sections. They also presented a bulk analysis and good analyses of separated phases: schreibersite (25.6% Ni, 0.47% Co, 0.09% Cu), rhabdites (41.4% Ni, 0.23% Co, 0.77% Cu), kamacite (6.39% Ni, 0.48% Co, 0.03% Cu), taenite (37.4% Ni, 0.67% Co, 0.64% Cu), and troilite (62.9% Fe, 35.45% S, 0.96% Cr, 0.28% Ni, 0.16% Cu). On the basis of their observations, they correctly classified Annaheim as a coarse octahedrite.

The meteorite has recently been reclassified as a medium octahedrite by Hey (1966: 22) and Douglas (1971: 4). Wasson (1970a), however, has retained the Og classification and notes that Ge-Ga and Ge-Ni plots fall slightly outside the group I fields; he thus designates Annaheim as an anomalous member of group I. The only gas-analytical work performed was published by Hintenberger et al. (1967) who determined $^3$He, $^4$He, $^{20}$Ne, $^{21}$Ne and $^{22}$Ne.

**COLLECTIONS**

Ottawa (9.20 kg endpiece, 3.10 kg endpiece and 199 g fragments), London (359 g), Copenhagen (20 g). It may be noted here that there is a discrepancy concerning the actual weight of the meteorite as found. Johnston & Ellsworth (1921) stated that it weighed 11.84 kg, but this must be wrong since the Canadian National Collection includes samples adding up to 13.1 kg (Dawson 1963: 5). If we take this figure of 13.1 kg and add the 359 g of the London specimen acquired in 1924, and further add 300-400 g to allow for loss in cutting, polishing and analyzing, we may cautiously conclude that the mass originally weighed about 13.8 kg. Perhaps 11.84 kg was a simple printer's error for 13.84?

**DESCRIPTION**

According to Johnston & Ellsworth (1921) the mass was roughly crescentic in outline, measuring 30 cm in length and 15 cm across at the widest part. The specimen varied in thickness from 5 cm at the center to 8 cm on one of the horns and 9 cm on the other. Relatively shallow regmaglypts, 2-3 cm across, covered the surface. On the slope of one prominence, a 3 cm thick troilite nodule was exposed.

Etched sections display a coarse Widmanstätten structure of straight, long ($\frac{L}{W} \sim 16$) kamacite lamellae with a width of 1.4±0.3 mm. The kamacite is rich in subboundaries decorated by 1 $\mu$ phosphide precipitates, and Neumann bands are common. Taenite and plessite cover about 5% by area. Comb and net plessite fields occur, but more common are individual taenite lamellae, often wide enough to display decomposed interiors. The taenite stains blue-black upon etching. Interiors display acicular martensite with retained austenite, or fine bayonet-shaped $\alpha$-particles.

Schreibersite is common as 10-100 $\mu$ wide grain boundary precipitates and as an occasional millimeter-sized skeleton crystal. Small grooves may be distinguished locally on the surface on the mass, indicating where a schreibersite crystal was ablated away during the atmospheric passage. Rhabdites are common as 2-15 $\mu$ thick tetragonal prisms in the kamacite. Most schreibersite crystals are apparently slightly brecciated and shear-displaced.

Troilite-graphite intergrowths occur as nodules up to 3 cm large. One such nodule was analyzed by Johnston & Ellsworth (1921) and found to contain 38% Fe (and Ni,Co), 22.3% S, 0.68% Cr and 38.7% C (as graphite). From the nodule they also separated a whitish cylindrical grain, 3 mm long and 1 mm in diameter, which was assumed to be apatite(?).

The fusion crust covers the meteorite as an almost unbroken black layer of oxides. A laminated, dendritically solidified, up to 0.5 mm thick, metallic fusion crust follows irregularly below the fused oxides. The heat-affected $\alpha_2$ zone is 1-3 mm thick and is composed of large, serrated crystallites, comparable to what is observed upon, e.g., Silver Crown and Bahjoi. Micromelted phosphides are common in the exterior half of the $\alpha_2$ zone, and the taenite rims and lamellae have lost their tarnished appearance.

Annaheim is a coarse octahedrite, structurally very similar to Goose Lake, Bogou, Bahjoi, Bischtübe, and Toluca. Its detailed trace element composition places it, according to Wasson (1970a), slightly outside the bulk of the irons of the resolved chemical group I.

## **Anoka**, Minnesota, U.S.A.

45°14′N, 93°15′W; 270 m

Fine octahedrite, Of. Bandwidth 0.34±0.06 mm. Annealed. HV 200±10.

Group IIIC. 11.75% Ni, about 0.30% P, 17.8 ppm Ga, 16.2 ppm Ge, 0.4 ppm Ir.

**HISTORY**

A mass of 1,108 g was found in 1961 in Anoka County (Meteoritical Bulletin, No. 32, 1964). It was described with figures of the exterior and of etched slices by Huss et al. (1966). The meteorite was struck with a shovel at a depth of about four feet when Joe Field, on his farm four miles northeast of Anoka, was excavating for a cesspool. Huss purchased the mass in 1963, and slices have since been made available from the American Meteorite Laboratory at Denver. A field search by Huss in the summer of 1963 failed to disclose more specimens. Wood (1964) presented a photomicrograph and several electron microprobe traces across various structural elements. Jaeger & Lipschutz (1967b) estimated the meteorite to be unshocked, i.e., having suffered shock intensities less than 130 k bar. Wasson & Kimberlin (1967) found that the chemical composition put Anoka close to Edmonton (Kentucky), Mungindi, and Carlton. Hintenberger et al. (1967) determined the amount of occluded, noble gases, while Voshage (1967) by the $^{40}$K/$^{41}$K method estimated a cosmic ray exposure age of 685±150 million years.

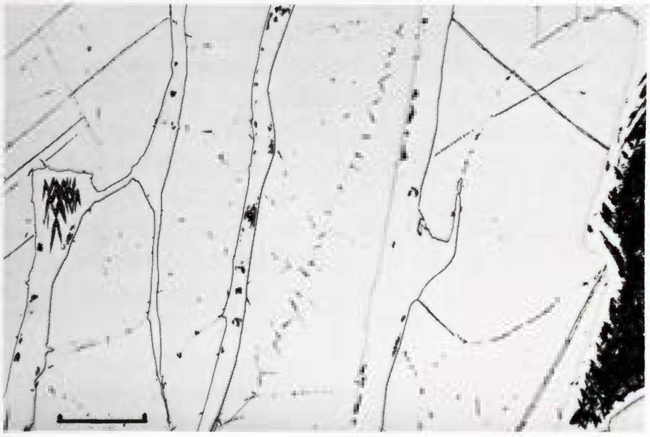

**Figure 247.** Anoka (Copenhagen no. 1970, 221). A very unusual fine octahedrite. The kamacite subboundaries are rich in carbide precipitates. The taenite displays tempered bainitic-martensitic structures. Etched. Scale bar 200 $\mu$.

**Figure 248.** Anoka (Copenhagen). The Neumann bands are decorated with minute carbides. A dense grid of lines parallel to $(111)_\gamma$ is seen in the central taenite lamella. Etched. Scale bar 50 $\mu$.

**COLLECTIONS**

American Meteorite Laboratory, Denver (main mass), Tempe (180 g endpiece), New York (39 g), Copenhagen (29 g).

**DESCRIPTION**

According to Huss et al. (1966) the extreme dimensions were 12 x 9.6 x 7 cm. "About 40% of its surface was covered with a sand-oxide shale which could not be removed without damaging the meteorite. The remainder of the specimen showed fairly good fusion crust." Indications of ablated spill-over material was also found, but well-developed regmaglypts were absent. Huss et al. (1966) compared the effects of the oriented flight on Anoka to similar effects believed to be present on Rio Loa. This comparison is, however, of no significance since Rio Loa acquired its peculiar structure by fragmentation and artificial reheating (page 925).

Etched sections display a fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 30$) kamacite lamellae with a width of 0.34±0.05 mm. The kamacite has numerous subboundaries which are unique by being significantly decorated by 1-3 $\mu$ wide carbide particles. Carbides also occur scattered in the kamacite as 1 $\mu$ particles and as "hairs" and irregular outgrowths upon the larger schreibersite crystals. Neumann bands are common; due to annealing they have become decorated along both sides with tiny grains, 0.5 $\mu$ across, of what appears to be taenite. The hardness of the kamacite is 200±10.

Taenite and plessite cover about 25% by area, mostly as dense fields and as unusually wide taenite ribbons, 30-60 $\mu$ wide, which separate individual kamacite lamellae very effectively. Normal comb and net plessite fields are absent. Anoka's typical field has a wide, yellow taenite rim (HV 260±15) followed by a martensitic transition zone (HV 275±15). Then follow duplex $\alpha + \gamma$ textures which resemble the ataxitic structures of group IVB (HV 240±10). The taenite rims show an oriented grid of what may be submicroscopic precipitates upon slipplanes, and the feathery acicular martensite also appears to have numerous

**Figure 249.** Anoka (Copenhagen). Irregular, flaky carbides on a grain boundary in kamacite. Minute taenite and carbide particles on the Neumann bands. Etched. Scale bar 20 $\mu$.

ANOKA – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Wood 1964 | 11.49 | | | | | | | | | | | |
| Huss et al. 1966 | 11.75 | 0.51 | | | | | | | | | | |
| Wasson & Kimberlin 1967 | 12.00 | | | | | | | | 17.8 | 16.2 | 0.4 | |

submicroscopic precipitates. The morphology and the hardness support the observation, from the decorated Neumann bands, that the meteorite was somewhat annealed in cosmos. Troilite was not observed.

Carbides occur commonly as fine-grained cohenite, as mentioned above, and as carbide roses inside about 10% of the dense plessite fields. The roses form 0.05-0.4 mm wide intricate intergrowths of haxonite with kamacite, taenite beads and occasional schreibersite grains. The hardness is 900±100, depending upon the actual proportions of the various components.

Schreibersite is common as skeleton crystals, typically 2 x 0.1 mm in size. They appear to be oriented Brezina lamellae, but the examined sections were too small for a conclusion to be reached. The schreibersite is brecciated and locally cemented together by terrestrial oxidation products, and it is enveloped by 0.2-0.4 mm wide rims of swathing kamacite. Schreibersite also occurs in very limited amounts as 10-50 μ wide grain boundary precipitates. Bulk phosphorus content is estimated to be 0.30-0.35%.

**Figure 250.** Anoka (Copenhagen). A taenite lamella. Due to cosmic annealing the acicular martensite is decomposing and submicroscopic α-particles have precipitated on $(111)_\gamma$ planes. Etched. Scale bar 20 μ.

**Figure 251.** Anoka (Copenhagen). Fusion crust to the left, followed by a heat-affected $\alpha_2$ zone which here is 1.2 mm thick. Etched. Scale bar 400 μ.

The fusion crust is well preserved, and duplex as usual. The exterior magnetite-wüstite layer is 50-120 μ thick, but corroded. The interior, dendritic-cellular metallic crust is

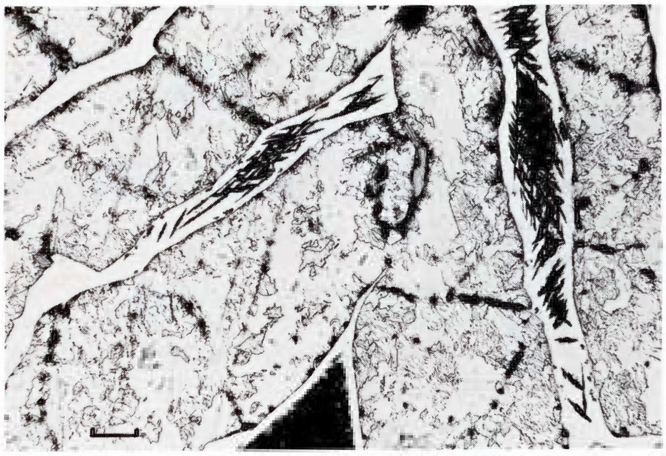

**Figure 252.** Anoka (Copenhagen). Detail of heat-affected $\alpha_2$ zone. The carbides are decomposed and have formed black bainite. Etched. Scale bar 100 μ.

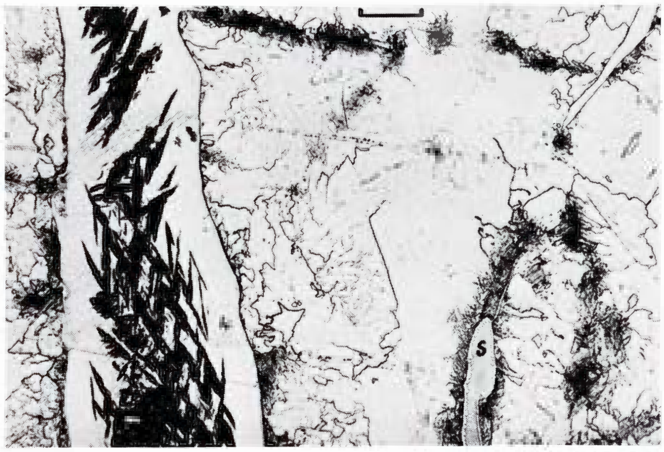



**Figure 253.** Anoka (Copenhagen). A detail of the heat-affected $\alpha_2$ zone with a melted schreibersite inclusion (S). Etched. Scale bar 50 μ.

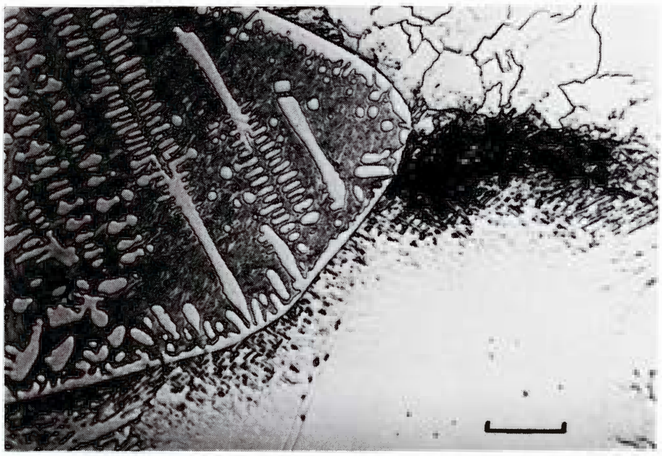

**Figure 254.** Anoka (Copenhagen). Detail of a melted schreibersite inclusion similar to Figure 253. Etched. Scale bar 20 μ.

composed of 1-12 layers, each normally 20-40 μ thick, that irregularly pinch and swell. Fine oxide globules, 1-20 μ in diameter, are dispersed in the metal. The dendrites show columnar growth perpendicular upon the unmelted substrate, and they have a hardness of 395±25, rather high because they have transformed to carbon-rich martensites. Under the fusion crust is an 0.8-1.6 mm thick $\alpha_2$ zone with melted phosphides present in the exterior 50%. The hardness of the $\alpha_2$ phase is 185±8, except near the grain boundary carbides where the hardness increases to over 400 due to the presence of martensitic reaction products.

Anoka is chemically and structurally closely related to Edmonton (Kentucky), Carlton, and Mungindi. It has, however, an unusual abundance of grain boundary carbides, and its detailed structure suggests an annealing period after initial cooling.

**Antofagasta.** See Imilac (in the Supplement)

## Apoala, Oaxaca, Mexico
17°40'N, 97°0'W

Medium octahedrite, Om. Bandwidth 0.65±0.15 mm. ε-structure. (HV 210±15).

Group IIIB. 9.7% Ni, 0.9% P, 0.6% S, 18 ppm Ga, 35 ppm Ge, 0.05 ppm Ir.

Many specimens in collections have been reheated artificially to about 900° C.

### HISTORY

A mass of about 85 kg was found in 1889, 10 miles east of Coixtlahuaca, according to Ward (1904a: 3). The mass was acquired for the Institute of Geology in Mexico City and here Ward, visiting in 1900, obtained about 3.0 kg for exchange purposes (letters, August 21, 1902, from H.A. Ward to Professor Merrill at the Smithsonian Institution). Some of this material was briefly described by Cohen (1905: 384), and figured by Brezina & Cohen (1886-1906: plate 39). Mauroy (1913) presented two more photomacrographs, while Perry (1944: plate 47) showed a troilite nodule. Haro (1931: plates 27-28) reproduced photographs of full slices, one of which (plate 28) was acquired in 1935 by the U.S. National Museum. Haro, however, reported an incorrect place of find, evidently mixing up some Apoala labels with Yanhuitlan labels. Nininger & Nininger (1950: 28 and plate 5) reported a 417 g Apoala specimen. This material, a part of which is now in London (no. 1959, 69), has been examined by me and found to be mislabeled. Dr. Nininger kindly informed me that the specimen was obtained from the Mexico City collection and believed to be from Apoala at that time. I suspect that the specimen is in fact a piece of Durango, and will treat it there.

### COLLECTIONS

Mexico City (78.2 kg main mass; 687 g slice), Chicago (2,046 g, from Ward), Washington (324 g), London (no. 86068: 283 g, from Ward) Ann Arbor (235 g), Vatican (79 g), New York (80 g), Los Angeles (32 g), Paris (13 g), Vienna (11 g), Strasbourg (5 g).

**Figure 255.** Apoala (main mass in Mexico City). The well-preserved meteorite shows fusion crust locally, and there are numerous cylindrical cavities from the ablational melting of troilite. Scale bar 5 cm.

### DESCRIPTION

During a recent visit to Mexico City, I examined and photographed the main mass. The overall dimensions are 44 x 30 x 20 cm, and the mass has a polished and etched cut of 30 x 17 cm. On this section are three large troilite nodules, 30 x 25, 30 x 22 and 20 x 20 mm, the first with a tongue of metal indenting the troilite. The exterior surface has about 10 holes of the same general size as the troilite nodules. In these holes, and on protected parts of the surface, the fusion crust is still visible. Straight furrows, resembling chisel marks, indicate where some large schreibersite lamellae partially melted out in the atmosphere. Sections perpendicular to the surface disclose a 0.8 mm thick laminated fusion crust underlain by a 2-4 mm wide heat-affected $\alpha_2$ zone with a microhardness of 205±20. Micromelted phosphides are present in the exterior 50% of the $\alpha_2$ zone. Apoala is only little corroded; the cup-shaped cavities are from the atmospheric flight, produced by ablation melting of troilite.

Apoala is a medium octahedrite with straight, long ($\frac{L}{W} \sim 30$) kamacite lamellae with a width of 0.65±0.15 mm.

**APOALA – SELECTED CHEMICAL ANALYSES**

| Reference | percentage Ni | Co | P | ppm C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wasson & Kimberlin 1967 | 9.7 | | | | | | | | 18.3 | 35.2 | 0.016 | |

The kamacite is hatched, suggesting shock-transformation above 130 k bar. Its hardness is surprisingly low, 210±15, suggesting that considerable annealing has occurred. It is not clear whether the annealing is of cosmic or artificial origin. Taenite and plessite cover about 35% by area. The ideal plessite field consists of a taenite rim, followed by a transition zone with two different martensite types, and enclosing a duplex interior of fine-grained $\alpha + \gamma$. Few comb plessite fields are present.

Schreibersite is dominant as Brezina lamellae. These are 0.2-1 mm thick plates, precipitated in the dodecahedral planes of the parent taenite crystal; in Apoala they reach the typical dimensions of 70 x 15 x 0.6 or 25 x 10 x 1 mm.

**Figure 256.** Apoala (main mass in Mexico City). A large sample has been removed on the left. Two globular troilite inclusions and one, partially ablated away, are clearly seen on the polished surface. Scale bar 5 cm.

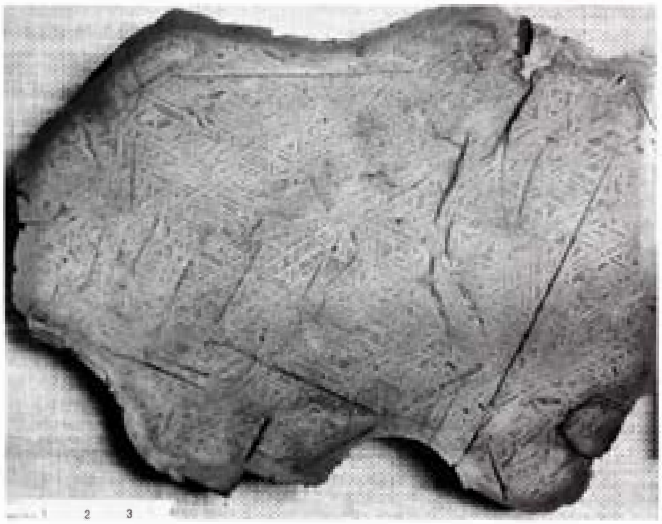

**Figure 257.** Apoala (687 g slice in Mexico City). Prominent Brezina lamellae of schreibersite. Scale bar 10 cm.

The lamellae are sheathed in 1-1.5 mm thick rims of swathing kamacite. Reichenbach lamellae reported as troilite by Perry (1944: 47) are in fact Brezina lamellae and consist of schreibersite. A 0.1 mm wide rim is precipitated on the troilite nodules. Schreibersite is further present as characteristic rows of tiny islands, located in the kamacite about 5-10 $\mu$ outside taenite and plessite.

The bulk phosphorus content was estimated by point counting. On a 180 cm$^2$ section, 54 phosphide inclusions were found with a total area of 920 mm$^2$, corresponding to 0.70% P bound in the large schreibersite crystals. No phosphorus analysis is known for the metallic part of the meteorite, but it is here assumed that it is about 0.20%, judging from the number and sizes of the microscopic precipitates and from the general similarity to other group IIIB irons. The total phosphorus content of Apoala is thus

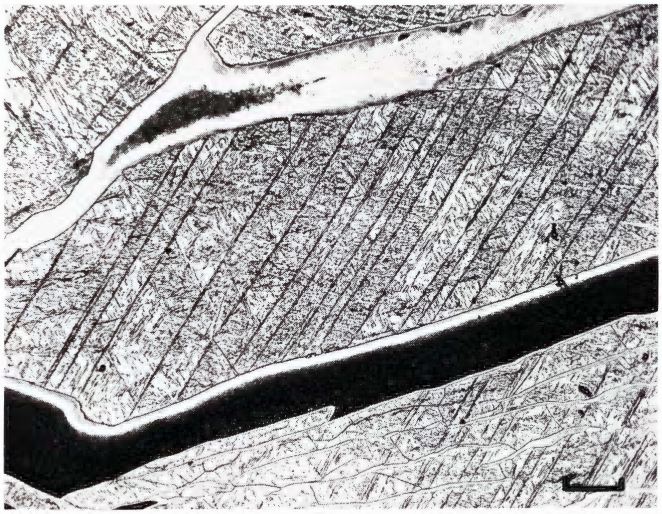

**Figure 258.** Apoala (U.S.N.M. no. 908). Shock-hatched kamacite, cloudy taenite and black taenite. Etched. Scale bar 100 $\mu$.(Perry 1950 Volume 1.)

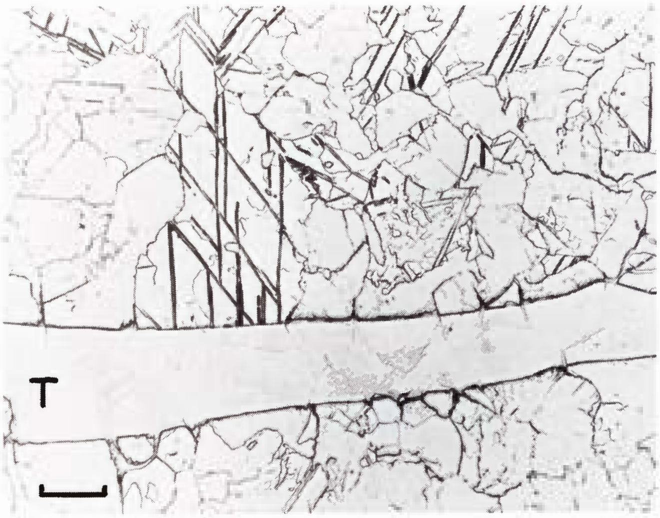


**Figure 259.** Apoala (Chicago no. 1008). Artificially reheated to about 900° C. The taenite lamella (T) is decomposed to a polycrystalline austenite aggregate, and both kamacite and taenite now show $\alpha_2$ structures. The Neumann bands are probably due to hammering. Etched. Scale bar 50 $\mu$.

0.9%, which is very high, as in most group IIIB meteorites. Forty-one of the 54 inclusions, having an area of 850 $mm^2$, could be shown to be lamellae precipitated in the dodecahedral directions $\{110\}$ of the original austenite single crystal. The remaining 13 inclusions, comprising 70 $mm^2$, were too small or too irregular to have a direction assigned to them, or they represented cross sections of lamellae, the directions of which were uncertain. At least 93% of all schreibersite lamellae could thus be shown to follow the $\{110\}$ planes of the pre-Widmanstätten structure. Brezina & Cohen (1886-1906: plate 39) also noted the strikingly well-developed crystallographic pattern in Apoala.

Troilite occurs as 5 to 30 mm well-rounded nodules. Point counting of 680 $cm^2$ indicated a bulk sulfur content of 0.6%. At least some of the nodules have been micromelted, probably in connection with a preatmospheric shock event, and have penetrated the adjacent schreibersite crystals and the metallic grain boundaries as 10-25 $\mu$ wide veinlets. These veinlets of fine-grained metal and sulfide ($\sim 1\ \mu$ grain size) are sensitive to corrosion and have been limonitized to a certain extent. Locally a cluster of 0.1 mm euhedric chromite crystals may be observed.

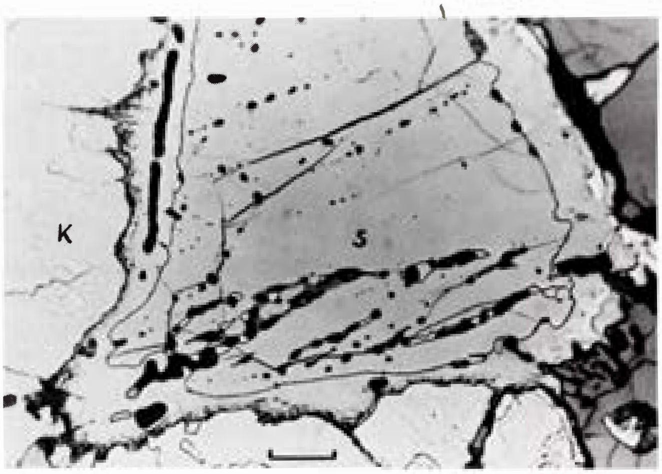


**Figure 260.** Apoala (Chicago no. 1008.) Artificial reheating to about 900° C has caused schreibersite (S) to react with terrestrial limonite and kamacite (K). The result is intricate, globular intergrowths and diffuse reaction zones. Etched. Scale bar 20 $\mu$.

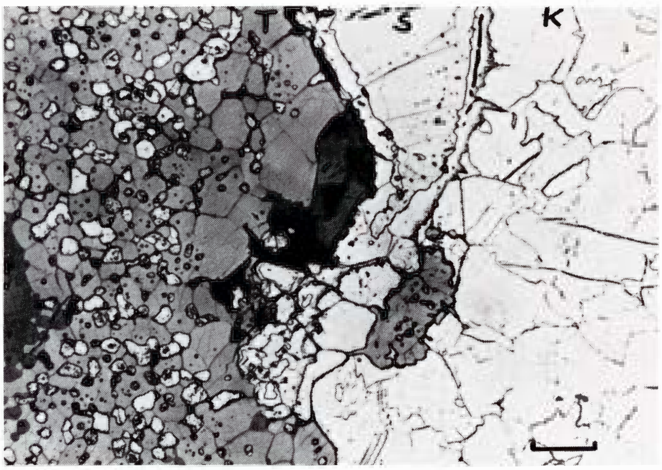


**Figure 261.** Apoala (Chicago no. 1008). Artificial reheating to about 900° C has caused troilte (T) to react with terrestrial limonite, kamacite and air. The result is fine-grained Fe-S-O eutectics, seen on the left of the photograph. Also, schreibersite (S) and $\alpha_2$-kamacite (K). Etched. Scale bar 50 $\mu$.

Unfortunately, some specimens of Apoala have been reheated artificially. The structure of the reheated specimens will be described on the basis of observations made upon Chicago no. 1008 (694 g) and London no. 86068 (283 g).

The kamacite lamellae display a polycrystalline mosaic of serrated $\alpha_2$ grains, 50-100 $\mu$ in diameter. Surprisingly, some of the $\alpha_2$ grains have Neumann bands, normally only seen in the equilibrated $\alpha$-phase. The only other known example of Neumann bands in the metastable $\alpha_2$ phase is Cacaria. Both irons have been hammered, both during and after heating operations. On Apoala, it may be seen how specimens have been broken apart by hot-chiseling along $\{111\}$ planes. The surface crust has a structure and color which suggest a temperature of 800-900° C; intercrystalline high temperature oxidation is present near the surface. The taenite is homogenized and converted into polycrystalline $\gamma$ grains which again are transformed to $\alpha_2$; because this $\alpha_2$ has a higher nickel content than the $\alpha_2$ of the kamacite lamellae, it etches differently.

The schreibersite bodies are complex. They have not melted, but have been sufficiently reheated to react with the adjacent limonite, introduced by corrosion. The resulting characteristic structures, seen in Figure 260, are very typical for corroded schreibersite that has been reheated artificially. Also, the troilite has reacted with oxygen or limonite and produced ternary Fe-S-O eutectics. It is difficult to escape the conclusion that the material has been reheated to about 900° C for a short time, probably in order to facilitate division. It is particularly apparent that the specimens obtained by Ward in 1900 have suffered reheating. The two sections cut later, 687 and 682 g, respectively, now in Mexico, Washington and Ann Arbor, appear to be undamaged, and indicate that the main mass is also undamaged.

Apoala is a shocked medium octahedrite that structurally and chemically is closely related to Bear Creek, Narraburra, and Smith's Mountain.

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

324 g part slice (no. 908, 11 x 10 x 0.5 cm; originally a 682 g part slice, exchanged in 1935 with Instituto Geologico, Mexico City. Later, however, Perry acquired a slice of 245 g for his collection; this is now in Ann Arbor.

## **Aprelskij**, Amur SSSR

A mass of 54.6 kg was discovered in 1969 in gold-bearing alluvium. It was acquired by the Academy of Sciences in Moscow, and provisionally classified as an octahedrite (Meteoritical Bulletin, No. 48, 1969).

## **Aragon.** See Cedartown

## Arispe, Sonora, Mexico

30°31′30″N, 110°22′W

Coarse octahedrite, Og. Bandwidth 2.9±0.5 mm. Neumann bands. HV 175±10.

Anomalous. 6.70% Ni, 0.47% Co, 0.3% P, 51 ppm Ga, 260 ppm Ge, 9 ppm Ir.

### HISTORY

A specimen of 124 kg (272 lbs) was found in 1898 in the rugged mountains 15 miles northwest of Arispe. It was later brought to Denver and described by Wuensch (1903) and by Ward (1902b), who cut most of it in parallel slices 1-2 cm thick. An endpiece of 32.7 kg is now in Chicago, a large slice of 11.4 kg is in the Colorado Museum of Natural History at Denver, and another full slice of 9.6 kg is in the U.S. National Museum. Two masses found in 1896, 25 miles northwest of Arispe (Farrington 1914) weighing 116 lbs (B) and 20 lbs (C), respectively, are now in the U.S. National Museum (no. 325, undivided) and Chicago (no. 781, 1 kg cut from it).

Six masses were acquired by Nininger between 1927 and 1953. They weighed 30.9 kg (D), 9 kg (E), 22.6 kg (F), 51.8 kg (G), 19.5 kg (H) and 60.3 kg (I). A field survey disclosed no craters but located at least three areas where specimens had been recovered through the years. One of these was about 3 km north of the Santa Rosalia mine, and two others were 11 and 16 km northwest of the site of the first find in 1898 (Nininger, personal communication).

Two further masses of 18.6 kg (J) and 31.2 kg (K) were recovered through the Hawley Brothers, assayers of Douglas, Arizona, and the last mentioned was analyzed by F.G. Hawley (Buddhue 1950). A 122 kg mass (L) that had been used as an anvil in Hermosillo, Sonora, was taken from Arispe on muleback sometime between 1910 and 1912. This is now undivided in the Tempe collection and has been figured by Nininger & Nininger (1950: plate 19).

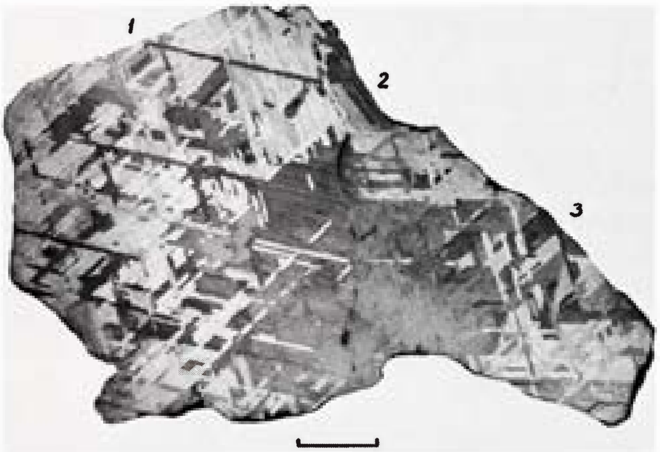


**Figure 262.** Arispe (U.S.N.M. no. 299). Section through the 124 kg mass, A. The meteorite is composed of several large precursor austenite grains of which three are seen in the photo. Etched. Scale bar 50 mm. S.I. neg. 1353C.

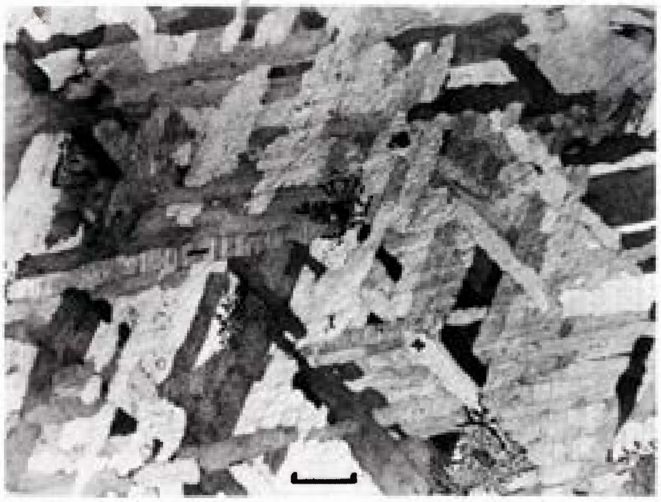

Figure 263. Arispe (U.S.N.M. no. 299). Detail of foregoing, showing coarse octahedrite structure and several cohenite nests. Etched. Scale bar 10 mm.

**ARISPE – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Hawley in Buddhue 1950 | 6.80 | 0.45 | 0.31 | 140 | 200 | | 200 | | | | 15.8* | |
| Goldberg et al. 1951 | 6.97 | 0.49 | | | | | | | 55.6 | | | |
| Lovering et al. 1957 | | 0.48 | | | | 46 | 110 | | 51 | 233 | | |
| Nichiporuk & Brown 1965 | | | | | | | | | | | 7.6 | 17.2 |
| Smales et al. 1967 | | | | | | 14 | 112 | 7.3 | 51 | 229 | | |
| Moore 1968, pers. comm. | 6.69 | 0.46 | 0.31 | | | | | | | | | |
| Wasson 1968, pers. comm. | 6.54 | | | | | | | | 50.8 | 260 | 9 | |

*The value is from Hawley (1939) and includes all platinum metals.

Three masses of 17.9 kg (M), 69.8 kg (N) and 22.0 kg (O) were acquired by the U.S. National Museum in 1938 and 1939. As late as 1954 a mass of 22.6 kg (P) was reportedly found in the same general area.

It thus appears that Arispe was an important shower of iron meteorites, comprised of at least 16 individuals ranging from 123 kg downwards, and scattered over a 20 km "line" extending from Mount San Antonio southeasterly toward Arispe. The coordinates for the midpoint of this line are those given above. The accumulated weight of specimens A-P is 683 kg, which appears to be a conservative minimum estimate of the Arispe shower.

Short descriptions with photomacrographs have appeared on several occasions: Ward (1902b), Wuensch (1903), Merrill (1916a: plates 12, 33), Perry 1944: plate 1), Nininger & Nininger (1950: plates 2, 19), Nininger (1952a: plate 5) and Mason (1962a: figure 52). Short & Andersen (1965) measured in detail the composition of the kamacite and taenite phases, and Frost (1965a) used Arispe as an example for calculating the bandwidth of octahedrites. Stoenner & Zähringer (1958) found by the K/A method the very high age of 6.8 x $10^9$ years; the method is, however, unreliable (Rancitelli & Fisher 1968). Schaeffer & Fisher (1960) estimated the cosmic ray exposure age to be 340 million years, using the data of Schaeffer & Zähringer (1960). Vilcsek & Wänke (1963) found a $^{36}Ar/^{36}Cl$ cosmic ray exposure age of 440±30 million years, a value revised by Chang & Wänke (1969) to 270±40 million years, based upon $^{36}Ar/^{10}Be$. The $^{21}Ne/^{26}Al$ method, as developed by Lipschutz et al. (1965) gave, however, only 120±20 million years, while the $^{40}K/^{41}K$ method (Voshage 1967) gave 905±90 million years. At the present time it is difficult to decide which method is most reliable. Hintenberger & Wänke (1964) measured the concentration of various noble gas isotopes.

**COLLECTIONS**

Washington (178.7 kg), Tempe (122.3 kg anvil, L; 13.4 kg endpiece of D; 1.66 kg slice of I); London (39.9 kg and 1.89 kg), Chicago (32.7 kg endpiece of A; 8.0 kg of C; 1.46 kg slices), Denver (11.4 kg slice of A; 4.6 kg; 8.4 kg), Vienna (13.8 kg), Utah (11.0 kg), Tucson (5.19 kg endpiece; 1.40 kg slice), New York (6.1 kg), Albuquerque (2.8 kg), Mainz (2.3 kg slice of I), Ann Arbor (1.8 kg), Mexico City (1.20 kg part slice of A), Helsinki (0.63 kg part slice of A), Harvard (0.57 kg), Budapest (0.50 kg), Canberra (0.45 kg), Tübingen (0.2 kg), St. Louis (0.05 kg), Copenhagen (54 g).

**DESCRIPTION**

The single fragments range in size from 50 x 35 x 25 cm (A) to 20 x 15 x 10 cm (C). They are irregular and rounded with poorly developed regmaglypts. Small-scale corrosion has been active, but apparently has not removed more than a few millimeters as the heat-affected rim zone is preserved on parts of many specimens. The 69.8 kg uncut specimen (N) displays a 25 mm wide and 25 mm deep cavity where troilite was burned out in the atmosphere. The wall of the cavity is still covered with a corroded fusion crust.

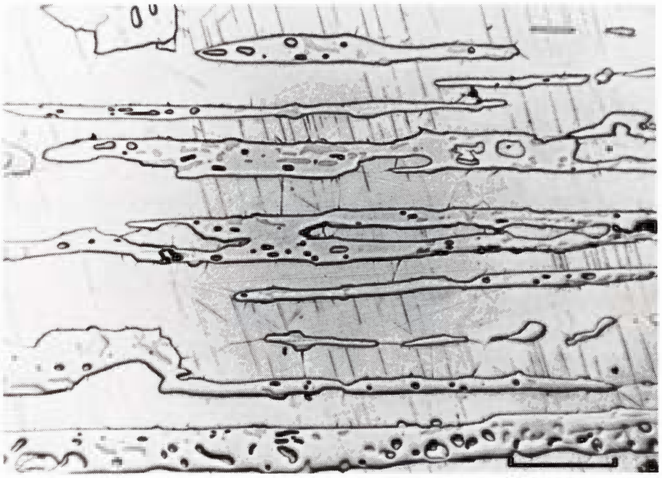

**Figure 265.** Arispe (Tempe no. 9.47). Elongated cohenite crystals, which stand in high relief due to their hardness. HV 1075±25. Etched. Scale bar 400 μ.

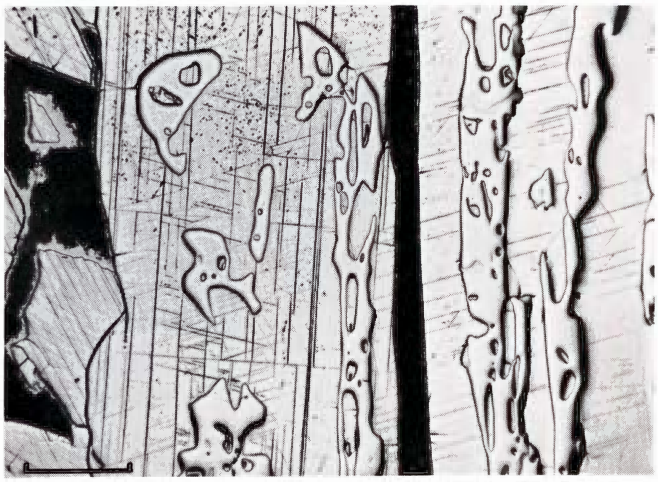

**Figure 264.** Arispe (Tempe no. 9.47). Elongated cohenite crystals, kamacite with Neumann bands, and pearlitic plessite (black). Etched. Scale bar 400 μ.

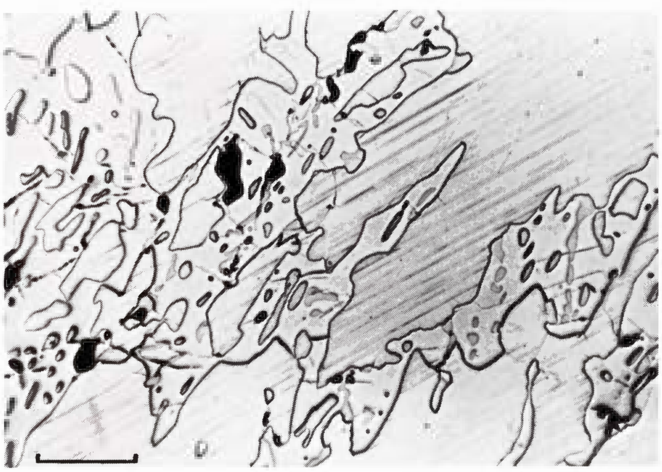

**Figure 266.** Arispe (Tempe no. 9.47). Branching cohenite crystal with inclusions of kamacite, taenite and schreibersite. Etched. Scale bar 400 μ.

The large specimen (A), which was extensively cut by Ward (1902b), shows a polycrystalline nature, with original austenite individuals up to 25 cm in diameter. The grain boundaries are clearly indicated by elongated troilite bodies 2-5 mm wide. On both sides of the grain boundary the α-lamellae are narrowly bundled, only one direction of the Widmanstätten pattern dominating at a time. This is probably because the α-lamellae nucleated heterogeneously at the grain boundary and grew inwards in parallel bundles until they came in contact with homogeneously nucleated lamellae in the interior of the grains. Quite similar development around the grain and twin boundaries may be observed in many other polycrystalline irons, e.g., Gibeon and Savannah.

The width of the α-lamellae is 2.9±0.5 mm. Neumann bands are common; they are somewhat indistinct and appear to be decorated along both sides with submicroscopic precipitates. This observation is supported by the fact that Neumann bands are sometimes selectively corroded near the surface, a phenomenon which I believe only occurs when microsegregation has created a chemical potential. The kamacite has a microhardness of 175±10; this decreases to a minimum of 145±10 at the transition to the heat-affected rim zone, which is 185±10 hard. Where cohenite has provided carbon for local martensite-bainite formation, it is still much harder.

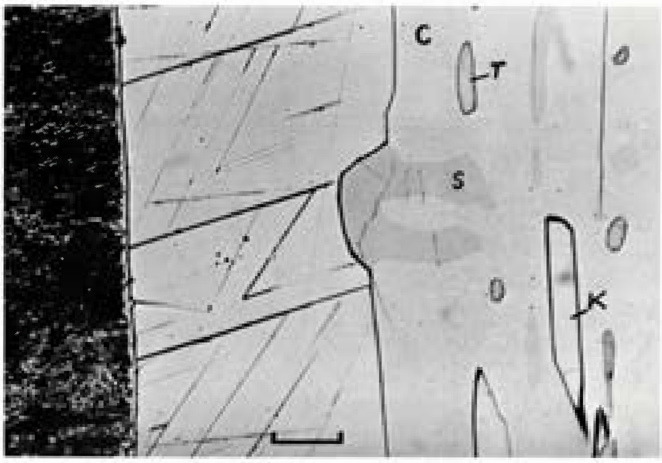

**Figure 267.** Arispe (Tempe no. 9.47). Detail of cohenite (C) with schreibersite (S), kamacite (K) and taenite (T) inclusions. To the left, dark pearlitic plessite. Etched. Scale bar 50 μ.

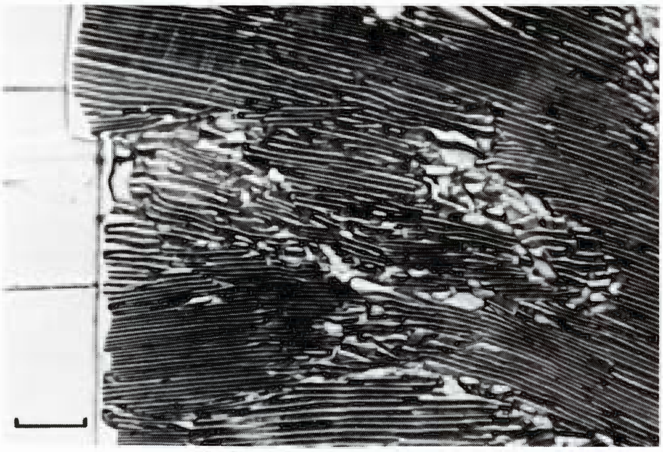
**Figure 268.** Arispe (Tempe no. 9.47). Pearlitic plessite. The kamacite of the lamellar structure is partially etched away, so that the taenite lamellae stand in distinct high relief. Scale bar 20 μ.

Troilite inclusions 1-3 mm in diameter are irregularly distributed. On 10 sections totaling 3,115 $cm^2$, 59 nodules were encountered with a total area of 15.9 $cm^2$, corresponding to an average content of 0.11% S in the meteorite. Troilite in the interior of the grains is in the form of well-rounded nodules while in the grain boundaries it occurs as elongated, rounded bodies. In one troilite nodule, a hard, black, angular mineral 3 x 2 mm was included; by visual inspection it was determined to be either chromite or a phosphate, like the sarcopside described from Bella Roca (Olsen & Fredriksson 1966). The smaller troilite nodules (0.1-0.5 mm) have been shock melted and now display a polycrystalline array of intergrown troilite, daubreelite and metal with 5-10 μ grain size.

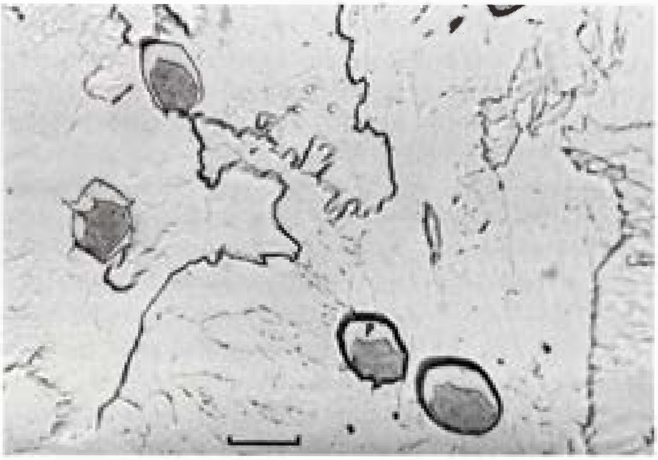
**Figure 269.** Arispe (Tempe no. 9.47). Detail of the heat-affected $\alpha_2$ zone with melted rhabdites. These solidified by heat conduction from the interior (above), so that the primary solidification products (P) grew from the interior sides of the walls. Etched. Scale bar 20 μ.

Schreibersite with a microhardness of 960±30 is present as laths and hieroglyphs, typically 5 x 1 mm in size, positioned centrally in the α-lamellae. It also occurs as 20-50 μ wide grain boundary precipitates, and envelops the troilite with 100-300 μ thick rims. Rhabdites are abundant as 5-20 μ thick prisms. A most unique characteristic of Arispe is the distribution of the cohenite nests. They occur as 1-2 $cm^2$ arborescent, palmate or feathery aggregates which are spaced with approximately one per 50 $cm^2$. Each branch may be 100 μ thick and may itself include tiny schreibersite, ferrite and taenite bodies. These cohenite complexes never are located near the original austenite grain boundaries, but apparently occur where carbon-saturated residual austenite became concentrated. Cohenite is also present as a 100-200 μ thick envelope around the larger schreibersite bodies. The microhardness is 1075±25.

As is always the case when iron meteorites are rich in carbon, the plessite is frequently pearlitic with single lamellas being about 1 μ thick. Plessite and taenite, however, are not abundant in Arispe, covering only about 2%, in harmony with the low overall nickel content of 6.7% Ni.

Carbon and sulfur determinations by Buddhue (1950) apparently represent inclusion-free material. A modest quantity of carlsbergite in the form of 5 x 1 μ hard, oriented particles occurs in the kamacite phase.

On several specimens the rim zone from atmospheric heating was observed. Due to lack of cutting data, however, it is not known if both primary and secondary surfaces developed a heated transformation zone. Heating was intense enough to create a 4 mm thick $\alpha_2$ zone, with melted phosphides in the exterior 50%. The cohenite melted to form ledeburite eutectics where the temperature was briefly above 1100° C. Farther in, carbon diffused out from the cohenite to create 20-50 μ thick, black-etching borders of bainitic-martensitic structures. Even a 100-500 μ thick, laminated fusion crust of dendritic iron may be found locally.

Occasionally, plastic deformation is observed over some square centimeters near the surface. The Widmanstätten structure with Neumann bands is elongated and/or curved as if a tensile test had been carried out. The included rhabdites are broken and arranged en-echelon because of their nonconformity with the plastic metal. The structure is best interpreted as caused by the breakup in the atmosphere of the main mass. Although part of the fracture would follow brittle inclusions and grain boundaries, the fracture zone occasionally would have to pass metallic areas, thus giving rise to a tensile fracture with local elongation and necking. Individuals from other showers show similar plastic features which in my opinion may be caused by the same series of events. Particularly illustrative specimens are found among Gibeon fragments.

Chang & Wänke (1969) found the terrestrial age of Arispe to be 240,000±50,000 years by measuring the decay rates of $^{36}Cl$ and $^{10}Be$. This is a surprisingly high age for an iron that still retains considerable parts of its heated rim

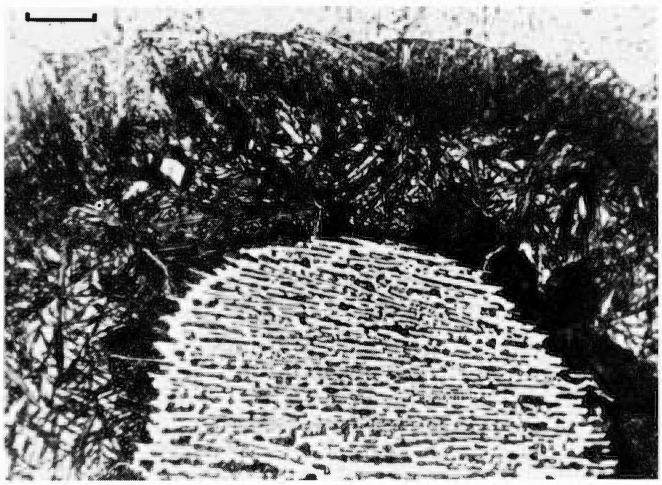

**Figure 270.** Arispe (Tempe no. 9.47). Cohenite crystals in the exterior part of the heat-affected $\alpha_2$ zone melted rapidly and solidified to ledeburitic structures. Acicular carbon-nickel martensite surrounds the melted material. Etched. Scale bar 20 μ.

zone, and it is hard to explain even considering the (present) aridness of the place of find, the Sonoran Desert zone, where only ocotillo, catclaw and cacti thrive.

In summary, Arispe is an unusual meteorite, with the same Ga-Ge content as group I meteorites like Toluca and Bischtübe, but with considerably less nickel and more iridium. The bandwidth is 2.9 mm, double that of Toluca and Bischtübe, and the cohenite nests are a unique feature. The polycrystallinity is rare, but far from extraordinary. Bendego may be a related iron.

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

9.6 kg slice (no. 299, 44 x 30 x 1.5 cm, part of A)
52.5 kg individual (no. 325, 35 x 20 x 13 cm, B)
17.9 kg individual (no. 1313, 19 x 16 x 11 cm, M)
69.8 kg individual (no. 1327a, 35 x 20 x 20 cm, N)
22.0 kg individual (no. 1327b, 25 x 19 x 18 cm, O)
4.63 kg endpiece (no. 826, 22 x 13 x 4.5 cm, part of D)
1.63 kg slice (no. 826, 25 x 15 x 1 cm, part of D)
0.7 kg smaller cuts and slices (nos. 1573, 2637, 2638, 3280)

## **Arlington**, Minnesota, U.S.A.

44°37′N, 94°3′W

Medium octahedrite, Om. Bandwidth 0.80±0.20 mm. Neumann bands. HV 160±10.

Anomalous. 8.52% Ni, 0.43% Co, 0.02% P, 21.3 ppm Ga, 64.9 ppm Ge, 6.1 ppm Ir.

### HISTORY

A mass of 8.95 kg was found by a boy, Joe Barry Jr., in 1894 on his father's farm 2.5 miles northeast of Arlington, in Sibley County. Because of the unusual flat shape of the meteorite it was easily broken in two with a sledge hammer, but both fragments eventually were procured for the University of Minnesota, where it was described by Winchell (1896) with several photographs. About 1 kg in 25-100 g slices was distributed through Ward's Establishment about 1900. Bauer (1963) estimated the cosmic ray exposure age to be 220 million years.

### COLLECTIONS

Washington (6.14 kg main mass), New York (996 g), Chicago (164 g), London (157 g), Vienna (112 g), Tempe (62 g), Berlin (55 g), Vatican (35 g), Bonn (34 g), Budapest (27 g), Harvard (24 g), Paris (16 g), Yale (10 g).

### DESCRIPTION

Arlington and Tawallah Valley are perhaps the flattest meteorites known. Arlington is bounded by two almost plane-parallel surfaces and its greatest dimensions are 39 x 39 x 2.5 cm, but the average thickness is only 2 cm. On superficial inspection, it resembles a furnace product or a cast iron slab. It is covered by 0.1-0.5 mm limonitic corrosion products, but the original flight markings may still be seen in many places as delicate striae, furrows and warts. One face, evidently the front side during flight, is largely smooth, but pockmarked all over with shallow indentations, 5 mm in diameter and less than 1 mm deep. The other side is more pitted, with grooves ranging from 10 mm across and 10 mm deep, to 40 x 20 mm across and 12 mm deep. Many grooves are irregularly filled with aggregates of 1-2 mm spheres which evidently are ablation products from the front side, recemented here. The edge of the plate is carved and furrowed showing the general direction of the airstream from front to back. Arlington is a rare example of stabilized flight, where part of the ablation products from the exposed front were accumulated as spherules on the protected rear, and here fused together to irregular aggregates in rapidly excavated whirlpool grooves. A similar ablation process took place on the Sputnik IV fragment as described by Marvin (1963).

The Widmanstätten structure is anomalously developed, with only few well-defined kamacite lamellae, the bandwidth of which is 0.8±0.2 mm. Most of the sections are covered by parallel, straight bundles of alpha with smaller bandwidth. Neumann bands are abundant. The microhardness is 160±10. It increases in the heat-affected $\alpha_2$ zone to 175±10, a rather low value due to the kamacite being poor in nickel and phosphorus. A hardness track across a 2 cm section through the meteorite is of type II, with the two recovery minima of about 145±5 occurring at a depth of 1.5-2 mm.

Taenite occurs as 10-50 $\mu$ wide, massive ribbons between the kamacite lamellae. Minor amounts of a very open-meshed comb plessite are present. Contrary to Winchell's opinion (1896), the iron is extremely homogeneous and free of inclusions. Schreibersite and rhabdite are not present in any form, in harmony with the analyses, and troilite and daubreelite are also absent. One single chromite crystal, 10 $\mu$ in diameter, was observed. There is no evidence of silicates or other inclusions along the edge of the large surfaces.

The friction-heated $\alpha_2$ zone is about 1.5 mm wide on the front side, but about 2 mm wide on the back side, where the temperature gradient was less steep during penetration of the atmosphere. Sections through the small, ablated spheres mentioned above show them to be composed of an extremely finely crystallized, and therefore rapidly solidified, nickel-iron alloy. The microhardness is 275±25. It is interesting that the contacting linear elements of the underlying Widmanstätten structure are often bent and distorted, indicating rather strong impacting and shearing forces in the plastic, hot material of the heat-affected zone.

Arlington is a meteorite of anomalous shape, structure and chemistry. It is difficult to understand how the overall flat shape of Arlington was achieved. The plate is not a fragment created by splitting along octahedral planes, as indicated by the Widmanstätten orientation, and it appears also to be devoid of embrittling inclusions.

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

5.73 kg main mass (no. 3281, 31 x 19 x 2 cm)
410 g part slice (no. 627, 5 x 5 x 2 cm)

## **Arltunga**, Northern Territory, Australia
## 23°28'S, 134°40'E

Ataxite, D. Extremely fine Widmanstätten pattern; 5 $\mu$ wide $\alpha$-spindles. HV 200±10.

Anomalous. 9.91% Ni, 0.63% Co, 0.24% P, 0.02% S, 74 ppm Ga, 80 ppm Ge, 17 ppm Ir.

**HISTORY**

A mass of 18 kg was found in 1908 by Dan Pedler, two miles south of the Government Cyanide Works at Arltunga, at the eastern end of the MacDonnell Ranges. The meteorite was purchased by the South Australian Museum, Adelaide, where it was described and figured by Mawson (1934) and Edwards (1943). It was included in Lovering & Parry's thermomagnetic study (1962) and was briefly examined by Axon (1968b).

**COLLECTIONS**

Adelaide (15.4 kg main mass and 335 g slice), Washington (979 g), London (369 g), Canberra (236 g), Sydney (157 ?? g).

**DESCRIPTION**

The angular mass has the overall dimensions 26 x 16 x 14 cm, with a flat base and irregular but generally smooth sides (Mawson 1934). Corrosion has attacked the mass, evenly removing at least 2 mm on all sides, as no fusion crust and no heat-affected zones are preserved. Mawson

**ARLINGTON – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Sharpless in Winchell 1896 | 8.61 | 1.02 | 0.045 | | | | | | | | | |
| Moore & Lewis 1968 | 8.50 | 0.44 | 0.02 | | | | | | | | | |
| Jarosewich 1968, pers. comm. | 8.55 | 0.41 | 0.02 | | | | | | | | | |
| Wasson 1968, pers. comm. | 8.42 | | | | | | | | 21.3 | 64.9 | 6.1 | |

The cobalt content in the 1896 analysis is too high, but otherwise the analyses agree remarkably well.

(1934) had assumed it to be a recent fall, but this is highly unlikely since the corrosion observed probably required thousands of years of exposure to the Central Australian climate. The polished surfaces become finely frosted in appearance when etched in Nital, as characteristic for ataxites. The only structural elements visible to the naked eye or handlens are tiny, reflecting troilite blebs, 100-500 μ in diameter, evenly distributed with about one per cm$^2$.

The ataxitic structure consists of a dense grid of plates or fingers of kamacite, aligned octahedrally in a plessitic matrix. The 50-100 μ long α-fingers are 5 μ wide on the average, but may increase to about 15 μ. Surprisingly, only few large schreibersite blebs appear to be present inside the α-lamellae, as most schreibersite is evenly distributed as 1-5 μ rounded, monocrystalline blebs. No Neumann bands are present. The plessitic matrix is an intricate, granulated mixture of kamacite, taenite and schreibersite. The taenite proper is hardly more than 1 μ wide, but it often widens to irregular, concave, 5 x 10 μ patches; the interior of these is duplex $\alpha + \gamma$ on a submicroscopic scale. The whole morphology resembles the structure of an acicular plessite type common in Laurens County. The microhardness of the matrix, averaging over several $\alpha + \gamma$ units, is 200±10. Lovering & Parry (1962) analyzed the kamacite and the taenite with a microprobe and found 7.5±1% Ni and 27-32% Ni, respectively.

The troilite nodules are anisotropic and monocrystalline, but most of them display lenticular twins, probably due to a mild shock. The average size of the nodules is 300 μ, but they range from 5 μ to 3 mm, and the small sizes are ubiquitous. The large nodules have a thin rim of kamacite. Daubreelite is not present, but a few angular chromite crystals 10 μ in diameter, normally associated with troilite, are present. Occasionally the chromite is developed as thin plates, 10 x 1 μ, also associated with troilite. The high overall chromium content reported in 1934 appears, however, to be in error.

From the crystallographic development it is clear that Arltunga was once a homogeneous austenite crystal. The homogeneous distribution of sulfides is unusual, and may indicate that they are the result of solid phase precipitation between 900° and 800°, when the solid solubility of sulfur in iron decreased below 0.02% S (Hansen & Anderko 1958). The development of the Widmanstätten structure is unusually fine, almost martensitic in appearance, and indicates that Arltunga cooled more rapidly than most other meteorites. This viewpoint was recently corroborated by Goldstein (1969), who listed Arltunga and Monahans as having the highest absolute cooling rate of 500° C per million years, in the range 700-400° C.

Arltunga has a superficial resemblance to other ataxites on the 10% nickel level, such as Del Rio, Monahans, and Nordheim. A closer inspection of the structural details, however, reveals significant differences, and comparison of the Ga-Ge-Ir concentrations supports the view that these meteorites are unrelated, with probably different places of origin. There remains, however, the intriguing possibility that Arltunga is a group IID iron, related to N'Kandhla and Richa, which has become metamorphosed to an entirely new structure. Similar metamorphism has been thoroughly treated under, e.g., Mejillones (IIA), Juromenha (IIIA) and Smithland (IVA).

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

534 g slice (no. 2467 a, 17 x 8 x 0.7 cm)
455 g slice (no. 2467 b, 16 x 8 x 0.6 cm)

## **Armanty**, Outer Mongolia, China

About 47°N, 88°E

A mass of about 30 tons was found before 1900, but very little is known of it. Analyses of small fragments by Dyakonova (1958; 1959) indicate that it is an octahedrite with 9.1% Ni. In 1965, it was transported about 500 km from the point of discovery to Urumchi, the capital of Sinkiang (Sky & Telescope 1965: 347). In this report, and in a report by Aristov (Meteoritika 1962: volume 22: 112) a few photographs of the exterior were presented, suggesting that the total weight must be close to 30 tons. For further references, see Hey (1966: 27) and Yavnel (1965a; 1968; 1971) and Pokrzywnicki (1969).

## **Aroos**. See Yardymly

## **Asheville**, North Carolina, U.S.A.

35°41'N, 82°37'W; 600 m

Medium octahedrite, Om. Bandwidth about 0.6 mm. ε-structure. HV 290±20.

Group IIIB on basis of nickel content and structure. 9.1% Ni.

**ARLTUNGA – SELECTED CHEMICAL ANALYSES**

Lovering's analysis is preferable with respect to cobalt and chromium. Point counting confirmed the phosphorus analysis. Point counting of the troilite inclusions on 400 cm$^2$ gave 0.02% S.

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Chapman in Mawson 1934 | 10.22 | 1.01 | 0.24 | | | 2600 | | | | | | |
| Lovering et al. 1957 | 10.08 | 0.63 | | | | 73 | 307 | | 30 | 68 | | |
| Wasson 1972, pers. comm. | 9.64 | | | | | | | | 76.8 | 81.5 | 17 | |
| Reed 1972b | 9.7 | | | | | | | | 71 | 79 | | |

HISTORY

A rounded mass nearly as large as a man's head was found on Colonel Baird's plantation, near French Broad River, six miles north of Asheville, Buncombe County (Shepard 1839; 1847: 79). Shepard passed his 276 g specimen over to Amherst College, Massachusetts (Shepard 1872a), while other small specimens eventually reached European collections; thus, about 340 g (now 271 g) came via Mr. Heuland in London to Vienna (Partsch 1843: 116). Most of the original mass appears to have been lost, but it probably did not exceed 15 kg, estimating from the early descriptions. Specimens corroded rapidly, even when stored under good conditions in collections. It was classified as a medium octahedrite with a bandwidth of 0.6 mm, and was compared to Hraschina, La Caille and Rodeo (Rose 1864a: 65; Brezina 1885: 209; 1896: 272; Klein 1906: 114).

COLLECTIONS

Vienna (271 g), London (115 g), Amherst (275 g), Yale (36 g), Washington (6 g). When the last catalogs of the respective collections were issued, a few grams were in each of the following Museums: Berlin, Paris, Moscow, Tempe and Chicago.

CHEMICAL ANALYSIS

9.07% Ni (Dyakonova 1958a).

DESCRIPTION

Only heavily corroded, small fragments are in the U.S. National Museum. They appear, however, to belong to a medium octahedrite with some schreibersite inclusions. The few blebs of uncorroded kamacite have a hardness of 290±20, suggesting a shock-hardened $\epsilon$-structure. The corroded material appears to correspond well to the observations of Brezina (1885) on better-preserved specimens: "0.6 mm bandwidth, kamacite with indistinct Neumann bands and dark-etching plessite. Many schreibersite bodies centrally in the kamacite, but irregularly dispersed." The nickel content and shock-hardened $\epsilon$-structure together indicate an iron of group IIIB, possibly similar to Grant or Cleveland. A final conclusion could not be reached due to the small amount of material available. The meteorite is probably of high terrestrial age.

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

1.5 g weathered fragments (no. 964, Shepard Collection no. 29)
4.7 g fragments, mainly oxide-shales (no. 1537 from Brit. Mus. no. 34375)

**Ashfork.** See Canyon Diablo (Ashfork fragment).

## **Aswan**, Egypt

23°59′N, 32°37′E

Medium octahedrite, Om. Bandwidth 1.2±0.3 mm. Neumann bands.

No reliable analysis available. Probably 8% Ni and 0.25% P and a member of group IIIA.

HISTORY

A mass of 12 kg was found about 1955 on the road leading from Aswan to the small oasis of Kurkur. It was briefly described by El Shazly (1958) who stated that the main mass was kept by the Egyptian Iron and Steel Company at Aswan. It has been included in age determination studies by Herr et al. (1961) and by Sobotovich (1964).

CHEMICAL ANALYSIS

The only available analysis, given by El Shazly (1958), is 5.69% Ni, but this is far too low for the structure. From structural considerations I would estimate the composition as 8.1±0.2% Ni, 0.25% P, and trace-element concentrations corresponding to an iron that is transitional between groups IIIA and IIIB.

DESCRIPTION

The mass is roughly conical with maximum dimensions 25 x 18 x 10 cm. El Shazly said (1958) that the surface was pockmarked by numerous small pits 2-3 mm in diameter, and that polished sections showed no characteristic structure. Consequently, he classed it as a nickel-poor ataxite.

The small end section in the U.S. National Museum displays, however, a definite octahedral structure with a bandwidth of 1.2±0.3 mm. Comb plessite is present, and decorated Neumann bands have been present in the kamacite lamellae. Schreibersite is common as 5 x 0.2 mm bodies centrally in the kamacite lamellae, and as 25-50 $\mu$ wide grain boundary precipitates. Rhabdites and other minerals were not observed on the small section.

The U.S. National Museum specimen has been heated so much that the surface is melted and covered with a 0.2 mm thick black, shiny magnetite crust. There are also tiny cemented metallic spherules present with dendritic structures. All the kamacite of the specimen has been transformed to aggregates of serrated $\alpha_2$ grains, indicating reheating temperatures above 800° C. The hardness is 170±15. Traces of the original Neumann bands are partially preserved because fine precipitates ($< 1\ \mu$) had been segregated here preterrestrially. Near the surface the phosphides have melted, and there is a thermal gradient similar to the one which can be established in the rim zone of rather fresh falls (see, e.g., Buchwald 1961b). There are, however, indications that part of the meteorite was heated by man, probably with an oxy-acetylene torch. As only a small specimen was studied, it is too early to conclude whether Aswan is a rather fresh fall or a weathered, pitted fall from which specimens have been cut with a torch; the author is inclined to the last explanation. Aswan evidently needs a new analysis and a restudy in larger sections. Please see also the Supplement.

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

11 g end section (no. 1865, 3 x 1.5 x 1 cm), reheated artificially

## Auburn, Alabama, U.S.A.

32°37'N, 85°30'W; 200 m

Coarsest octahedrite, Ogg. Bandwidth 5-10 mm. Neumann bands. HV 160±10.

Anomalous. 5.2% Ni, about 0.3% P, 44 ppm Ga, 70 ppm Ge, 0.02 ppm Ir.

### HISTORY

A mass of about 3.6 kg was plowed up many years before 1869 on the Daniel Plantation, about one mile west of East Alabama College, Auburn, Macon County (Shepard 1869). It exhibited large irregularly shaped "concretions," which obscurely showed traces of octahedral cleavage. It was easily broken in the blacksmith's shop with a sledge hammer. J.L. Smith (1870) criticized Shepard's analysis and pointed out that cobalt was always present in meteoric irons. Cohen (1905) described a small fragment, and Böggild (1927) discussed the crystallography of the rhabdites. Auburn is listed as a hexahedrite in Hey's Catalog (1966), but as discussed below, is rather a coarsest octahedrite related to Tombigbee, and more remotely to Sikhote-Alin.

### COLLECTIONS

Amherst (2,455 g), Washington (200 g), New York (99 g), Stockholm (42 g), London (37 g), Chicago (28 g), Copenhagen (23 g), Vienna (18 g). Because this meteorite parts easily along corroded grain boundaries, it has been extensively distributed. Most museums apparently possess angular, corroded fragments of 25-50 g, or weakly adhering aggregates of angular "fingers." During the present preparation of some fragments, allegedly of Auburn, it was discovered that they belonged to Lime Creek. This mislabeling may occur elsewhere.

### DESCRIPTION

The largest preserved specimens are two heavily corroded fragments, in Amherst, that are disintegrating along the grain boundaries. They are composed of fingers and platelets of kamacite, much like El Burro, Sikhote-Alin and certain specimens of Tombigbee. A violent corrosion has penetrated along all grain boundaries and frequently has separated the meteorite completely into grains, typical sizes of which are 3 x 2 x 0.5 cm, 3 x 1 x 1 cm, and 1 x 1 x 1 cm. Polished sections show that the individual grains consist of monocrystalline ferrite with Neumann bands. The microhardness is 160±10. Locally small taenite islands 30 x 10 $\mu$ in size, with still smaller schreibersite inclusions, are present.

Troilite-daubreelite-schreibersite intergrowths occur as small scattered nodules 25-50 $\mu$ in diameter. The troilite is a polycrystalline aggregate of 2 $\mu$ grains, apparently due to shock melting. Schreibersite occurs as scattered, angular platelets up to 0.5 x 0.1 mm in size; they are, in fact, large rhabdites. There are also indications that 0.1-0.2 mm wide schreibersite precipitates originally were present in the now heavily corroded grain boundaries. Small rhabdites, about 2 $\mu$ in diameter, exist in profusion. Point counting gives about 0.3% total phosphorus. Near the grain boundaries, selective corrosion has attacked the relatively nickel-poor surroundings of the rhabdites. The natural heat-affected rim zone has been removed by corrosion.

Locally, a very small $\alpha_2$ zone may be distinguished in connection with plastic deformation. It probably indicates that the blacksmith used some heat or hot-chiseling in order to split the mass. It may also mean that the measured hardness, 160, is low, due to mild artificial annealing.

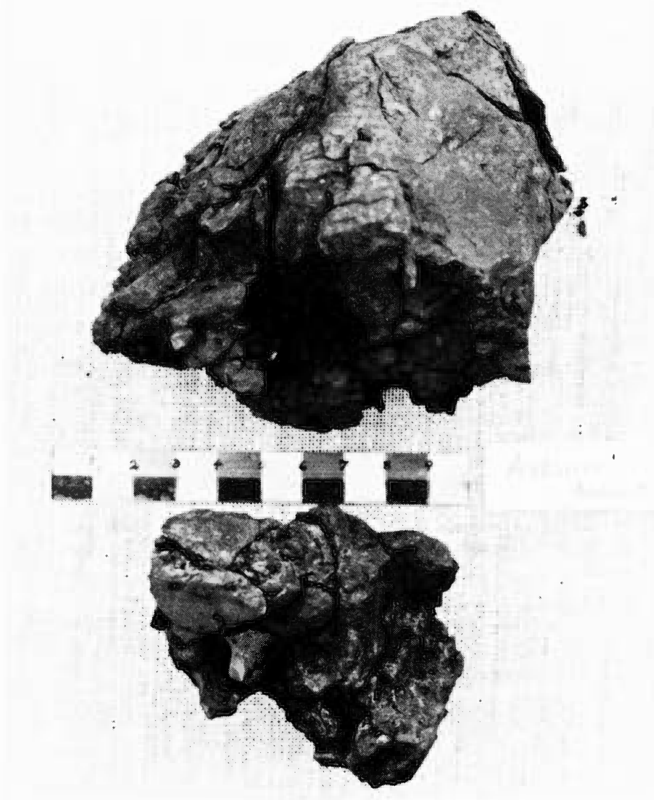

**Figure 271.** Auburn (Amherst). The largest samples of Auburn are these two masses of 1.7 and 0.7 kg, respectively. They are, due to terrestrial weathering, decomposing along the very coarse Widmanstätten lamellae. Scale bar 10 cm.

AUBURN – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Moss in Hey 1966 | 5.9 | | | | | | | | | | | |
| Wasson 1970, pers. comm. | 4.6 | | | | | | | | 44.0 | 69.9 | 0.02 | |

Considering the structural similarity to group IIB, it is somewhat unexpected that the chemical data, particularly the low germanium content, place Auburn well outside this group. It is, however, interesting to note that Auburn in many respects is similar to Tombigbee, especially to the more uncommon variety of Tombigbee with octahedral structure. Tombigbee was found in numerous fragments, also in Alabama, but 250 km further west. The large distance between the two well-documented places of find make it appear unlikely that the two falls are associated. The conclusion of the present examination is that Auburn is an anomalous iron, transitory between the coarsest octahedrites and the hexahedrites, and closely related to Tombigbee, Bellsbank and La Primitiva. Under terrestrial corrosion and treatment with a sledge hammer, it almost completely disintegrated into individual coarse grains.

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

20 g angular fragment (no. 35, 4 x 1 x 1/2 cm)
191 g angular fragments (no. 957, many pieces, the largest 45 g)
24 g angular fragment (no. 3282, 25 x 18 x 10 mm)

## Augusta County, Virginia, U.S.A.

Approximately 38°10′N, 79°5′W

Medium octahedrite, Om. Bandwidth 1.15±0.15 mm. ϵ-structure. HV 305±15.

Group IIIA. 8.1% Ni, about 0.15% P, 18.4 ppm Ga, 35.5 ppm Ge, 8.9 ppm Ir.

### HISTORY

A mass of 69 kg was found in 1858 or 1859 by Alf, a Negro, belonging to Robert Van Lear on whose land the 25 kg Staunton mass No. 1 was found in 1869. Alf tried to sell the 69 kg mass in Staunton, asking a dollar but, failing, he threw it away. The mass was later used in building a fence, but eventually was rediscovered by M.A. Miller (see Greenbrier County), who sold it in 1877 to Ward's Natural History Establishment. Ward cut the specimen into numerous slices and distributed it at least as early as 1879; see, e.g., his catalog (1892: 9, 41). The mass was described as Staunton No. 4, with a figure of the exterior, by Mallet (1878) who without further proof assumed it to belong with the other Staunton masses which he previously (1871) had described. Only Brezina (1896: 278, 363) objected and pointed out that the structure of No. 4 was significantly different from the others. It seems however, to have been too late; large amounts of material cut from the various blocks had already been distributed, and neither Wülfing (1897: 341) nor Farrington (1915: 423), nor in more recent time Hey (1966: 463) accepted Brezina's conclusion. Unfortunately, slices from this mass and from five more masses have therefore, in all collections, indiscriminately been labeled "Staunton."

The same appears to be true of the 7.1 kg mass which was described as another Staunton mass (No. 6) by Campbell & Howe (1903). This mass had been found by W.N. Wilson at an unknown date and place in Augusta County and in 1870 had been donated to the Washington & Lee University. The description and the photomacrograph given by Campbell & Howe, and the included analysis by Whitfield, all indicate that the 7.1 kg mass is of the same type as the 69 kg mass. Dr., later Sir, William Ramsay (1895) examined the 7.1 kg mass, and an undetermined one of the other masses, and proved for the first time the existence of helium and argon in meteorites.

When in the present study I discovered that two different meteorites were hidden under the common name

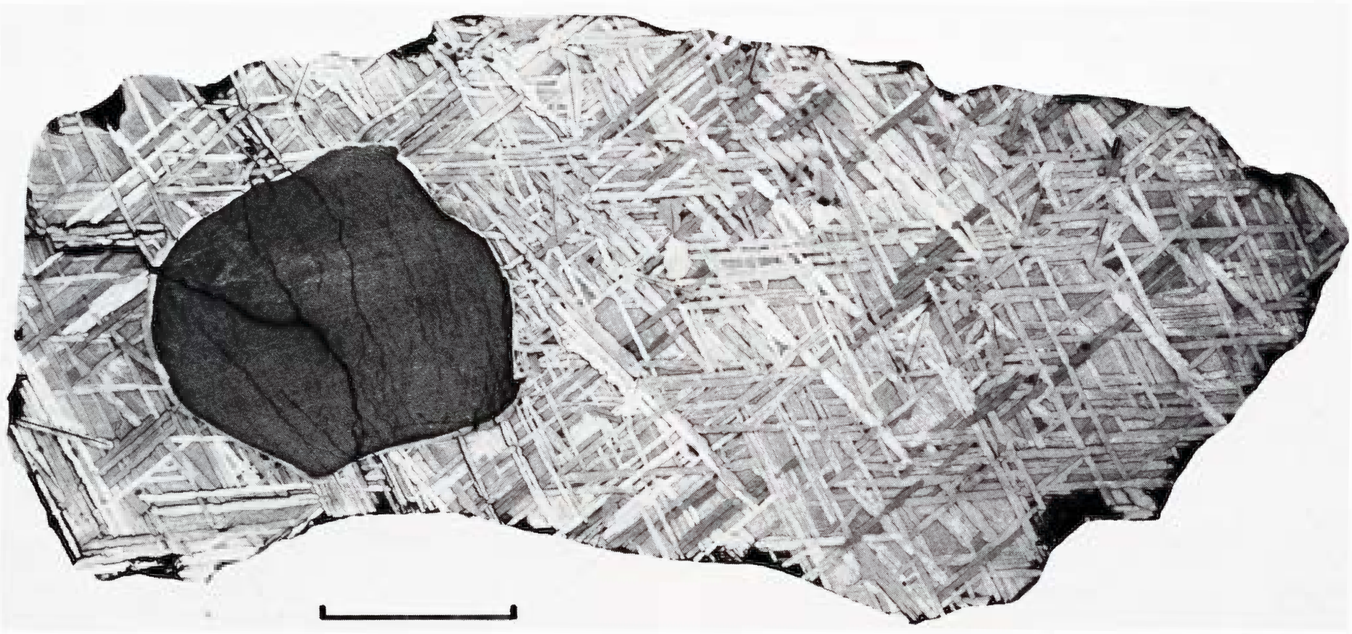

**Figure 272.** Augusta County (U.S.N.M. no. 808). A slice which is typical for Augusta County material. A large troilite inclusion and several very thin chromite-troilite Reichenbach lamellae, enveloped in swathing kamacite. Etched. Scale bar 30 mm. S.I. neg. 1578A.

Staunton I asked for modern analyses to be performed. These confirm fully that masses Nos. 4 and 6 are different from Nos. 1 through 3 and possibly different from No. 5. I propose to use the name Augusta County for Nos. 4 and 6 since their origin is not exactly known except for the county and since this name was used by Mallet (1878) in the original description.

Brezina (1880b) examined the orientation of the Reichenbach lamellae and gave an excellent photomacrograph, which today may be of help when trying to identify Augusta County specimens. Other publications have appeared, but since no one has identified the examined material it is of little interest to quote the works. Perry (1944: plate 3) gave a photomacrograph of a slice which may be identified as Augusta County. Brett & Henderson (1967: figure 4) gave a photomicrograph with an insufficient caption. The correct description of the phases are, from left to right, kamacite, limonite, schreibersite (white), chromite (dark, 3 μ wide lamella), troilite, limonite, troilite, kamacite. This material was also from Augusta County.

**COLLECTIONS**

The following is a preliminary reconstruction of the locations of slices cut from Augusta County, Nos. 4 and 6: Vienna (4,840 g), Washington (4,835 g), Chicago (1,582 g; 1,260 g), Harvard (2,740 g), Berlin (1,470 g), New York (1,143 g), London (Brit. Mus. no. 54820, 1,292 g), London (University College No. 3004, 915 g), Ann Arbor (401 g) Tübingen (162 g), Copenhagen (55 g). Many other specimens are in collections, notably Budapest (6.57 kg), Rome (2.90 kg), Paris (2.77 kg), Sydney (1,346 g), Yale (953 g), and Stockholm (831 g); I have not seen these latter slices, and they may have come from one of the authentic Staunton masses.

**DESCRIPTION**

The 69 kg mass has the extreme dimensions 45 x 29 x 20 cm, while the dimensions of the 7.1 kg mass are unknown. The specimens in the U.S. National Museum, of which one is a 1.56 kg endpiece, show that the masses are corroded and covered with 0.1-2 mm thick crusts of terrestrial oxides. Some exfoliation along corroded Widmanstätten planes has taken place. No fusion crust and almost no heat-affected $\alpha_2$ zones were detected, so it seems that on the average more than 2 mm has been lost during a long terrestrial exposure.

Etched sections display a normal, medium Widmanstätten structure of straight, long $(\frac{L}{W} \sim 20)$ kamacite lamellae with a width of 1.15±0.15 mm. The subboundaries are decorated with a few 0.5-2 μ rhabdites, but otherwise rhabdites are absent. Due to shock above 130 k bar, the kamacite is transformed to the hatched, shock-hardened $\epsilon$-variety with a hardness of 305±15, with occasional softer spots. On specimen no. 3375 about 1 mm of the heat-affected $\alpha_2$ zone is preserved locally. The hardness drops from the interior high level to 200±8 in the $\alpha_2$ zone (hardness curve type I).

Taenite and plessite cover about 40% by area, as comb and net plessite and as martensitic and black-etching, duplex fields. The tarnished taenite ribbons and rims have a hardness of 390±15; adjacent, martensitic transition zones increase in hardness to 450±20. Duplex interiors, with poorly resolvable individual taenite grains, have a hardness of 360±20, until the readily resolvable textures reach hardness levels comparable to the surrounding kamacite lamellae.

Schreibersite is not present as larger bodies, but common as 10-50 μ wide grain boundary precipitates, and as 5-50 μ thick blebs in the plessite. It also forms discontinuous, 5-30 μ wide precipitates upon the troilite nodules and the chromite-troilite Reichenbach lamellae. The bulk phosphorus content is estimated to be 0.15±0.03%.

Troilite forms some very large nodules, e.g., 6.5 x 5 x 4 cm, but small, rhombic and lenticular bodies of about 2 x 2 and 4 x 0.5 mm are also common. The troilite is monocrystalline but displays lenticular deformation twins; most of the nodules are enveloped in distinct 0.5-1.5 mm wide rims of swathing kamacite.

Reichenbach lamellae occur with a frequency of about one per 10 cm². Brezina (1880b) showed that the very thin lamellae mainly occurred in the $(100)_\gamma$ planes and this was

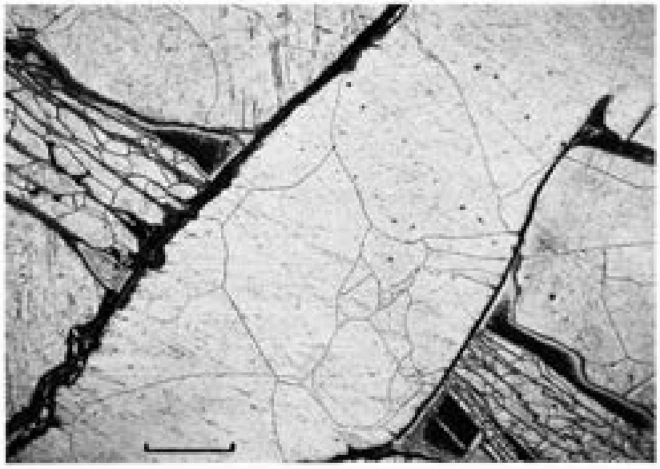

**Figure 273.** Augusta County (U.S.N.M. no. 808). Shock-hatched $\epsilon$-structure and subboundaries in the kamacite. Two comb plessite fields with black taenite wedges. Black limonite vein along left grain boundary. Etched. Scale bar 40 μ. (Perry 1950: Volume 4.)

**AUGUSTA COUNTY – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Wasson 1970, pers. comm. | 8.12 | | | | | | | | 18.4 | 35.5 | 8.9 | |

confirmed in the present study. The lamellae in Augusta County apparently never follow the Widmanstätten structure. They are typically 20 x 15 x 0.05 mm in size and consist of a backbone of chromite, upon which troilite and schreibersite are precipitated in varying proportions. Since the assemblage is sensitive to corrosion, the troilite in particular may be converted to pentlandite and the adjacent kamacite rim to limonite, which blurs the relationship somewhat. An examination with the aid of the electron microprobe confirmed that the straight, 2-5 $\mu$ wide backbone consists of chromite and that the 10-30 $\mu$ wide precipitates are normal troilite and schreibersite. The troilite is mainly monocrystalline. In places the lamellar assemblages swell to bulb shapes; it is normally the troilite component that increases in size, while the two other constituents remain rather constant in their dimensions. The Reichenbach lamellae are enveloped in asymmetrically developed kamacite rims, 0.2-1 mm wide.

Augusta County comprises at least two masses, of 69 and 7.1 kg. It is distinct from Staunton, but was apparently found only a few kilometers from this shower. Characteristics for Augusta County, as compared to Staunton, are (i) a bandwidth of 1.15 mm, (ii) straight, unswollen $\alpha$-lamellae, (iii) a shock-hardened $\epsilon$-structure with a hardness of about 300, (iv) local, large troilite nodules, (v) abundant Reichenbach lamellae, (vi) only small amounts of schreibersite, and (vii) numerous chromite crystals. Augusta County resembles Kayakent, Cumpas, Ivanpah, Bagdad, Thunda and Trenton, and is a typical member of group IIIA.

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

134 g part slice (no. 69, 5.5 x 4 x 0.7 cm)
purchased from Ward 1886
1,564 g endpiece (no. 808, 16 x 5 x 4 cm)
911 g slice (no. 808, 20 x 8 x 0.7 cm)
from the Roebling Collection
1,662 g slice (no. 1149, 25 x 17 x 0.6 cm)
in the Shepard Collection 1884
119 g part slice (no. 3083, 6 x 5 x 0.5 cm)
355 g part slice (no. 3084, 9 x 8 x 0.6 cm)
from the Bosch Collection
90 g part slice (no. 3375, 6 x 3 x 0.6 cm)
from the University of Minnesota, no. 4120

## **Augustinovka**, Dnepropetrovsk District, Ukrainian SSR

48°4'N, 35°5'E

Medium octahedrite, Om. Bandwidth 0.80±0.15 mm. $\epsilon$-structure. HV 285±20.

Group IIIB. 9.86% Ni, 0.8% P, 0.9% S, 18.9 ppm Ga, 33.1 ppm Ge, 0.04 ppm Ir.

Most specimens listed as Verkhne Dnieprovsk are fragments of Augustinovka.

### HISTORY

A heavily weathered mass from the village Augustinovka was briefly mentioned, with an analysis of the limonitized crust, by Alexejev (1893). According to Kupffer (1911), the 400 kg mass was recognized in 1890 under a cover of 4 m loess on the left bank of the Dnepr River. The villagers, who worked the loess and clay deposits, sent the mass to Jekaterinoslav (Dnepropetrovsk); from there it was dispatched to the Mining Institute in Leningrad in about 1890 (Meunier 1893b). A few years before, small weathered specimens from the same region had been acquired by other collections under the name Verkhne Dnieprovsk (Brezina 1885). For this material Julian von Siemaschko gave the date of find as 1876 (catalog, 1882) or 1869 (catalog, 1885), but the weights and exact place of origin were unknown. Wülfing (1897) and Cohen (1905), who briefly described the material, maintained that Augustinovka and Verkhne Dnieprovsk were two different falls, and most western authors and catalogs apparently subscribe to this idea. They are thus entered separately in Mason (1964), Horback & Olsen (1965) and Hey (1966). Nevertheless, Brezina (1896) and Kupffer (1911) stated that all specimens belong to the same mass, and this opinion is backed up by Krinov (letter to E.P. Henderson, September 13, 1946), and by Yavnel (1968), who in his bibliography treats Verkhne Dnieprovsk as a synonym for Augustinovka. No material labeled Verkhne Dnieprovsk is in any Russian collection.

Since the state of weathering, the detailed macro- and microstructure, and therefore also the composition, of Augustinovka and Verkhne Dnieprovsk specimens in this study were found to be identical, and the localities, as far as can be assessed, are within 50 km distance, it is here concluded that all material belongs to one weathered mass. This view is further corroborated by the fact that all specimens of Verkhne Dnieprovsk are small, near-surface fragments, which easily may have been detached from the large mass before it was shipped to Leningrad and registered as Augustinovka. There is, of course, the discrepancy of date of find, but since Siemaschko is uncertain, giving both 1869 and 1876 as finding dates for Verkhne Dnieprovsk, I think it is safe to conclude that the 400 kg mass began to appear by the working of the loess deposits in the late 1870s and that small surface fragments immediately came into circulation under the name Verkhne Dnieprovsk while the main mass in 1890 was shipped to Leningrad where it was briefly mentioned under the name Augustinovka, by Alexejev, who had no knowledge of the detached fragments. Although Verkhne Dnieprovsk thus appears to have priority as a name, it is here decided to use the name Augustinovka because this is the name attached to the main mass and to most specimens in collections. It is, furthermore, the exact locality while Verkhne Dnieprovsk is a nearby town through which the first detached specimens were passed.

Photomicrographs of both types were given by Brezina & Cohen (1886-1906: plates 12 and 37), who noted that Augustinovka was closely related to Bella Roca and Cuernavaca. Brezina showed that the schreibersite lamellae were precipitated in dodecahedral planes of the high temperature austenite crystal (1904a, A.).* The term Brezina lamellae often has been used for this characteristic array that appears to be particularly common in group IIIB. Ward (1904a; plate 3) gave a photomacrograph (A.), and Zavaritskij & Kvasha (1952) described the specimens (A.) in Moscow with photomicrographs and a drawing. Olsen & Fredriksson (1966) found coexisting sarcopside and graftonite as millimeter-sized inclusions in troilite in a V.D. specimen. Wasson & Kimberlin (1967) gave an analysis and a short description of a V.D. specimen. Age determinations, on A., have been reported by Starik et al. (1960; 1963).

*A. and V.D. refer to specimens labeled Augustinovka and Verkhne Dnieprovsk, respectively.

**COLLECTIONS**

Leningrad (327 kg main mass, A.), Chicago (1,262 g A.; 97 g V.D.), London (925 g A.; 24 g V.D.), Moscow (900 g A.), Helsinki (316 g A.), New York (303 g A.; 77 g V.D.), Riga (250 g V.D.), Uppsala (205 g A.), Stockholm (103 g) A.), Yale (103 g A.), Prague (96 g A.), Washington (99 g).

**DESCRIPTION**

The weathered mass is of an irregular, lenticular shape. No fusion crust or regmaglypts are preserved; in fact, many kilograms have been lost as shale during the millenniums of burial in the loess deposits. The laminated shale is often 2 cm thick; occasionally partially preserved schreibersite crystals are preserved among the oxides. The heated rim zone from atmospheric penetration has, of course, long ago been removed by corrosion. Limonite veins, 25-100 $\mu$ wide, penetrate deep into the interior, particularly along schreibersite and troilite inclusions. Near the surface the corrosion attacks along the subgrain boundaries in alpha, which also points to a high terrestrial age. It would be interesting to have a dating made to obtain a quantitative idea of the terrestrial age.

The following is based upon polished sections of both Augustinovka and Verkhne Dnieprovsk specimens. Since all observations show that the specimens are identical, no further attempt to keep the observations apart will be made.

The Widmanstätten structure is beautifully developed with isolated, straight ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 0.80±0.15 mm. There are distinct subgrain boundaries in the lamellae, often decorated with tiny rhabdites, and the lamellae show the shock-hardened $\epsilon$-structure indicative of peak pressures above 130 k bar. The hardness is correspondingly high at 285±20. Plessite covers about 40% of the metallic part of the etched surface and may be developed either as comb plessite in a micro-Widmanstätten structure; or as dense, duplex $\alpha + \gamma$ fields with less than 2 $\mu$ wide, vermicular taenite in cellular kamacite; or as martensitic fields in which the acicular to feathery plates are parallel to the gross Widmanstätten pattern. The martensitic areas are, in addition, usually intercalated between the taenite and the duplex $\alpha + \gamma$ of the larger fields, evidently reflecting a gradient in the nickel content.

Schreibersite is dominant as Brezina lamellae, parallel to $\{110\}$ of the austenite. These are typically 30 x 5 x 0.5 mm, but may reach larger dimensions. Other bodies occur as rosette- or Y-shaped skeleton crystals, or as giant rhabdites. All are monocrystalline. The phosphides have nucleated a 1-1.5 mm wide rim of swathing kamacite. Schreibersite is further present as 25-100 $\mu$ wide grain boundary precipitates and as 3-10 $\mu$ vermicular bodies in the duplex plessite fields. It is probable that almost submicroscopic rhabdites exist in the kamacite. Point counting shows that the total amount of phosphorus in the meteorite is about 0.8%.

Troilite is, like schreibersite, a dominant phase, covering about 4% by area of the 400 cm$^2$ sections I have seen. This corresponds to about 0.9% S. The troilite occurs as almost perfect spheres, 10-20 mm in diameter. They are enveloped in 0.5-1 mm schreibersite and 1 mm kamacite, but cohenite and graphite are absent, although reported by


**Figure 274.** Augustinovka (Moscow). Two troilite globules, the left one with a black phosphate inclusion. Several Brezina lamellae with swathing kamacite. To the right terrestrial corrosion. Etched. Scale bar in cm.

AUGUSTINOVKA – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Trofimov 1950 | | | | 670 | | | | | | | | |
| Wasson & Kimberlin 1967 | 9.86 | | | | | | | | 18.9 | 33.1 | 0.04 | |

several authors. In some specimens, e.g., Moscow's 400 g plate, 3 x 2 mm phosphate inclusions are located in the troilite. Material from a Chicago specimen was identified by Olsen & Fredriksson (1966) as sarcopside $(Fe,Mn,Ca)_3(PO_4)_2$ with minor amounts of graftonite, with the same empirical formula, but calcium-free.

In U.S. National Museum no. 224, small rounded grains 30-300 μ across in the kamacite phase are tentatively identified as phosphates. They appear under optical examination as semi-transparent, grayish-blue to green, and weakly anisotropic, showing thin, parallel laths. If the identification is valid, the phosphates are not restricted to occur within the troilite, but may occur distributed in the metal phase. Chromite occurs locally as 100 μ euhedric bluish-gray hard crystals associated with schreibersite.

Augustinovka is structurally and chemically a typical group IIIB, closely related to Chupaderos and Grant. It is an old, weathered fall which has developed shales of sizes comparable to Canyon Diablo and Santa Apolonia. Specimens labeled Verkhne Dnieprovsk are in every detail identical to Augustinovka, e.g., bandwidth, ε-structure, plessite development, amount and morphology of schreibersite-troilite, phosphate minerals and weathering. For these and reasons given above it is concluded that the two meteorites are in fact identical, having only reached the scientific world at different times and through different channels.

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

65 g part slice, A. (no. 224, 3 x 2.5 x 0.8 cm)
34 g part slice, A. (no. 2639, 3 x 3 x 0.5 cm, figured by Brezina and Cohen 1886-1906: plate 37, figure 4)
82 g shale fragments, A. (no. 960, largest is 2 cm thick)
127 g laminated shale, A. (no. 2641, 2 cm thick)

## Avče, Slovenia, Yugoslavia
### 46°6′20″N, 13°41′E; 150 m

Hexahedrite, H. Kamacite single crystal larger than 10 cm. Neumann bands.

Group IIA, judging from the structure, with about 5.5% Ni and 0.2% P.

**HISTORY**

Although Avče is a well-documented fall, hardly anything is known about it. Berwerth (1908), who published a preliminary account, believed it to be an octahedrite, but in later catalog entries the hexahedral nature of the mass is indicated.

According to Berwerth (1908) a mass of 1,230 g was observed to fall at 8:45 a.m. on March 31, 1908, near Avče, in the Isonzo Valley. The coordinates given by him are, however, erroneous, and the locality is not in Italy, as believed by Baldanza (1965), Hey (1966) and Buchwald (1968a: map no. 11). Avče (Italian Auzza), was then a village on the Austrian side of the Austrian-Italian border; it is now a part of Yugoslavia.

Johann Kolenc of Avče, who was working in a field at the time of fall, reported the "cannon ball" to the gendarmerie and said that he had heard a detonation in the air, immediately followed by a whistling and sizzling noise. This lasted more than two minutes, and then suddenly he saw that a 5 cm thick branch of an apple tree was broken and soil was scattered from the impact site only 40 m away. Believing it to be a cannon ball fired from the Italian side of the border, Kolenc dared not approach the site until the afternoon; he excavated the mass from a depth of about 30 cm. It is interesting to note that Kolenc neither saw the meteoritic trail nor any kind of light phenomena; consequently he had only imprecise ideas of the direction from which the mass came. The noises were, however, said to come from the northwest. Unfortunately, Berwerth, who acquired the entire meteorite for the Vienna collection, never instituted a thorough search for other witnesses so the above report is all that is known today of the circumstances of fall.

**COLLECTIONS**

Vienna (main mass).

**CHEMICAL ANALYSES**

An inappropriate analysis may be found in Doelter's Handbuch der Mineralchemie, volume 3: 575: 5.10% Ni, 95.17% Fe, 0.36% Co, 0.12% Si.

**DESCRIPTIONS**

The eminent mass, which is a softly rounded wedge or crescent, weighs 1.23 kg and measures approximately 11 x 6 x 5 cm in three perpendicular directions. The entire surface is covered with a black fusion crust of iron oxides to which virtually no damage has occurred. On the section examined, the thickness of the crust ranges from 0.05 to 0.8 mm. The direction of the fine striae in the crust indicates that the convex surface was the apex during the flight, while the opposite concave or flat part was the posterior surface. The apex and the adjacent sides are smooth while the posterior shows shallow but distinct

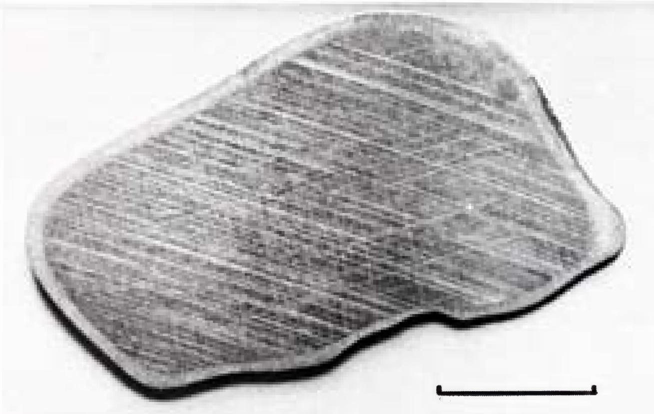

**Figure 275.** Avče (Vienna H 10,029). A full slice through the smoothly rounded hexahedrite, shown in Figure 41. The heat-affected $\alpha_2$ zone is seen as a continuous matte rim. Etched. Scale bar 20 mm.