

**Figure 1984.** Wood's Mountain (U.S.N.M. no. 1271). Detail of a whirlpool intrusion showing rapidly solidified metal with dendritic-columnar growth. Magnetite and wüstite are also present; most of the black oxides are, however, colloform limonite from terrestrial corrosion. Etched. Scale bar 80  $\mu$ . (Perry 1939b: plate 6.)

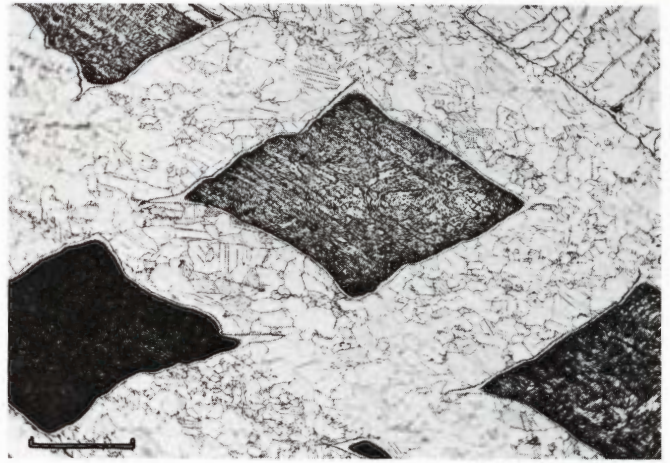
tion. Neumann bands are present in limited amounts and, of course, differently oriented in each recrystallized unit. In most places the hardness is  $190 \pm 10$ , but it ranges upwards to 255 in heavy shear zones of imperfect recrystallization.

Taenite and plessite cover about 50% by area. The taenite ribbons are often wildly zigzagging as a result of the cosmic kneading, and the plessite fields may be completely sheared, with adjacent parts displaced 0.2-1 mm relative to each other. The plessite fields are rather well annealed, with recrystallized kamacite and spheroidized taenite. Everywhere the taenite is serrated and with diffuse borders on a micro-scale. The structure is evidently not very well equilibrated, as the wide hardness range also indicates. Before the cosmic annealing the plessite seems to have been present in the various forms typical of Gibeon and other group IVA irons.

Corrosion penetrates one to two centimeters into the mass, particularly attacking the troilite-metal mixtures. Pentlandite veins the troilite. It is interesting to note that the recrystallized ferrite is transformed to limonite before the grain boundaries and the taenite indicating a relatively high phosphorus concentration in the wide boundaries.

Schreibersite was not seen and is probably not present, in accordance with the analytical results which show 0.05% P or less in the alloy.

Troilite occurs as 1-20 mm nodules. Some large, weathered nodules are located in the cleavage planes and have, no doubt, facilitated the splitting of the mass into two fragments. The troilite is brecciated and recrystallized to angular units, 25-100  $\mu$  in diameter. Along the periphery of some of the nodules the troilite is shock-melted and sends fine veinlets out in fissures into the metal. Troilite is also present in irregular pockets in the plessite and other unexpected parts of the structure. It appears that it was shifted to these places by the plastic deformation and it may, in fact, have acted locally as a low-melting lubricant facilitating the heavy shear-displacement observed.



**Figure 1985.** Wood's Mountain (U.S.N.M. no. 1271). A fine octahedrite of group IVA. The plessite fields are annealed and the kamacite lamellae are recrystallized. In the recrystallized grains is a new generation of Neumann bands. Etched. Scale bar 200  $\mu$ . (Perry 1950: volume 5).

Daubreelite occurs as 10-100  $\mu$  wide, brecciated bars in the troilite. Rhythmic intergrowths of troilite and daubreelite in parallel 1  $\mu$  lamellae are common in the transition zone between troilite and daubreelite. The structure is probably a two-phase recrystallization phenomenon.

Wood's Mountain is a fine octahedrite, which is related to Gibeon, Charlotte and Altonah. It is, however, unusual because of its heavy cosmic deformation which almost conveys the impression of fluidal structures in some places. The kamacite and the troilite are recrystallized, and troilite melts have been injected into the metal far out from the original nodules. The mass is considerably corroded, but a little of the whirlpool-fusion crust is still preserved in intrusive pockets. Chemically Wood's Mountain is a typical group IVA iron.

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

322 g half of 850 g fragment (no. 717, 10.5 x 5.5 x 1.3 cm)  
1,750 g half of 3 kg fragment (no. 1271, 15 x 9 x 5 cm)  
31 g polished slice (no. 1625, 4.5 x 2 x 0.5 cm)  
Cast of McDowell County (no. 718, 11 x 6 x 3.5 cm)

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#### Wooster, Ohio, U.S.A.

40° 46' N, 81° 57' W; 300 m

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Medium octahedrite, Om. Bandwidth  $1.00 \pm 0.15$  mm. Neumann bands. (HV 182±6).

Group unknown, perhaps IIIA. Estimated 7.8% Ni, 0.15% P.

The specimen examined, and probably the whole mass, has been artificially reheated to 600-700° C.

#### HISTORY

A mass of about 50 pounds was discovered about 1858 by Peter Williams in the woods near Wooster in Wayne County. The finder believed it to be a mass of silver, or to contain silver, so he took it to Professor James C. Booth, of the U.S. Mint at Philadelphia. Williams declined, however, to part with the meteorite, and neither he nor the main mass has ever been heard of since. Booth had detached a

small portion, which he passed over to J.L. Smith who gave an inadequate description (1864). Smith called the meteorite "Wayne County"; he subdivided the fragment into numerous tiny fragments, stamped with his identification number, 103, and used the material for exchange. Small splinters are in a surprisingly large number of collections today. Brezina (1885: 211) classified Wooster as a medium octahedrite together with Trenton, Rowton and Burlington.

**COLLECTIONS**

Philadelphia (14 g), Chicago (11 g), Harvard (7 g), Paris (5 g), London (5 g), New York (4.2 g), Stockholm (2.7 g), Calcutta (2 g), Vatican (1.7 g), Göttingen (1.2 g), Berlin (1 g), Vienna (fragment). The specimen in Washington (Merrill 1916a: 199: Shepard Collection no. 65; presently no. 1183 of 4.5 g [not 2.81 g]) turned out to be a mislabeled meteorite of a highly unusual type; see Dehesa.

**ANALYSIS**

Smith (1864) found 6.01% Ni, 0.73% Co, 0.13% P. Of these values, the phosphorus determination appears to be good but perhaps a little low. From structural observations, I would estimate the iron to contain 7.8±0.2% Ni, 0.5% Co and 0.15:0.02% P.

**DESCRIPTION**

When I realized that the Washington fragment with which I first worked could not be authentic material, Dr. V. Manson, of the American Museum of Natural History, lent me the New York specimen, No. 90 of 4.2 g. This is a small fragment, chiseled from the main mass and measuring 2 x 1 x 0.5 cm. However, it is large enough for all the characteristics to be assessed.

No fusion crust and no heat-affected zones are present. The present surfaces appear to be interior surfaces exposed by chiseling and rupturing along Widmanstätten planes and phosphides.

Wooster is a medium octahedrite with straight, long ( $\frac{l}{W} \sim 15$ ) kamacite lamellae with a width of 1.00±0.15 mm. Neumann bands are common. Taenite and plessite cover 25-30% by area, mostly as comb and net plessite and as black taenite. Schréibersite is not present as larger bodies but is common as 20-50 μ wide grain boundary precipitates. Rhabdites are common as 1-3 μ thick prisms in the kamacite lamellae. A single, small troilite nodule, 50 μ across, is present in the section.

These primary, genuine structures have, however, been superimposed by secondary structures which are the result of reheating. The kamacite matrix is partially recrystallized to lobed ferrite grains, 20-100 μ across, especially around the Neumann bands. The rhabdites are almost resorbed, and the troilite is recrystallized to 20 μ grains. The subboundaries of the kamacite are marked, and a fine oriented grid of ultrafine needles (about 6 x 0.5 μ typically) occurs abundantly in the kamacite. This seems to be a forerunner of the isothermal taenite which appears at reheating to about 700° C for a few hours (Brentnall & Axon 1962).

The structures are thus clearly a result of brief reheating to 600-700° C. That the reheating was artificial can be proved by the following observations: (i) The terrestrial, limonitic corrosion products are decomposed by heat, showing fine disseminated metal grains, 0.5 μ across. (ii) Intricate laceworks of metal and high temperature oxides occur along the surface and along corroded grain boundaries. (iii) There are 2-3 μ wide, creamcolored reaction zones which separate the phosphides and the corrosion products.

Since it seems unlikely that Professor Booth or J.L. Smith should have reheated the iron without mentioning it, I must conclude that the main mass, from which they chiseled a portion, had already been heated by the owner, and that all the material in collections at present, is damaged.

Wooster appears to have been a rather normal, medium octahedrite, probably of group IIIA, and related to such irons as Cape York, Dexter, Kyancutta and Rowton.

**Xiquipilco.** See Toluca

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**Yanhuitlan, Oaxaca, Mexico**

17°32'N; 97°21'W; 2100 m

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Fine octahedrite, Of. Bandwidth 0.33±0.05 mm. α<sub>2</sub> matrix. HV 166±6.

Group IVA. 7.52% Ni, 0.40% Co, 0.02% P, 0.02% C, 0.04% S, 1.75 ppm Ga, 0.10 ppm Ge, 2.7 ppm Ir.

The whole mass has been artificially reheated to 700-800° C.

**HISTORY**

The confusion about the meteorites from the state of Oaxaca is extreme. The following names/meteorites are involved and hopelessly mixed up in most collections: Apoala, Cholula, Goldbach's Iron, Humboldt's Iron, Misteca, Oaxaca, Teposcolula and Yanhuitlan. The reconstruction given below is based on the literature and on an examination of a large number of preserved specimens.

A mass of about 421 kg (?) was found by Indians at the foot of a hill called Deque Yucunino between Teposcolula and Yanhuitlan. They transported it to Yanhuitlan and here it was being used as an anvil when the traveler A.F. Mornay (i.e. Mornay known for his discovery of the iron meteorite Bendego, 1816) with difficulty cut a piece from it in the year 1825. In 1832 the bishop of Puebla also had a little piece cut off (El Mosaico Mexicano, 1840 (3) 219, quoted by Fletcher 1890a: 171). About the same time, Baron Karawinsky from Munich had a piece of eight grams cut off which was presented to the Vienna Collection in 1834 (Partsch 1843: 134). However, it was described under the name of the province, Oaxaca, in which Yanhuitlan is situated. Similarly, Baron A. von Humboldt obtained a specimen of approximately a hundred grams

from the anvil about this time. Through the chemist, Carol Goldbach, 36 g of Humboldt's specimen went to Vienna between 1885 and 1895. This and another fragment of 15 g were described under the name of Teposcolula by Brezina (1896: 268 and plate VIII). Teposcolula is a small town 19 km west of Yanhuitlan.

The main mass was transported in 1864 to the City of Mexico and was described by Castillo & Loza (1864) and Burkart (1866). Since then the Yanhuitlan meteorite has been preserved in the Natural Museum, Museum de Chopo. In 1967 this museum was closed and new museum buildings were opened in a different place; Yanhuitlan, Descubridora and other meteorites remained temporarily, however, in the abandoned museum.

Although the meteorite Yanhuitlan was thus known to the Mexicans and a few travelers from the early nineteenth century, it did not receive attention in scientific circles until late in the same century. It was not mentioned by Rose (1864a) nor by Brezina (1885); neither was it included in the "Catalog of All Recorded Meteorites" by Huntington (1888), nor listed by Fletcher (1881) as being in the collection of the British Museum. It may thus be concluded that very little was known of the 421 kg Yanhuitlan mass by the end of the nineteenth century. Fletcher (1890a: 173) in his treatise on the Mexican meteorites was forced to conclude that Yanhuitlan, Misteca and Oaxaca were synonyms and that all specimens so labeled originated from the same 421 kg mass. Wülfing (1897) was of the same opinion. The erroneous analysis, 1.83200% Ni (sic), by Rio de la Loza (Castillo & Loza 1864), quoted by Burkart (1866) and Barcena (1876), did not help to solve the problem.

However, when describing the Vienna specimens, Brezina (1896: 268) realized that Misteca was different from Yanhuitlan (=Teposcolula).

About the year 1900, H.A. Ward on one of his travels to Mexico City, came in possession of a significant lump

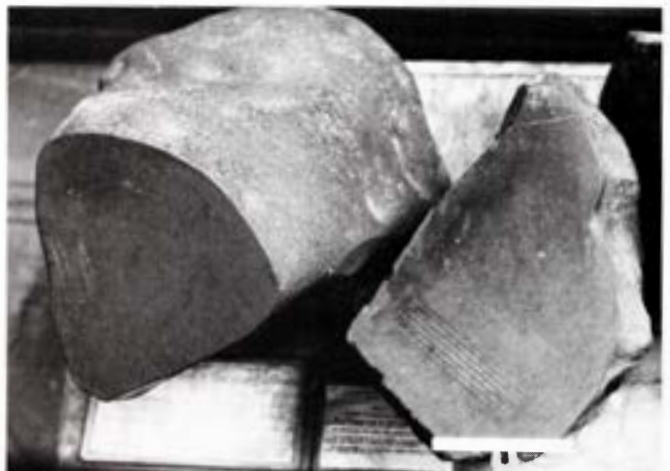


**Figure 1986.** Yanhuitlan (Museum de Chopo, Mexico City; no. 1). The mass is roughly an oblique triangular prism. The anvil part is seen below to the left. Large slabs and minor samples have been cut from the opposite end. Scale bar approximately 10 cm.

from the 421 kg Yanhuitlan mass. In the Ward-Cooney Catalog (1904a: 27) specimens totaling 16,380 g are listed, and in the following years these and other specimens were sold. As late as in Ward's Price List of 1931 (Page 10) an oval slab measuring 20 x 26 x 0.7 cm and weighing 2,870 g was offered for sale. This slab was bought by Nininger and is now at Tempe. The interesting thing is that this slab is etched "MISTECA" in Ward's special technique, and it was therefore listed in Nininger's Catalog (1950) as Misteca. There is, however, no doubt that Ward mislabeled his specimens (in a very durable way) convinced that Misteca and Yanhuitlan were synonyms, just as most authorities of his time agreed. Even Cohen (1903d: 177) called the tetrahedric 421 kg mass "Misteca" and so did Farrington (1903: 123). Fletcher (1914: 121) 10 years later still considered Misteca synonymous with Yanhuitlan. A slab of 16 x 17 cm, weighing 1,280 grams, which is genuine Yanhuitlan, was listed as Misteca in Merrill's Catalog of meteorites in the U.S. National Museum (1916a: 107).

In 1905, however, Cohen (Page 316) discovered that Yanhuitlan was different from Misteca, which he had analyzed in 1892 (Page 151). Farrington (1915: 496) accepted Brezina's and Cohen's conclusions, but in the most recent treatise on Mexican Meteorites by Haro (1931) only Castillo & Loza (1864) and Fletcher (1890a) are quoted and the newer results are not discussed at all. Moreover, Haro (1931: plate 26) presented a photomicrograph of alleged Yanhuitlan material. This material is, however, mixed up and composed of different meteorites (no. 25a, 46 g of an Om; No. 25b, 10 g of an Of; No. 25c, 36 g of an Of; b and c may be Yanhuitlan specimens).

Therefore, my conclusion is that the confusion about Yanhuitlan started around 1890, and was high at the time when significant amounts of Yanhuitlan were traded for the first time in the years 1901-1931. Since then only minor amounts seem to have changed owners. Slabs and specimens labeled or etched "MISTECA" and bought directly or indirectly from Ward during this century are probably all



**Figure 1987.** Yanhuitlan (Museum de Chopo, Mexico City; no. 1). To the left the Yanhuitlan meteorite from above. To the right, one half of the Charcas (Descubridora) mass. Compare Figure 562. White ruler below right measures 15 cm.

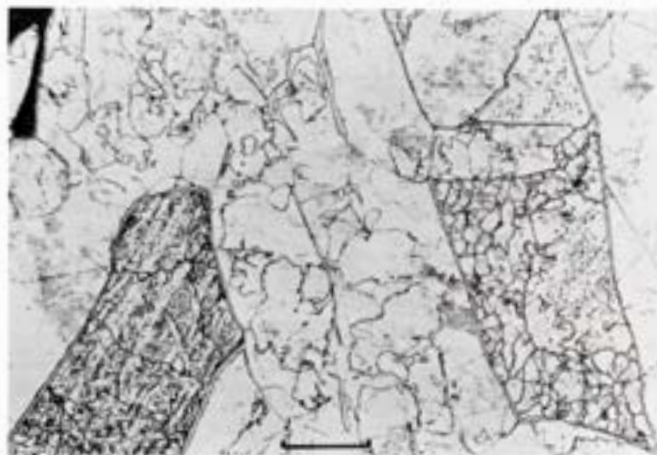
Yanhuitlan specimens as defined below. Almost all specimens labeled “Misteca” and incorporated in collections before 1890 are probably genuine “Misteca” as described in this book on page 828.

Burkhart (1866: plate VII) gave figures of the main mass. Brezina (1896: plate VIII, figures 4 and 5) presented photomicrographs of etched sections, and Brezina & Cohen (Atlas 1886-1906: plate 38) produced other photomicrographs. Cohen (1905: 316) described the material with an acceptable analysis, and Brett & Henderson (1967) discussed the lamellar troilite inclusions on the basis of a photomicrograph. Jaeger & Lipschutz (1967b) and Jain & Lipschutz (1970) discussed the disordered microstructure but were not able to detect whether the kamacite “recrystallization” was of cosmic or artificial origin. As will be shown below, the Yanhuitlan main mass displays a genuine primary macrostructure upon which is superimposed an  $\alpha_2$  structure from artificial reheating.

Munk (1967) determined the amount of neon, argon, krypton and xenon on a specimen which, at that time, was mislabeled Misteca but which is genuine Yanhuitlan. Schultz & Hintenberger (1967) and Hintenberger et al. (1967) measured a number of other noble gas isotopes, while Voshage (1967) by the  $^{40}\text{K}/^{41}\text{K}$  method found a cosmic ray exposure age of  $370 \pm 55$  million years.

#### COLLECTIONS

Museum de Chopo, Mexico City (main mass of about 300 kg ?), Chicago (9.66 kg endpiece and 7.34 kg slice),



**Figure 1988.** Yanhuitlan (U.S.N.M. no. 459B). Fine octahedrite of group IVA. Artificially reheated. The kamacite is recrystallized or converted to unequibrated  $\alpha_2$  grains, and the plessite fields are annealed. Etched. Scale bar 300  $\mu$ .

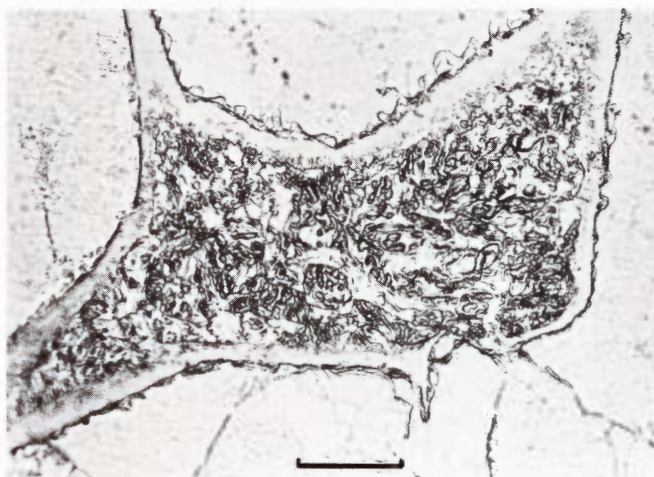
Tempe (no. 162a of 2.8 kg and no. 129a of 280 g), Bally (2.14 kg, labeled Oaxaca), Washington (1.20 kg), Tübingen (330 g, no. 9112082, labeled Misteca), London (296 g), Helsinki (221 g), Ann Arbor (161 g), Calcutta (147 g), Strasbourg (107 g), Canberra (66 g), Vienna.

The following specimens are mislabeled Misteca in the catalogs of the respective collections. Most of them probably represent Yanhuitlan material which could easily be checked by macroscopic examination: Vienna, Budapest (1.10 kg), Rome (878 g), Harvard (487 g), New York (140 g), Prague (140 g), Bonn (134 g), Amherst (105 g), Paris (90 g), Vatican (70 g), Ottawa (43 g), Tübingen (20.8 g).

#### DESCRIPTION

The meteorite is roughly pear-shaped with smoothly rounded edges and with the average dimensions of 45 x 35 x 35 cm. Its former size was larger, because the pointed end was detached (before 1864) leaving a cross section of 27 x 25 cm. The weight is doubtful, only an early figure of 421 kg (Castillo & Loza 1864; Burkart 1866) has been quoted; the present weight appears to be significantly smaller, perhaps about 300 kg, estimating from the dimensions.

For a time the meteorite was in use as an anvil. The pointed end must have been downwards, anchored in the soil, while the opposite – more massive – end served as the anvil face. This face is over an area of 22 x 15 cm, heavily deformed from hammering and chiseling. From the anvil



**Figure 1989.** Yanhuitlan (U.S.N.M. no. 459). A plessite field which is diffuse and shows indistinct boundaries to adjacent kamacite due to artificial reheating. Etched. Scale bar 30  $\mu$ .

#### YANHUITLAN – SELECTED CHEMICAL ANALYSES

The last two analyses were performed on Tempe No. 129a and No. 162a, respectively, which at the time of

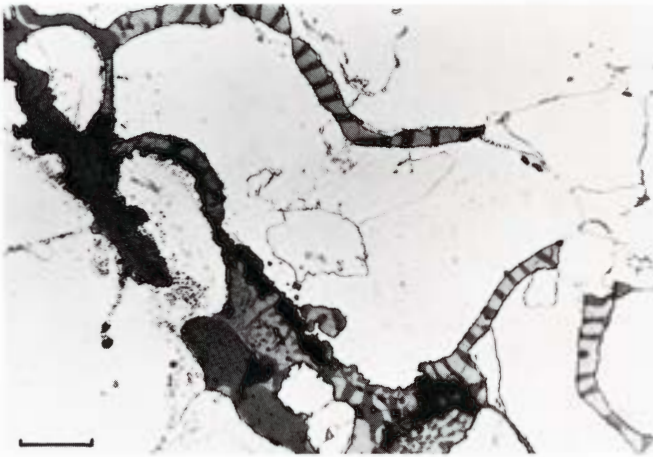
the analysis were believed to belong to different meteorites, Yanhuitlan and Misteca, respectively.

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1967a	7.50								1.75	0.105	2.7	
Moore & Lewis 1968	7.48	0.40	0.02	370	320							
Moore & Lewis 1968	7.59	0.39	0.02	105	560							

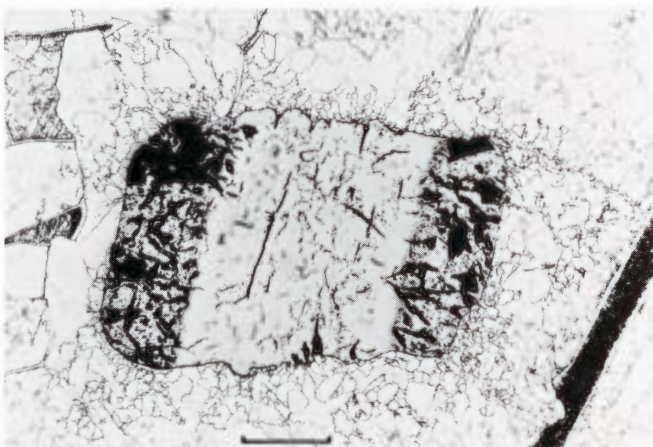
end a fine fissure extends over many decimeters across the block without dividing the block in two, however. Its largest width is 1 mm at the bottom of a severe chisel mark. The fissure appears to bear evidence of an early unsuccessful attempt to divide the mass.

The surfaces are smoothly rounded and exhibit no fusion crust. Irregular depressions are present locally in the massive end; they resemble regmaglypts but no conclusion could be reached since specimens from this part were not available. On sections the heat-affected  $\alpha_2$  zone could not be detected. On the other hand, corrosion has attacked the meteorite only superficially along cracks and sulfide inclusions.

Etched sections display a fine Widmanstätten structure of straight, long ( $\frac{L}{W} \sim 30$ ) kamacite lamellae with a width of  $0.33 \pm 0.05$  mm. Some sections exhibit bent and distorted kamacite lamellae; but whenever this was observed, clear indications of artificial surface deformation were also present. Such sections evidently came from the anvil end of



**Figure 1990.** Yanhuitlan (Tempe no. 129a). Troilite and limonite have during artificial reheating to about  $800^\circ\text{C}$  reacted and formed low-melting Fe-S-O eutectics. These have penetrated along the high temperature boundaries of the metal. Etched. Scale bar  $20\ \mu$ .



**Figure 1991.** Yanhuitlan (U.S.N.M. no. 459B). An altered sulfide nodule in granulated kamacite. Annealed plessite fields to the left and right. No phosphides at all. The sulfide nodule originally had a central daubreelite bar, surrounded by two troilite crystals. Compare Figures 1992 and 1993. Etched. Scale bar  $300\ \mu$ .

the mass, e.g., Tempe No. 129a, which is a  $7.5 \times 5 \times 0.8$  cm section (280 g) and which can be nicely refitted to a hammered and cut part of the main mass.

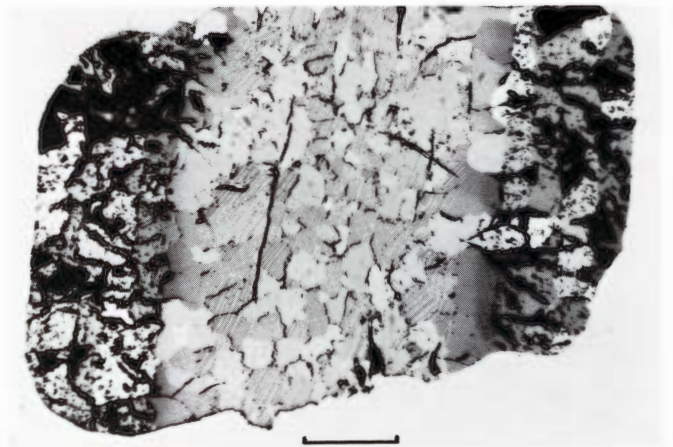
Taenite and plessite cover 40-50% by area. The fields are of the comb, net and cellular types and, in addition, many black taenite fields occur. At high magnification (60x objective) these may sometimes be resolved into fine-grained, duplex  $\alpha + \gamma$  fields.

Schreibersite and rhabdites were not detectable in the optical microscope; this is in line with the average of the reported bulk phosphorus analyses, 0.04%.

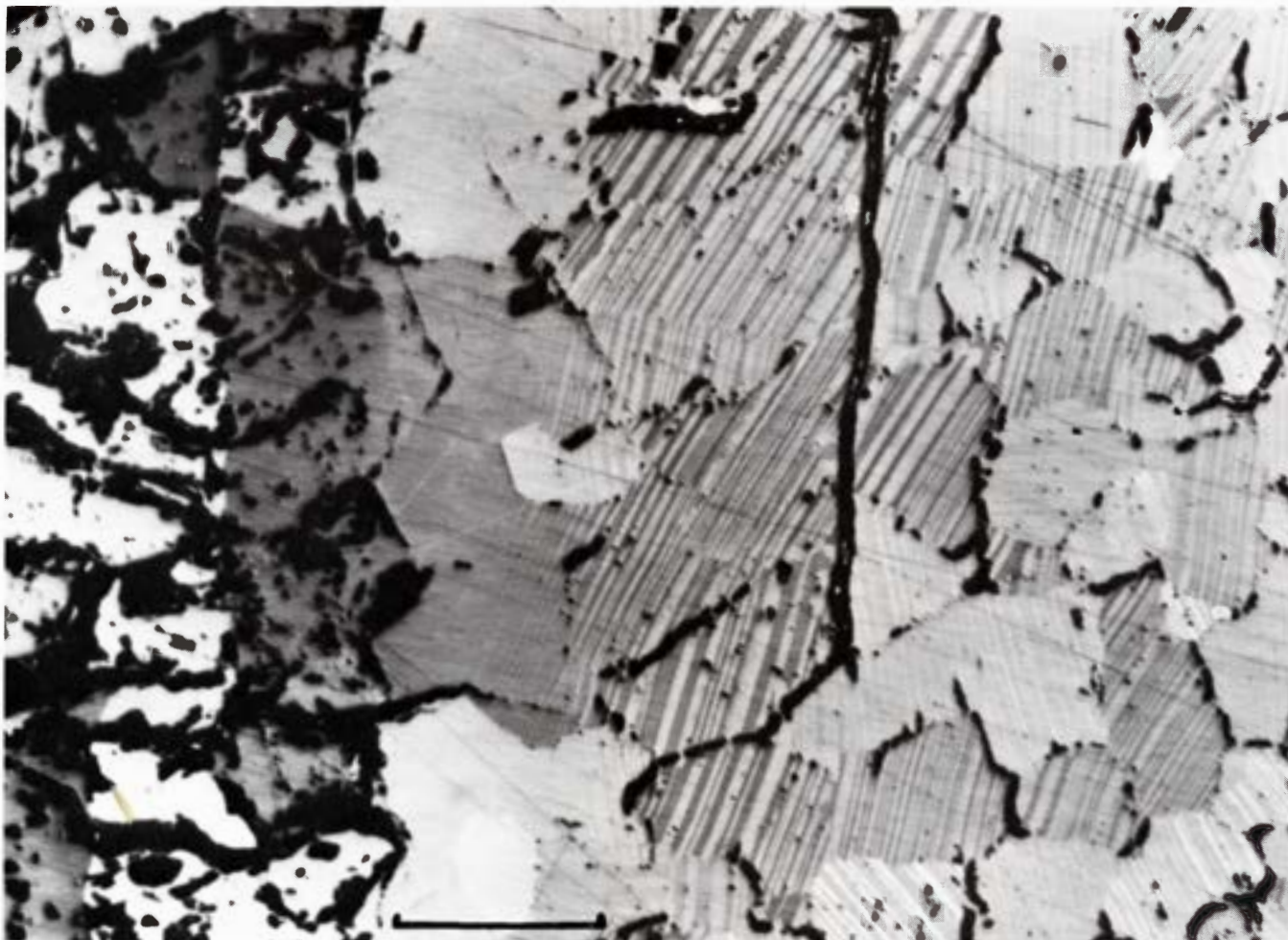
Sulfides are common as lenticular-lamellar bodies, ranging in size from  $22 \times 0.8$ , through  $9 \times 1$ , to  $2 \times 0.3$  mm. On a  $397\text{ cm}^2$  section, 62 troilite blebs smaller than  $1\text{ mm}^2$  were counted (total:  $31\text{ mm}^2$ ) and nine larger than  $1\text{ mm}^2$  (total:  $41\text{ mm}^2$ ). The total of  $72\text{ mm}^2$  corresponds to 0.18% by volume or 0.039% S by weight, which agrees with the reported wet chemical analyses of 0.020, 0.032 and 0.056, averaging 0.036% S. The sulfides were originally somewhat deformed single crystals of troilite, with daubreelite lamellae precipitated parallel to the (0001) base of troilite. A thorough annealing has, however, recrystallized the troilite to aggregates of  $50\text{-}200\ \mu$  units. Similarly, the daubreelite is recrystallized; and furthermore, each grain is decomposed to parallel stacks of alternating troilite and daubreelite (or brezinaite) in  $1\text{-}5\ \mu$  wide lamellae. A similar development is present in Rodeo and other artificially reheated irons.

Sulfides are also common as tiny, bluish angular grains,  $5\text{-}50\ \mu$  across, isolated in the kamacite lamellae. They may be brezinaite or daubreelite.

Several specimens have been examined in the present study, both from the anvil end and from large slabs (25 cm in diameter) cut at least 40 cm from the anvil end. All of them exhibit the same reheated microstructure. The kamacite does not contain Neumann bands, but it is decomposed to serrated  $\alpha_2$  units,  $50\text{-}200\ \mu$  across. They are far from equilibrium and have a hardness of  $166 \pm 6$ . The taenite has



**Figure 1992.** Yanhuitlan. The nodule in Figure 1991, polished and under crossed polars. The troilite at left and right is recrystallized (and chipped); the daubreelite is also recrystallized but, in addition, each grain is decomposed to parallel stacks of alternating troilite and daubreelite. Scale bar  $200\ \mu$ .



**Figure 1993.** Yanhuitlan. Detail of Figure 1992. Troilite at left and troilite-daubreelite at right. Intergranular cracks are ubiquitous and cause fragments to be torn out during sample preparation. Polished. Crossed polars. Scale bar 100  $\mu$ . See also Figure 26.

blurred edges due to arrested diffusion at temperatures above about 700° C. Near the surface the structural elements are bent due to hammering, and it is even possible to detect a few artificial Neumann bands within some of these near-surface  $\alpha_2$  grains.

Fine laceworks have developed around the limonite-filled surface cracks, and the limonite itself has partially decomposed to magnetite and wüstite. Where near-surface troilite nodules have been in contact with oxygen (or corrosion products) they have reacted and formed low-melting liquids which have penetrated irregular fissures and solidified in fine-grained Fe-S-O eutectics. Troilite and daubreelite, which were embedded in the massive part of the meteorite, recrystallized as noted above.

All observations thus indicate that the mass has been artificially reheated, not only by being used at one end as an anvil, but also quite thoroughly on another occasion. This event was possibly the unsuccessful attempt to divide the mass with heat and chiseling. It is reasonably certain that the whole mass was artificially reheated to about 700-800° C for a matter of hours.

Yanhuitlan's primary structure and chemical composition indicate that it is a fine, phosphide-free octahedrite, closely related to Gibeon, Maria Elena, Putnam County and Social Circle. Each of these four group IVA meteorites have, in detail, very different microstructures. It is rather difficult now, because of the artificial reheating, to detect which microstructure Yanhuitlan had when it fell, but indications are that its kamacite and troilite-daubreelite textures correspond best to those of Putnam County.

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

1.00 kg part slice (no. 459B, 15 x 16 x 0.6 cm; labeled "Misteca" in Merrill's Catalog (1916a: 107))

About 200 g smaller sections from above (no. 459B)

A large polished and etched slab of 1,400 g, labeled "Yanhuitlan" (no. 459A), turned out to be a mislabeled Roebourne specimen.

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**Yardea, South Australia**  
32°25'S, 135°30'E

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Coarse octahedrite, Og. Bandwidth 2.0±0.4 mm. Neumann bands. HV 185±10.

Group I. 6.8% Ni, about 0.22% P, 90 ppm Ga, 394 ppm Ge.

## HISTORY

A mass of about 3.3 kg was discovered in 1875 by Mr. James Martlew about 4 miles south of Yardea sheep station. It was covered by soil, lying about 15 inches under the surface on a flat limestone plateau, half a mile distant from the northern foot of the Gawler Ranges. The finder hacked off a fragment, but the main mass, of 3,269 grams, was acquired for the Mineralogical Collection of the South Australian Museum, Adelaide (Wülfing 1897: 389). Ward (1904a: 28) acquired a 73 g fragment, now in Chicago, and Anderson (1913: 66) cataloged the mass as a medium octahedrite. This classification has unfortunately persisted with the material in all later catalogs, e.g., Farrington (1916: 309), Horback & Olsen (1965: 316) and Hey (1966: 527). Paneth (1954) reported a substantial quantity of helium gas,  $30 \times 10^{-6} \text{cm}^3$  per g, in the meteorite.

## COLLECTIONS

Adelaide (3.12 kg), Chicago (73 g), Berlin (1 g).

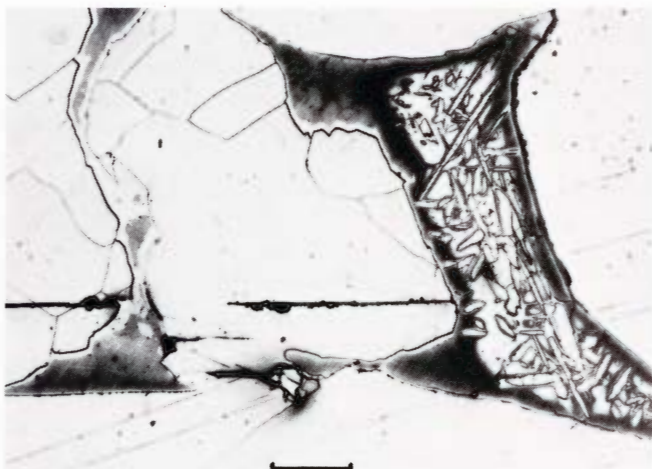
## ANALYSIS

No analytical work has been reported until recently. The data by Reed (1972b) on Yardea and Mount Sir Charles were obtained on mislabeled (interchanged) material. In a letter to the author, dated April 18, 1974, Dr. S.B.J. Reed reported the correct values for Yardea: 6.8% Ni, 90 ppm Ga and 394 ppm Ge.

## DESCRIPTION

Through the kind cooperation of Dr. E. Olsen, Chicago, it was possible to examine the 73 g sample in the Field Museum (No. 935, an endpiece of 4 x 2.5 x 2 cm). It is weathered and without fusion crusts. Two or three deep chisel marks indicate the finder's efforts to detach samples, but otherwise the material is undamaged and has not been artificially reheated.

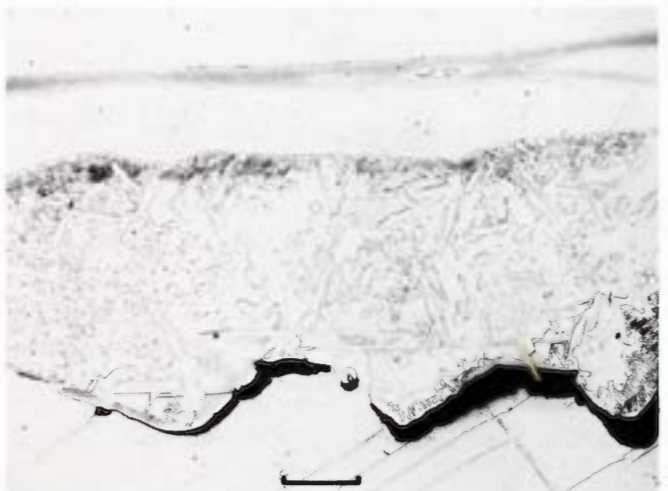
The etched section reveals a coarse octahedral structure of irregular, bulky ( $\frac{l}{w} \sim 7$ ) kamacite lamellae with a width



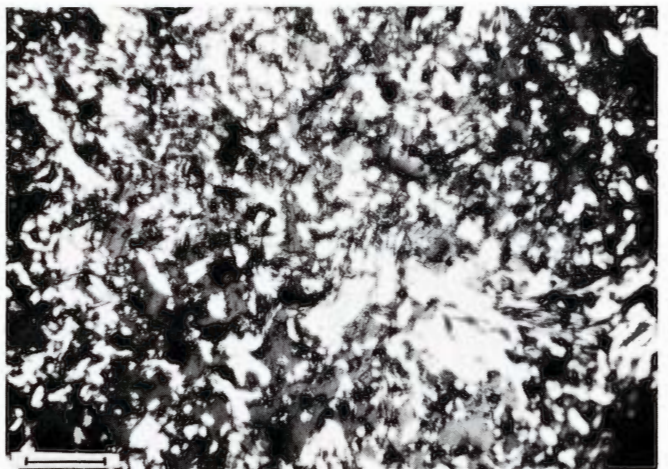
**Figure 1994.** Yardea (Chicago no. 935). Acicular plessite field to the right. Yellow high-nickel taenite rim and cloudy taenite edges. A fissure (horizontal) follows a cubic cleavage plane in kamacite. Etched. Scale bar 100  $\mu$ .

of  $2.0 \pm 0.4$  mm. Local grain growth has created almost equiaxial grains 5-10 mm across, so that residual taenite lamellae and plessite fields may now be found within a kamacite grain. Irregular, 2-3 mm wide rims of swathing kamacite envelop the troilite-silicate-graphite nodule. The kamacite is rich in subboundaries that resemble barbed wire, because of a profusion of  $1 \mu$  oriented precipitates. Undecorated Neumann bands are common. The hardness is  $185 \pm 10$ .

Taenite and plessite cover about 5% by area, mainly as comb plessite and as acicular varieties. The cloudy taenite lamellae of the comb plessite have hardnesses of  $410 \pm 25$ , while the yellowish taenite wedges of the acicular fields are softer,  $310 \pm 25$ . The reason for this is not clear, but it seems to be a general case in the taenite and plessite fields of group I. Spheroidized fields with 5-20  $\mu$  taenite globules, and pearlitic fields with  $1 \mu$  wide taenite lamellae, are



**Figure 1995.** Yardea (Chicago no. 935). A plessite field with pearlitic edges and spheroidized interior. An intergranular crack is filled with terrestrial corrosion products. Lightly etched. Scale bar 50  $\mu$ .



**Figure 1996.** Yardea (Chicago no. 935). The interior of a complex troilite-silicate-graphite nodule. In this picture, under crossed polars, graphite dominates in twisted and fan-shaped units (white-gray-black). Polished. Scale bar 50  $\mu$ .

common – often in intergrown varieties. The bulk nickel content of Yardea is estimated to be  $7.0 \pm 0.3\%$ .

Schreibersite is common. It forms an irregular 0.3-0.6 mm wide rim upon the troilite, and it is precipitated upon the grain boundaries as 20-100  $\mu$  wide veinlets. Schreibersite is also present within the plessite fields as unusually large, indented particles, 50-150  $\mu$  across. Rhabdites occur in profusion in the kamacite lamellae as prisms, 5-20  $\mu$  across. All phosphides are brecciated and somewhat displaced by the same shear forces that strained the surrounding metallic matrix plastically. Individual segments are rotated or displaced 2-10  $\mu$ , and terrestrial corrosion has later invaded the fissures and recemented the fragments. The bulk phosphorus content is estimated to be  $0.22 \pm 0.04\%$ .

Part of an ablation-melted troilite nodule is still preserved in the surface. It measures about 6 mm in diameter, and the inner 3 mm is preserved, situated about 2 mm below the surrounding ablated metal. The troilite is monocrystalline and undamaged by mechanical deformation. It includes a large amount of graphite and silicates. The graphite is a polycrystalline felt of typically 5 x 25  $\mu$  units, and the silicates are unevenly dispersed in it, as scalloped, irregular grains, 50-300  $\mu$  across. Apparently two different silicates occur, but they were not identified.

Carlsbergite occurs commonly as oriented 30 x 1  $\mu$  platelets in the kamacite. Cohenite was detected as a 50-150  $\mu$  wide, discontinuous rim around the schreibersite on the troilite. The cohenite is shattered, but has not started decomposition to graphite plus ferrite.

Along parts of its periphery Yardea has preserved the heat-affected  $\alpha_2$  zone as an up to 2.5 mm wide rim with micromelted phosphides in the exterior part. On other parts it is lost, so it appears that the mass has on the average lost 1-2 mm by terrestrial weathering.

Yardea is an inclusion-rich coarse octahedrite which as its closest relatives may have such well known irons as Canyon Diablo, Cranbourne, Seymour, Burkett and Yenberrie. It is unrelated to the other iron meteorites recorded from South Australia. It is a typical member of group I with a composition similar to Yardymly, Cranbourne and Canyon Diablo.

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### Yardymly, Azerbaijan SSR

$38^{\circ}56'N, 48^{\circ}15'E$

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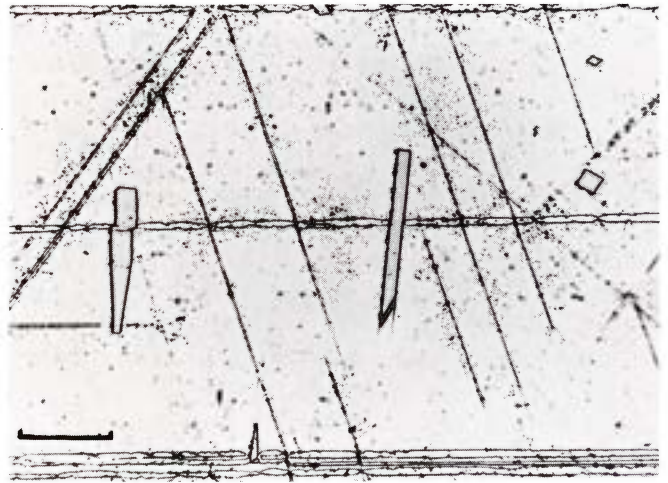
Coarse octahedrite, Og. Bandwidth  $2.2 \pm 0.5$  mm. Annealed. HV  $148 \pm 10$ .

Group I. 6.75% Ni, 0.43% Co, 0.14% P, 0.4% C, 88 ppm Ga, 387 ppm Ge, 1.8 ppm Ir.

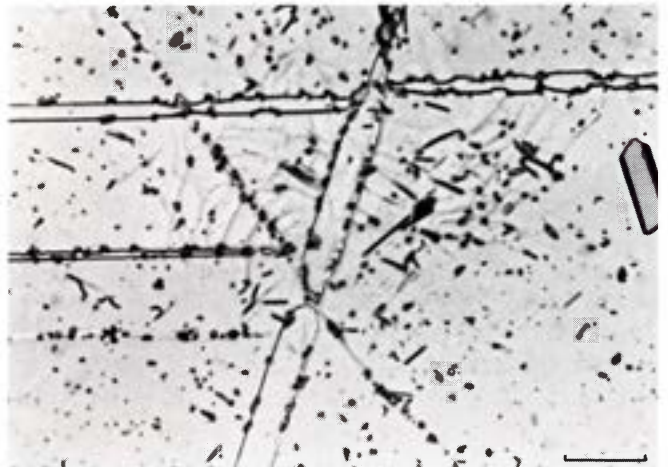
Also known under the synonym Aroos, particularly in papers reporting isotope studies.

#### HISTORY

The Yardymly shower fell on November 24, 1959, at 7:05 a.m. Moscow time (4:05 a.m. G.M.T.) northeast of



**Figure 1997.** Yardymly (U.S.N.M. no. 1940). A coarse octahedrite of group I similar to, e.g., Yardea and Cranbourne, but cosmically annealed. In the kamacite lamellae the Neumann bands are decorated. A sheared rhabdite crystal to the left. Etched. Scale bar 100  $\mu$ .



**Figure 1998.** Yardymly (U.S.N.M. no. 1940). High magnification reveals the fine precipitates on the Neumann bands. They may, however, also be revealed in a different way, compare Figures 2002 and 2003. Etched. Oil immersion. Scale bar 10  $\mu$ .

Yardymly near the Iranian border. Six specimens, totaling 152.6 kg, were recovered from an elliptical strewnfield 8 x 1.5 km in size. The major axis extended in a southwest-northeast direction which also was the direction of flight. The recovered specimens weighed 127, 11.3, 5.9, 5.7, 2.3 and 0.36 kg. The largest fragment of 127 kg, was recovered in the northeastern end of the ellipse, while the smallest fragment of 360 g, was recovered in the southwestern end. The distribution of individual fragments conveniently illustrates the atmospheric deceleration and sorting of fragments according to size. Eyewitnesses reported that the original luminous trajectory from the parent mass was inclined  $45-50^{\circ}$  to the horizontal, while the decelerated specimens from the breakup fell more steeply, inclined  $60-85^{\circ}$  to the horizontal. The 127 kg fragment produced a funnel-shaped hole, 190 cm deep and 200 x 280 cm at the

opening; the other fragments only buried themselves a few decimeters. A full report of the fall and a description of some of the specimens was published by Kashkai & Aliev (1961), who also gave a map and photographs of the exterior shape of the individual specimens.

Yudin & Edeleva (1963) described the microstructure and presented photomicrographs, and Vdovykin (1964) examined in detail the composition of a troilite-graphite nodule. Kvasha (1962: 152) presented photomicrographs of the exterior of a fragment and of the etched section through it. Jaeger & Lipschutz (1967b) found shock intensities below 130 k bar from examination of the kamacite phase.

Yardymly has been extensively studied in order to determine the isotopic composition. Starik et al. (1960) and Marshall & Feitknecht (1964) examined the lead isotopes, and Sobotovich (1964) discussed the results in greater detail. Wetherill (1964) examined the molybdenum isotopes, Chakraborty et al. (1964) the silver isotopes and Kohman & Goel (1963) the carbon-14 isotope. Various noble gas isotopes were studied by Hintenberger & Wänke (1964).

The  $^3\text{He}/^4\text{He}$  determinations by Signer & Nier (1962) lead to an estimate of  $800 \pm 150$  million years for the cosmic ray exposure age. A different treatment of the same data by Bauer (1963) lead to 850 million years. Vilček & Wänke (1961; 1963) found by the  $^{36}\text{Cl}$  method  $540 \pm 30$  million years. Additional  $^{36}\text{Cl}$  data were given by Goel & Kohman (1963). From  $^{21}\text{Ne}/^{26}\text{Al}$  measurements, the exposure age was found to be  $1000 \pm 100$  million years (Lipschutz et al. 1965), while  $^{39}\text{Ar}/^{38}\text{Ar}$  determinations by Schaeffer & Heymann (1965) gave  $650 \pm 40$  million years. Voshage (1967) found  $915 \pm 50$  million years by the  $^{40}\text{K}/^{41}\text{K}$  method, while Chang & Wänke (1969) found  $520 \pm 30$  million years by the  $^{36}\text{Ar}/^{10}\text{Be}$  method. Lämmerzahl & Zähringer (1966) found  $950 \pm 230$  million years by the  $^{40}\text{Ar}/^{38}\text{Ar}$  method. Fireman (1966) discussed the neutron exposure ages as estimated from  $^{60}\text{Co}/^{39}\text{Ar}$  ratios. Determinations of other long-lived, radioactive isotopes were performed by Honda & Arnold (1964). The half-life of  $^{53}\text{Mn}$  was improved upon by Kaye & Cressy (1965) on the basis of meteorite observations.

The discordancy in ages found by the various methods appears to be beyond the experimental error limits. Fisher

(1967) suggested that a time-independent space-erosion effect of  $2 \times 10^{-8}$  cm per year would resolve the discrepancy and bring all the radiation ages into agreement within an error limit of  $\pm 10\%$ . Yardymly's exposure age was recalculated correspondingly to 620 million years.

#### COLLECTIONS

Baku (about 133 kg), Moscow (5.5 kg), Washington (81 g).

#### DESCRIPTION

The largest specimen of 127 kg has an average measurement of  $48 \times 26 \times 23$  cm and is shaped somewhat like the head of a sow. The regmaglypts are pronounced, ranging from 20 to 25 x 40 mm in cross section. The other extreme is the small fragment of 360 g, measuring  $8.5 \times 6 \times 2.5$  cm. The regmaglypts on this specimen are correspondingly small, ranging from 8-15 mm in diameter. All fragments are well covered with regmaglypts, indicating that they had a sufficiently long flight after the breakup to become severely ablated. The original fracture surfaces can hardly be detected now. In addition to the regmaglypts, Yardymly's surface also shows prominent pits due to ablational removal of troilite-graphite nodules; typical pits are 10-15 mm across and of similar depths.



Figure 1999. Yardymly (U.S.N.M. no. 1940). An acicular plessite field with pearlitic edges. The Neumann bands have almost disappeared but rows of precipitates remain. The kamacite matrix is polygonized. Etched. Scale bar 20  $\mu$ .

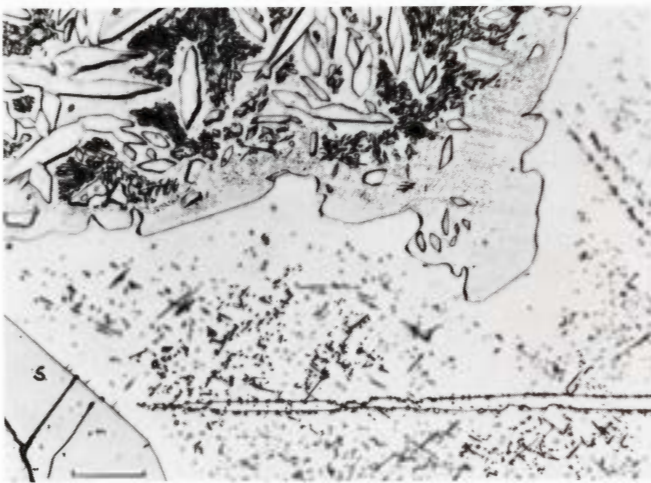
#### YARDYMLY – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm				Pt
	Ni	Co	P					Zn	Ga	Ge	Ir	
Dyakonova in Kashkai & Aliev 1961	6.61	0.41	0.18	2000			100					
Boronskaja in ibid. Yudin & Edeleva 1963	6.96	0.41	0.10	4400								
Cobb 1967	6.73	0.49					139		94		2.1	
Wasson 1970a	6.71	0.42							88.2	387	1.6	

Etched sections disclose a coarse Widmanstätten structure of short, bulky kamacite lamellae with a width of  $2.2 \pm 0.5 \mu\text{m}$ . In numerous places late grain growth has resulted in large, irregular kamacite grains, 10-15 mm across. The kamacite is rich in Neumann bands. These are all well decorated by  $0.2\text{-}2 \mu$  thick phosphide precipitates which follow both sides of the deformation twins. Many Neumann bands are partly annihilated, now terminating  $10\text{-}50 \mu$  adjacent to taenite and schreibersite inclusions. In  $10\text{-}50 \mu$  wide zones around schreibersite, the kamacite is recrystallized to  $5\text{-}20 \mu$  wide units. The microhardness of the kamacite is unusually low,  $148 \pm 10$ . The low hardness and the microstructure indicate a thorough cosmic annealing.

Taenite and plessite cover, on the average, 2-3% of the sections, either as  $10\text{-}100 \mu$  wide lamellae or as irregular fields of concave outlines, rarely exceeding 1 mm in size. The fields are developed as acicular plessite with  $5\text{-}10 \mu$  wide kamacite spindles, as pearlitic plessite with  $0.5\text{-}2 \mu$  wide taenite lamellae or as spheroidized plessite with taenite spherules,  $2\text{-}30 \mu$  in diameter. Many fields are distinctly decomposing on a microscale, the taenite rim exhibiting frayed edges and internal, micron-sized kamacite islands. Other taenite veinlets exhibit a densely spaced grid like the one described in Anoka and others. Also, all taenite etches in dirty brown-yellow colors, suggesting a submicroscopic two-phase structure of  $\alpha$  and  $\gamma$ . The microhardness of the taenite and pearlitic plessite is  $165 \pm 5$ , exceedingly low values which must be ascribed to a thorough cosmic annealing.

Schreibersite is common as angular inclusions 1-2 mm thick, or as  $10 \times 1 \text{ mm}$  lamellae. It also occurs as  $30\text{-}100 \mu$  wide grain boundary veinlets and as 0.5 mm thick, partly shattered rims around the troilite nodules. Rhabdites are abundant, mostly as tetragonal prisms  $5\text{-}15 \mu$  thick. They are frequently shear-displaced  $1\text{-}5 \mu$  along the Neumann bands, but the fractures are later healed by diffusional

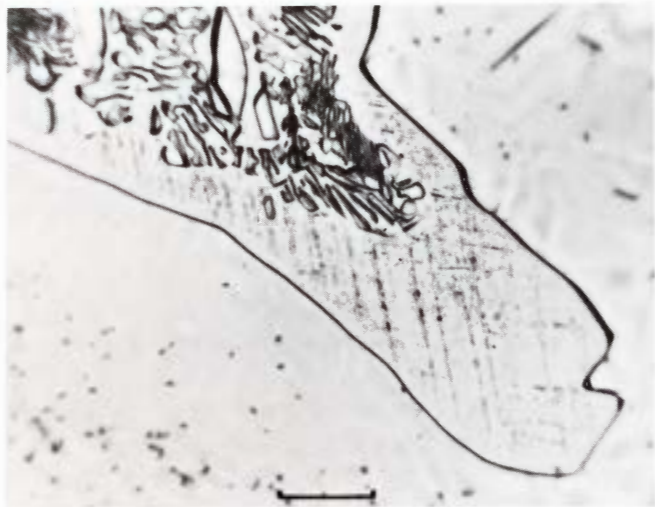


**Figure 2000.** Yardymly (U.S.N.M. no. 1940). An acicular plessite field with wide taenite edges, showing deformation grids that are decorated with submicroscopic precipitates, probably of kamacite. Annealed Neumann bands and acicular precipitates in the kamacite matrix. To the left a schreibersite crystal. Etched. Scale bar  $20 \mu$ .

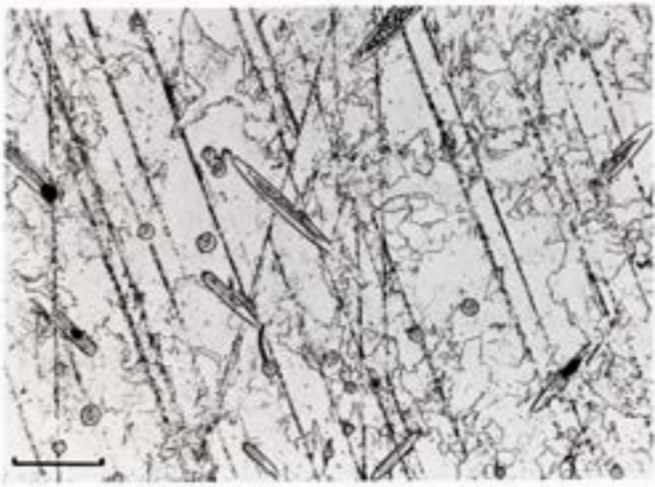
processes. A large number of fine ( $< 1 \mu$ ) phosphide precipitates occur everywhere in the kamacite.

Troilite occurs as elliptical grains ranging from  $0.1\text{-}30 \text{ mm}$  in diameter. It is frequently intimately mixed with graphite. Kashkai & Aliev (1961) examined a nodule composed of graphite and troilite in the ratio 1:1 and determined the troilite and graphite reflections by X-ray diffraction analysis. A similar analysis was carried out by Vdovykin (1964). The troilite is polycrystalline and contains numerous angular fragments of daubreelite and schreibersite,  $1\text{-}200 \mu$  in size. The schreibersite fragments evidently come from the rim zone which was brecciated and partly dispersed in the molten troilite phase by some violent preatmospheric event.

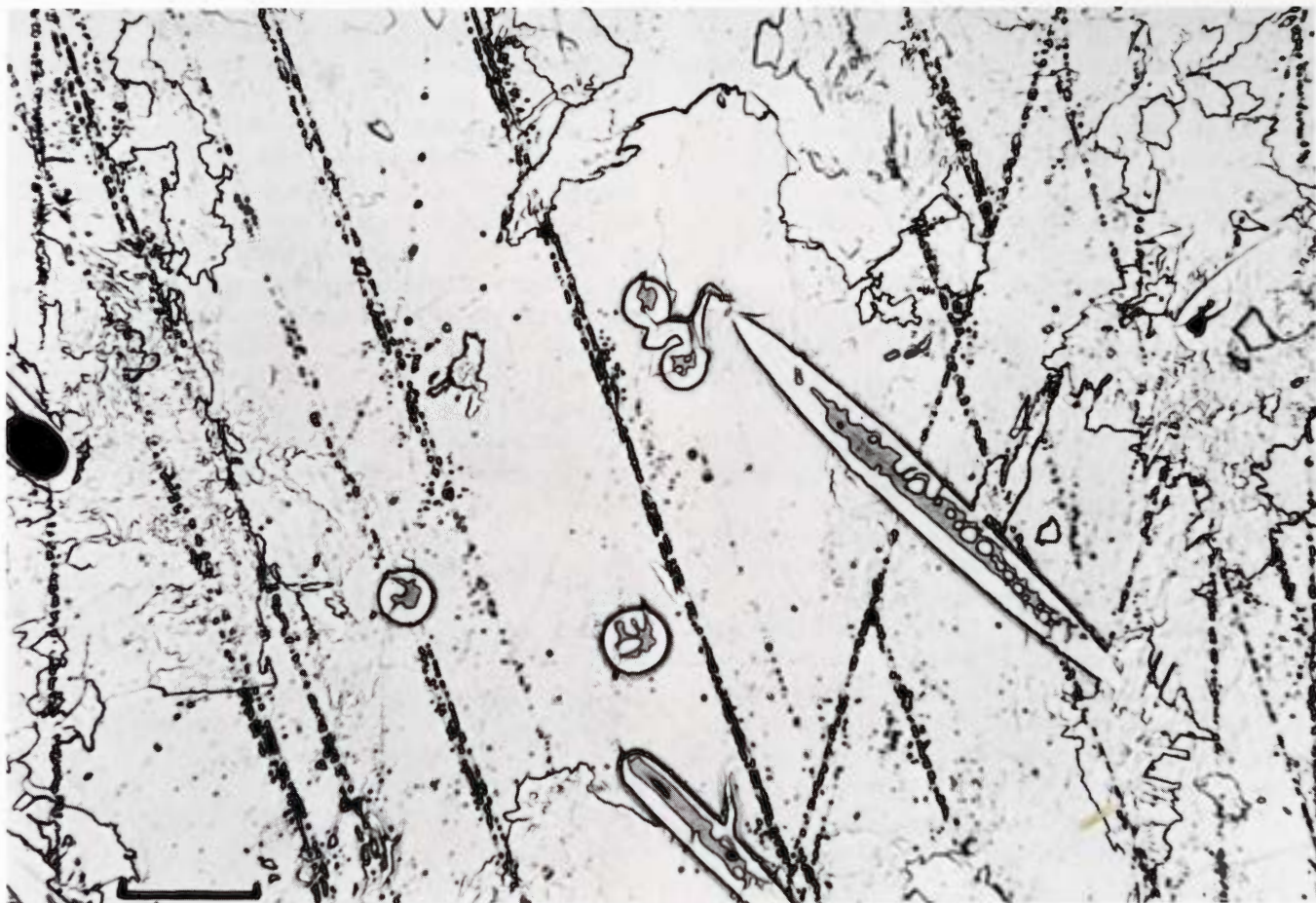
Graphite occurs as  $0.4\text{-}1 \text{ mm}$  irregular cakes in the kamacite phase; cliftonitic development was not detected. Some of the graphite cakes are enveloped in schreibersite



**Figure 2001.** Yardymly (U.S.N.M. no. 1940). Detail of a taenite edge with decorated deformation grids. Etched. Oil immersion. Scale bar  $10 \mu$ .



**Figure 2002.** Yardymly (U.S.N.M. no. 1940). Heat-affected  $\alpha_2$  zone. Part A (page 53) with fused phosphides. These solidified with dendrites – free in the melt or attached to the wall. Gasholes (black) are often present. Etched. Scale bar  $200 \mu$ . See also Figure 49.



**Figure 2003.** Yardmyly (U.S.N.M. no. 1940). Detail of Figure 2002. The traces of the Neumann bands are still visible although the kamacite has been through an  $\alpha \rightarrow \gamma \rightarrow \alpha_2$  transformation. The traces are formed by rows of fine precipitates which had no time to become resorbed during the brief reheating in the atmosphere. Etched. Scale bar 10  $\mu$ .

crystals, up to 2 mm in size, so at least this graphite must be an early precipitate. Cohenite was not detected in the available sections. Whether it is completely absent or just not revealed in the sections is a matter of opinion. Perhaps the secondary cosmic annealing, responsible for the softness and recovery of the  $\alpha$  and  $\gamma$  phases, also decomposed any preexisting cohenite. In that case some graphite lamellae ought to be present, however.

Chromite is common as 0.05-0.2 mm euhedral crystals. Situated in the kamacite phase, it often forms the nucleus of graphite and schreibersite crystals. Carlsbergite is present as a minor accessory in the  $\alpha$ -phase, forming 1-2  $\mu$  blebs.

The fusion crust is a striated or warty or smooth deposit of magnetite plus wüstite, 50-100  $\mu$  thick. It includes minute droplets of yellowish metal, enriched in nickel. Under the oxide layer is the metallic part of the fusion crust, 0-200  $\mu$  thick. Individual sheets are 20-50  $\mu$  thick and composed of dendritic-cellular metal with a dendritic armspacing of about 1  $\mu$ . Several fissures which formed during the atmospheric breakup are now filled with metallic melts. Typical is a 20 mm long crack, 100-200  $\mu$  wide, and almost completely filled with fine-grained dendritic melts. The metallic melts contain numerous globules of oxides. They are few and small (< 1  $\mu$ ) in the

early layers, but increase in size ( $\sim 25 \mu$ ) in the later layers, probably because the meteorite then reached a denser atmosphere with a higher oxygen partial pressure.

Under the fusion crust there follows the normal heat-affected  $\alpha_2$  zone. It is 1-2 mm thick and composed of numerous serrated  $\alpha_2$  units, each 25-100  $\mu$  in size. In the exterior 50% of the  $\alpha_2$  zone, the embedded phosphides are micromelted. The melts frequently form continuous 1-5  $\mu$  wide films in the grain boundaries, and internal stresses in the  $\alpha_2$  zone have in several places strained the zone so much that 0.2-1 mm long microcracks have developed perpendicular to the surface. The hardness of the  $\alpha_2$  zone is  $173 \pm 5$ . It decreases to  $148 \pm 10$  at a depth of 2-3 mm and remains on this level through the meteorite (hardness curve type III).

Yardmyly is a coarse octahedrite related to such irons as Gladstone, Cranbourne and Kaalijärv. In its secondary annealed structure, produced by a cosmic annealing which may have raised the temperature to 400-500° C for a while, it resembles Seeläsgen. It is a typical member of group I.

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

80 g part slice (no. 1940, 4.5 x 3.5 x 1 cm) probably from one of the 5 kg specimens

**Yarri, Western Australia**  
Approximately 29°27'S, 121°13'E

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm.  $\epsilon$ -structure. HV 280±20.

Group IIIA. 7.92% Ni, 0.45% Co, 0.17% P, 19.8 ppm Ga, 38.5 ppm Ge, 4.0 ppm Ir.

#### HISTORY

In 1908 a mass of 3 pounds 5½ ounces (i.e., 1.52 kg) was sent for identification to the Geology Department, School of Mines, Kalgoorlie. The owner, a prospector, said that it was found at "Yarri, 8 miles from Yerilla." Cleverly & Thomas (1969) found inconsistencies in the old report and concluded that the mass had probably been found within a circle with an eight-mile radius centered on Yerilla. The coordinates above are for Yerilla, an abandoned gold mining township.

McCall & de Laeter (1965: 55 and plate 14) gave preliminary information and a photograph of the exterior, showing a cut end. A full and eminent description, with map sketch and photographs appeared in 1969 (Cleverly & Thomas). The microhardness testing method was applied to its full advantage and important observations on the hardness gradient in the heat-affected zones were discussed.

It is assumed in the previous reports that the original mass weighed 1.52 kg. However, in Tempe there is a 210 g endpiece (No. 679.1, 6 x 3.5 x 3 cm) presumably acquired by Nininger in the 1950s. The original mass must therefore have weighed about 1.75 kg.

#### COLLECTIONS

School of Mines, Kalgoorlie (1.5 kg main mass), Tempe (210 g).

#### DESCRIPTION

According to Cleverly & Thomas (1969), the mass now measures about 10 x 7.7 x 3.5 cm. It possibly weighed 1.75 kg originally, but several small pieces had been hacked off at an early date. The form is that of a thick, doubly arched slab, evidently only slightly altered by weathering. The fusion crust is lost, but a heat-affected  $\alpha_2$  zone is preserved over substantial parts of the prepared sections.

Yarri is a medium octahedrite displaying straight, long ( $\frac{l}{w} \sim 25$ ) kamacite lamellae with a width of 1.00±0.15 mm. The kamacite is rich in subboundaries, but these are obscured by the hatched  $\epsilon$ -matrix from a cosmic shock

event. The  $\epsilon$ -matrix is shock-hardened to 280±20 and does not show any annealing effects.

Taenite and plessite cover about 35% by area, mostly as comb and net plessite but also as dense dark-etching types and as fields with a Widmanstätten felt of acicular  $\alpha$ -platelets. The cloudy taenite lamellae have hardnesses of 360±30, evidently shock-hardened like the kamacite lamellae.

Schreibersite does not occur as large crystals (and cannot be the cause of the pits on the surface as believed by Cleverly & Thomas) but only as 20-90  $\mu$  wide grain boundary veinlets and as 5-50  $\mu$  blebs inside the open plessite fields, substituting for  $\gamma$ -particles of similar sizes. Rhabdites were not detected.

Troilite is probably present as 1-2 cm nodules and may be the cause of the pits on the surface, formed by ablatational melting during the atmospheric flight.

The heat-affected rim zone becomes visible as a 1-3 mm wide matte border by suitable etching with 2-5% Nital. It is a transformation zone – not a recrystallization zone, as believed by Cleverly & Thomas. It formed by the rapid transformation of kamacite ( $\alpha$ ) to taenite ( $\gamma$ ), which then, upon cooling, transformed diffusionless to  $\alpha_2$  by a martensitic mechanism. The  $\alpha_2$  grains are unequibrated, serrated and hard, 200±20. In contrast, recrystallized  $\alpha$ -grains form from cold-worked  $\alpha$ -grains by nucleation and growth, and are ideally equilibrated, equiaxial and soft, about 155±5 for a similar composition (7% Ni, 0.05% P).

Yarri is a shock-hardened medium octahedrite of a common type. Close relatives are Juncal, Samelia, Merceditas, Cumpas and Augusta County. Chemically, it is a typical member of group IIIA, and thus also related to Charcas, Sandtown and Roebourne. These are, however, significantly different in their structures because of annealing in space, or on Earth (Charcas).

**Yarroweyah, Victoria, Australia**

35°59'S, 145°35'E

Hexahedrite, H. Shock-recrystallized.

Group IIA. 5.59% Ni, 0.48% Co, about 0.20% P, 59 ppm Ga, 171 ppm Ge, 18 ppm Ir.

#### HISTORY

A mass of 9.6 kg was found in 1903 about 7 km south of Yarroweyah railway station in the County of Moira. The mass was lying on the surface of the ground in a paddock belonging to Mr. T. Holden, and was found by his boys. It

**YARRI – SELECTED CHEMICAL ANALYSES**

References	percentage			ppm								
	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Cleverly & Thomas 1969	8.06	0.45	0.17		40		220					
Scott et al. 1973	7.77								19.8	38.5	4.0	

was acquired in 1913 for the Melbourne Museum and described by Walcott (1915) as a nickel-poor ataxite. The coordinates above are from the original description. An entirely different coordinate set is given by Hey (1966: 527); it is not clear whether the second set is based on later information or is a misprint.

#### COLLECTIONS

National Museum, Melbourne (main mass), Canberra (149 g).

#### DESCRIPTION

According to Walcott (1915), who presented two photographs of the exterior, the mass measured  $22\frac{1}{4} \times 16 \times 15\frac{1}{4}$  cm in its extreme dimensions. The average dimensions in three perpendicular directions are only  $20 \times 11 \times 9$  cm. The mass is weathered, displaying sharply carved bowls with sharp ridges in between. No unambiguous regmaglypts can be distinguished. Both fusion crust and heat-affected  $\alpha_2$  zones are apparently lost as the result of weathering.

I have not seen slices from this mass, but the old description by Walcott indicates that Yarroweyah has a structure similar to Holland's Store, Wathena and Mejillones. This means that the mass is a shock-recrystallized hexahedrite originally with a structure similar to that of, e.g., Coahuila and Boguslavka, and belonging to the resolved chemical group IIA. This interpretation tallies well with the analytical data by Lovering and Wasson, quoted below.

It is recommended that the material be subjected to a modern metallographic examination.

### Yenberrie, Northern Territory, Australia

Approximately  $14^\circ\text{S}$ ,  $132^\circ\text{E}$

Coarse octahedrite, Og. Bandwidth  $2.1 \pm 0.4$  mm. Neumann bands, HV  $205 \pm 15$ .

Group I. 6.85% Ni, 0.49% Co, about 0.18% P, 87 ppm Ga, 312 ppm Ge, 2.9 ppm Ir.

#### HISTORY

A mass of 291 pounds (132 kg) was found in 1918 by John Hoare. It lay embedded in sandy soil about 20 miles south southeast of Yenberrie. A portion of 12.5 kg was detached and sent to the U.S.A., while the main mass was

acquired for collections in Sydney. Mingaye (1920: 314, 597) gave the above information and presented detailed analyses. Hodge-Smith (1939) reported the coordinates quoted above and presented a photograph of the exterior.

#### COLLECTIONS

Sydney (42.29 kg), Sydney, Commonwealth Official Collection (32.98 kg), Chicago (4.50 kg), Washington (3.83 kg), New York (3.76 kg), London (599 g).

#### DESCRIPTION

It appears that the main mass has not been examined or described. From a photomicrograph in Hodge-Smith (1939), it can be seen that the mass is of an irregular pear-shape with several sharp edges and large shallow cavities. The visible portions are probably mainly carved by corrosion, while fusion crust and regmaglypts seem to have disappeared.

The specimens in Washington are slices with significant superficial corrosion. The fusion crust and the heat-affected



**Figure 2004.** Yenberrie (U.S.N.M. no. 607). A coarse octahedrite of group I. Cohenite crystals (black) are common in the upper half of the sample. Deep-etched. Scale bar 20 mm. S.I. neg. 42036B.

#### YARROWEYAH – SELECTED CHEMICAL ANALYSES

In an otherwise inadequate analysis, Walcott (1915) reported 0.20% P and 0.02% Cl. The chlorine was believed to come from the cosmic mineral, lawrencite, but since the mass is weathered and the chlorine was only noted in the

near-surface zones, it appears more plausible that it was introduced along grain boundaries by ground water during long terrestrial exposure.

References	percentage			C	S	Cr	Cu	ppm				Pt
	Ni	Co	P					Zn	Ga	Ge	Ir	
Lovering et al. 1957	5.70	0.48				67	144	48	154			
Wasson 1969	5.48							59.3	171	18		

$\alpha_2$  zones are removed and no hardness gradient from the interior towards the surface could be detected. It appears that at least 5 mm has been lost by terrestrial weathering. To a minor extent corrosion attacks the interior along grain boundaries and phosphides.

Etched sections display a coarse Widmanstätten structure of straight but bulky ( $\frac{l}{w} \sim 8$ ) kamacite lamellae with a width of  $2.10 \pm 0.40$  mm. The narrower bandwidths are associated with the cohenite-rich regions. Locally, grain growth has created almost equiaxial kamacite grains 5-10 mm in diameter. Subboundaries decorated with 1-3  $\mu$  rhabdites occur abundantly. The Neumann bands are sharp and undecorated; the hardness of the somewhat cold-worked kamacite phases is  $205 \pm 15$ .

Taenite and plessite cover 2-5% by area, and all the varieties typical of group I are present. The comb plessite may form fields of several square millimeters. The taenite ribbons display pearlitic decomposition to fine-grained lamellar aggregates of  $\alpha$  and  $\gamma$ ; the  $\gamma$ -lamellae range in thickness from submicroscopic size to 2  $\mu$ , and the micro-hardness varies accordingly (HV  $240 \pm 30$ ), the finer having the higher hardness. The bluish-black, tarnished taenite rims (HV  $375 \pm 25$ ) merge into martensite with high-carbon, high-nickel morphology (HV  $375 \pm 25$ ) in which retained taenite (HV  $300 \pm 20$ ) is common. Spheroidized and acicular fields are also present.

Schreibersite forms 10 x 1 mm lamellae or 0.2-1 mm branching aggregates, normally enveloped in 0.1-0.5 mm

thick cohenite layers. Schreibersite is further common as 20-80  $\mu$  wide grain boundary precipitates and as tiny blebs inside and along the edge of plessite fields. Rhabdites are ubiquitous, either as 5-15  $\mu$  widely spaced tetragonal prisms, or as clouds of dense precipitates of small particles ( $< 1 \mu$  across). The Neumann bands are wide where they pass the first type but decrease significantly in width where they pass the fine precipitates. The bulk phosphorus content is estimated to be 0.15-0.20%. Mingaye (1920) found 0.161 and 0.195% P in duplicate determinations.

Cohenite occurs abundantly in some specimens but is practically absent in other sections only 5-10 cm distant. It forms rounded, somewhat branching monocrystalline units, typically 3 x 0.5 mm in size. It is oriented along Widmanstätten lamellae and contains small inclusions of kamacite, taenite and schreibersite. No decomposition to graphite was detected. Its hardness is  $1100 \pm 25$ .

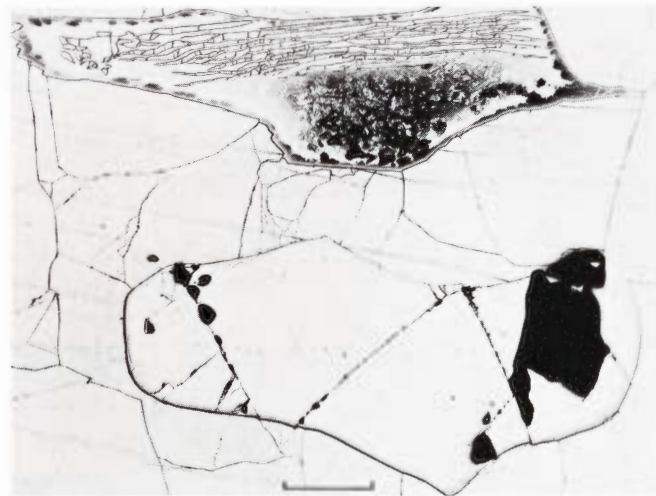
Both schreibersite and cohenite are brecciated and frequently displaced in successive steps along subparallel shear zones. The relative displacements rarely exceed 20  $\mu$ , however.

Troilite, graphite and silicates were not detected in the available sections; these minerals will, however, no doubt be present in other specimens.

Yenberrie is a typical inclusion-rich coarse octahedrite of group I. It is closely related to Canyon Diablo, Seymour, Silver Crown, Smithville, Youndegin and other coarse octahedrites.



**Figure 2005.** Yenberrie (U.S.N.M. no. 607). An open-meshed comb plessite field which was being resorbed when all diffusion stopped. Schreibersite crystals (S). Note the numerous subboundaries. Etched. Scale bar 300  $\mu$ .

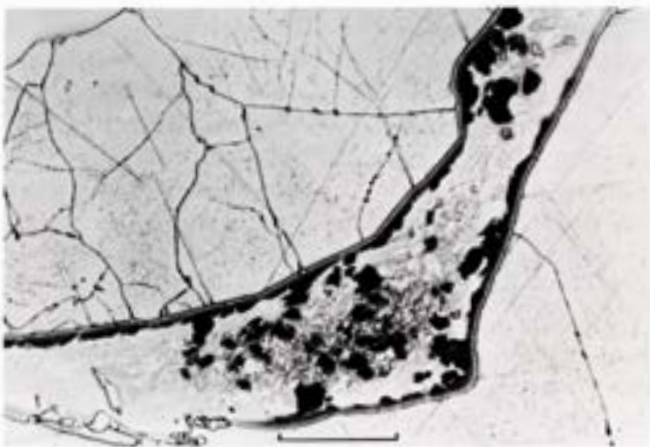


**Figure 2006.** Yenberrie (U.S.N.M. no. 607). Comb plessite with cloudy taenite edges. Compare Figure 109. Below a typical cohenite crystal, which chipped during sample preparation. Etched. Scale bar 300  $\mu$ .

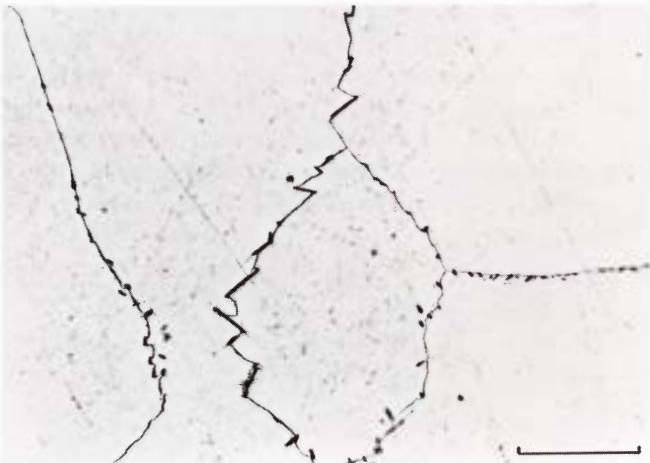
YENBERRIE – SELECTED CHEMICAL ANALYSES

References	percentage			C	S	Cr	Cu	ppm Zn	Ga	Ge	Ir	Pt
	Ni	Co	P									
Mingaye 1920			0.18	690			170					2.6
Lovering et al. 1957	6.97	0.49				2.6	132		88	344		
Wasson 1972, pers. comm.	6.72								86.7	312	2.9	

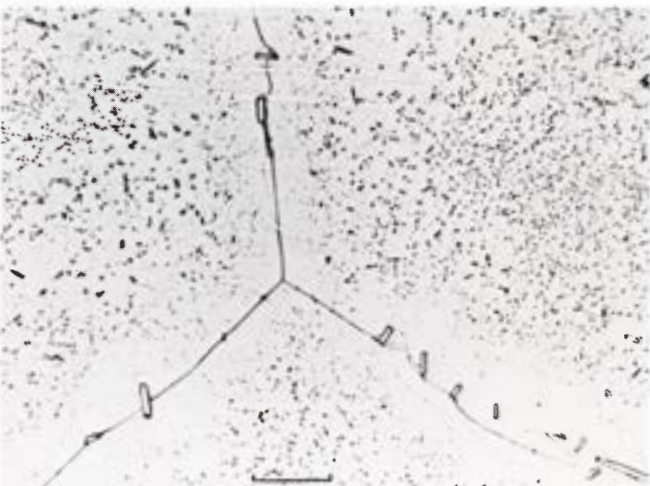
While Mingaye correctly found a total of 7.44% Ni+Co, his individual figures must be incorrect, and they are not quoted here.



**Figure 2007.** Yenberrie (U.S.N.M. no. 607). Taenite with cloudy edges and martensitic interior in which cloudy patches occasionally occur. Part of the explanation may be sought in the taenite lamella being parallel to the plane of section. Etched. Scale bar 200  $\mu$ . See also Figures 109 and 119.



**Figure 2008.** Yenberrie (U.S.N.M. no. 607). The grain and subgrain boundaries of the kamacite are pinned by numerous fine precipitates, mainly of phosphides. Etched. Scale bar 200  $\mu$ .



**Figure 2009.** Yenberrie (U.S.N.M. no. 607). Three subboundaries with angular rhabdite precipitates. The adjacent kamacite is P- and Ni-depleted and free of precipitates. Etched. Scale bar 50  $\mu$ .

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

3.54 kg on three slices (no. 607)  
290 g part slice (no. 1626)

#### York (Iron), Nebraska, U.S.A.

Approximately 40°52'N, 97°35'W; 500 m

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm.  $\epsilon$ -structure. HV 305±15.

Probably group IIIA. About 7.7% Ni and 0.12% P.

#### HISTORY

A mass of 835 g was found in 1878 on the farm of Robert M. Lytle, near York in York County. The mass was plowed up from a depth of 20 cm in virgin, black loamy prairie soil. It was in the finder's possession until 1895 when it was acquired by Barbour (1898) who described it and gave figures of the exterior and of etched slices.

#### COLLECTIONS

New York (701 g), Washington (30 g).

#### ANALYSES

Kunz reported (in Barbour 1898) 7.38% Ni and 0.74% Co. The sum appears correct, but the present author would expect that some of the nickel has been included with the cobalt. The meteorite is estimated to have the following composition: 7.7±0.2% Ni, 0.50% Co, 0.12±0.02% P, with trace elements placing it in the chemical group IIIA.

#### DESCRIPTION

The mass, of which the major part is in New York, has the average dimensions of 8.5 x 7.5 x 4 cm. At one end there is a cut and polished face 5.5 x 4 cm in size. It is somewhat weathered, but since the heat-altered  $\alpha_2$  zone is still preserved as a 0.5-1.5 mm thick rim zone, at most 1-2 mm has been lost by corrosion. In places even a little of the fusion crust is preserved, albeit in a weathered form. The exterior morphology is surprisingly angular for such a small monolith. Other small meteorites with individual flight paths, as e.g., Freda, Föllinge and Avče, have smoothly rounded shapes, representing the surviving nuclei of larger meteorites. York, however, has a convex, rather smooth side and an opposite side covered with coarse regmaglypts, 1.5-2.5 cm across and 1 cm deep. The shape suggests that it is only a minor fragment of a larger mass which was never found. Perhaps it belonged with the 13.2 kg Lancaster County mass, reported by Barbour (1903), but now lost.

Etched sections display a medium Widmanstätten structure with straight, long ( $\frac{L}{W} \sim 30$ ) lamellae with a width of 1.00±0.15 mm. There is little contrast between the plessite fields and the kamacite lamellae, since the fields are very open-meshed, kamacite-rich, and all kamacite has been converted by shock to the crosshatched  $\epsilon$ -type. The