 1613. Shrewsbury (Copenhagen no. 1910, 301). Detail of a troilite-silicate-graphite nodule. The silicates (dark) are brecciated and fragments are dispersed through the shock-melted troilite (T). Graphite (G) and schreibersite (S). Polished. Scale bar 200 μ.

Specimen in the U.S. National Museum in Washington:
337 g slice (no. 422, 11 x 5.5 x 1 cm)

Sierra Blanca, Mexico

Coarse octahedrite, Og. Bandwidth 1.35±0.20 mm. Neumann bands.

Probably group I. About 8% Ni and 0.3% P judging from the structure.

May be a transported fragment of the Toluca shower.

HISTORY

The origin of this meteorite is very uncertain. The following paragraph appeared in the Gazetas de Mexico for

Wednesday, September 8, 1784, (Chladni 1819: 338; Burkart 1856: 278; Fletcher 1890a: 149):

> "In the Sierra Blanca, three leagues (i.e., 12 km) from the Villa Nueva de Huaxuquilla (the present Jimenez in the state of Chihuahua) and twelve from El Valle de San Bartholomé (the present Valle de Allende), various masses of iron weighing 20, 30 and more quintals (1 quintal = 46 kg), have been discovered: Fire has been put to them, and some pieces have been cut off with chisels. They proved to be workable, but owing to the expense the attempts have been given up."

As Fletcher states, Sierra Blanca is not given on any available map, but the name would be appropriate to most hills in the neighborhood, since they are composed of limestone. As discussed under Chupaderos and Morito, there were four large masses found, in fact, – and probably many small ones – in this area, but they eventually came to be known under names different from Sierra Blanca, such as Adargas (Conception), Chupaderos and Morito (San Gregorio).

The name Sierra Blanca only became associated with two fragments, one of about 230 g in Dorpat (Tartu) and one of 175 g in the Berlin Collection. Around 1834 the latter had been part of the collection of Dr. Bergemann who possessed several Mexican irons. The Dorpat specimen has apparently never been described, but Rose (1864a: 63) briefly mentioned that the Berlin specimen contained rhabdites and Neumann bands and was very similar to the Toluca iron.

Fletcher (1890a: 149) stated that the small specimens in other collections, had been cut from the Berlin material, but he provided no description. The very small fragment now in Chicago was once part of the collection of Ward (Catalog 1904a), who probably obtained it on one of his visits to Berlin.

To summarize it may be stated that today only four fragments are known as Sierra Blanca material, and three of these are known to be part of the same piece. The Dorpat specimen may be so, too, but no information is available. The evidence for the specimens coming from the Jiménez area appears to be very weak. An exchange of labels in Bergemann's collection appears possible throughout.

COLLECTIONS

Dorpat (Tartu, 228 g, one specimen), Berlin (141 g and 5 g), London (no. 35186, 15 g, acquired 1863 by exchange with Berlin), Chicago (2 g on two fragments).

ANALYSIS

No analysis has been performed, but the present author would expect about 8% Ni and 0.3% P, with an amount of trace elements putting it in group I.

DESCRIPTION

So that I might determine whether the material could be fragments chiseled from either one of the Chupaderos masses or from Morito, the London specimen was kindly lent me by Dr. M. Hey. It is a wedge-shaped endpiece with the dimensions 42 x 14 x 8 mm, and it has been exposed to considerable terrestrial corrosion. It is flattened somewhat by hammering, and locally overfolded ears and squeezed metal are easily identified.

The polished and etched section displays a border case between medium and coarse octahedrites. The Widmanstätten structure consists of swollen, rather short ($\frac{L}{W} \sim 10$) lamellae with a width of 1.35±0.25 mm. The lamellae are straight, except near the surface where they are bent by hammering. No fusion crust and no heat-affected α_2 zone are preserved. Corrosion penetrates along the octahedral lamellae and particularly attacks the nickel-poor alpha phase of the plessitic areas and around the rhabdites. The specimen appears to be of a considerable terrestrial age.

Neumann bands are common, and the subgrain boundaries of the ferrite phase are copiously decorated with 1-10 μ phosphides. In several places recrystallization of the ferrite phase has just started, particularly in the Neumann band intersections and around faulted phosphide crystals. The new ferrite grains reach 25-50 μ sizes and appear to be the result of a late, gentle, artificial reheating to about 500° C. Plessite covers about 20% by area, partly as comb plessite, partly as acicular areas and partly as fine-grained pearlitic ribbons, with individual taenite lamellae of 0.2-1 μ width. Some of the broader wedge-shaped fields have martensitic interiors. There are two generations of lenticular martensite plates. One, the older, etches easily, presumably because by the gentle reheating it has been annealed and some carbide precipitation has taken place. The other, younger, etches only lightly and appears to have formed upon cooling from the reheating that decorated the first martensite.

Schreibersite occurs as 1 x 0.4 mm skeleton crystals and as 100-200 μ wide grain boundary precipitates. They are very fragmented and locally show boudinage, possibly partly because the fragment has been hammered. Rhabdites, 2-25 μ in cross section are very common; also, these are faulted and displaced.

The structure is very different from the Morito and the Chupaderos masses, so the fragment can not be from these masses. On the other hand, all structural and morphological details are identical to those of a Toluca iron, albeit not all Toluca characteristics, such as troilite-graphite nodules and cohenite inclusions, are present on the little piece investigated. Since Rose (1864a: 63) had an opportunity to compare his larger piece to Toluca and found it similar, I believe it may, cautiously, be concluded that the Sierra Blanca specimens are mislabeled Toluca specimens. A mislabeling also appears possible because the Toluca iron was made known to the Mexican public only a few months later than the Sierra Blanca note in the same weekly newsletter (Gazetas de Mexico, December 15, 1784). In any case, the Sierra Blanca iron is structurally, and probably chemically too, impossible to distinguish from typical Toluca specimens – except for the slight, artificial reheat-

ing that created an incipient recrystallization and a few other anomalous features in Sierra Blanca.

Sierra Gorda, Antofagasta, Chile
22°54′S, 69°21′W

Hexahedrite, H. Single crystal larger than 14 cm. Decorated Neumann bands. HV 205±15.

Group IIA. 5.48% Ni, 0.53% Co, 0.23% P, 61 ppm Ga, 170 ppm Ge, 43 ppm Ir.

HISTORY

A mass was found at the coordinates given above, on the railway between Calama and Antofagasta, close to Sierra Gorda, the location of a silver mine (E.P. Henderson 1939; as quoted by Hey 1966: 448). Henderson (1941a) gave slightly different coordinates and an analysis; but since he assumed Sierra Gorda to be just another of the North Chilean hexahedrites, no further description was given. The meteorite was allegedly found in 1898, but the original weight is unknown (E.P. Henderson, personal communication). Perry (1944: 78, plate 52) presented two photomicrographs. Recently Wasson & Goldstein (1968) reexamined the iron and gave a photomicrograph. They concluded that it is a separate fall, unassociated with the eight hexahedrites of the North Chilean group. The same conclusion is reached by the present author. Bauer (1963) determined the quantity of helium-3 and helium-4 and deduced a cosmic ray exposure age of 110 million years.

COLLECTIONS

Washington (17.3 kg), Ferry Building, San Francisco (about 7 kg), Chicago (550 g), New York (315 g), Ann Arbor (165 g). The original mass evidently weighed at least 26 kg.

DESCRIPTION

According to Roy S. Clarke (personal communication) the main mass now weighs 16.3 kg and measures 22 x 15 x 13 cm. A large endpiece of 7 kg and several slices have been removed, leaving a cut surface of 17 x 10 cm. The mass has a relatively smooth domed surface (22 x 15 cm) overlying a concave surface with irregular depressions, from a few cm to 8 cm in length. There is a series of what appears to be chisel marks around the center of the domed surface over an area of 6 x 7 cm. Other small areas on the edges of the specimen could also be the result of hammering; but the damage is only superficial, and artificial reheating has not occurred. The meteorite is severely weathered; the oxide crust on the domed surface is paper-thin and between 1-2 mm on the concave surface.

Etched slices show that Sierra Gorda belongs to the hexahedrites. It is a single kamacite crystal with Neumann bands extending from edge to edge with no directional changes. No fusion crust and no heat-affected α_2 zones were detected on the specimens examined. In one place a hardness gradient to low values of 168±5 (recovery) was observed – which indicates that the α_2 zone here had only

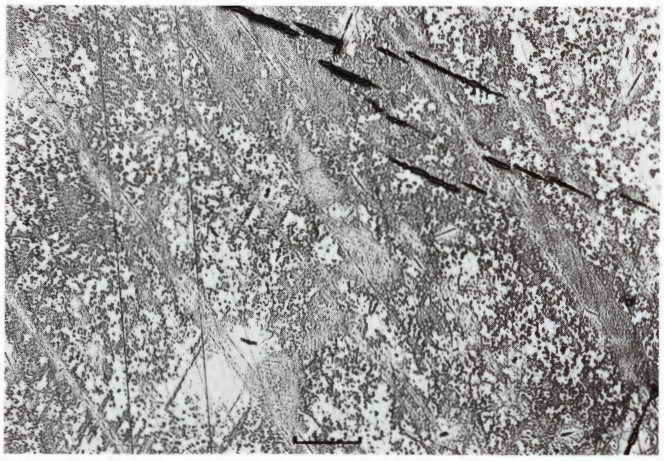

Figure 1614. Sierra Gorda (U.S.N.M. no. 1307). Hexahedrite with light and dark shaded areas. Several prominent cracks follow the cubic cleavage planes in the kamacite. Etched. Scale bar 1 mm. See also Figure 202.

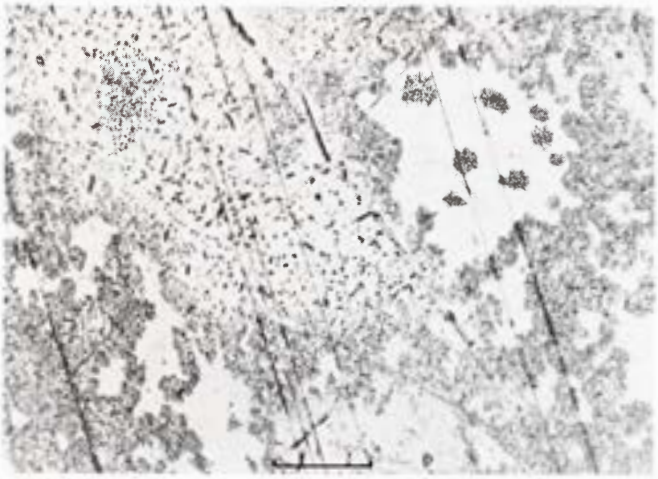

Figure 1615. Sierra Gorda (U.S.N.M. no. 1307). The light areas are clear precipitate-free kamacite, while the dark areas are rich in rhabdites of various dimensions. Etched. Scale bar 200 μ.

SIERRA GORDA – SELECTED CHEMICAL ANALYSES

References	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson 1941a	5.58	0.25	0.23									
Goldberg et al. 1951	5.59	0.53							65.5			
Wasson 1969	5.27								57.4	170	43	

Wasson & Goldstein (1968) found the kamacite to be rather inhomogeneous with an average composition of 5.51±0.5% Ni and 0.25±0.05% P.