(~ 400° C). The kamacite around the graphite-haxonite aggregate is highly anomalous to a distance of 1 mm, with numerous undulating subboundaries decorated with rhabdites.

The aggregate described above is unusual, but related to other poorly preserved aggregates in the North Chilean hexahedrites. It probably started at a high temperature with the precipitation from solid solution of a few cliftonite crystals. These later served as nucleation sites for more graphite, now of a microcrystalline nature. Finally, in a last attempt to get rid of dissolved carbon, the kamacite rejected carbon to form haxonite at a time when rhabdites had already precipitated.

Besides the minerals mentioned above, Walker County also contains a modest amount of the chromium nitride, carlsbergite, as 5 x 1 μ platelets. Chromite occurs as 50-200 μ euhedral crystals which are intergrown with troilite and daubreelite. Cohen (1905: 172) observed at least two different types of silicate grains; they were detected in the residue from dissolving a 43 g specimen for analysis.

There are indistinct, 5-10 μ wide reaction zones of a lacework type between the corrosion products and the kamacite. There also seem to be 0.5-1 μ metallic beads in the limonite. This, in connection with the rather low hardness for a hexahedrite which shows no signs of cosmic annealing, indicates that the finder reheated the meteorite slightly, probably for a short time to about 400° C. The evidence is circumstantial and far from so decisive as, e.g., is the case for Rodeo, Ruff's Mountain and Victoria West.

Walker County is a normal hexahedrite with a large number of rather evenly distributed rhabdite plates. Structurally and chemically, it is closely related to the North Chilean hexahedrites even as far as the occurrence of graphite nodules is concerned.

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

13 g part slice (no. 120)
259 and 10 g endpiece (no. 379, 8 x 4.5 x 1.5 cm and mounted fragment)
8 g fragment (no. 3144)

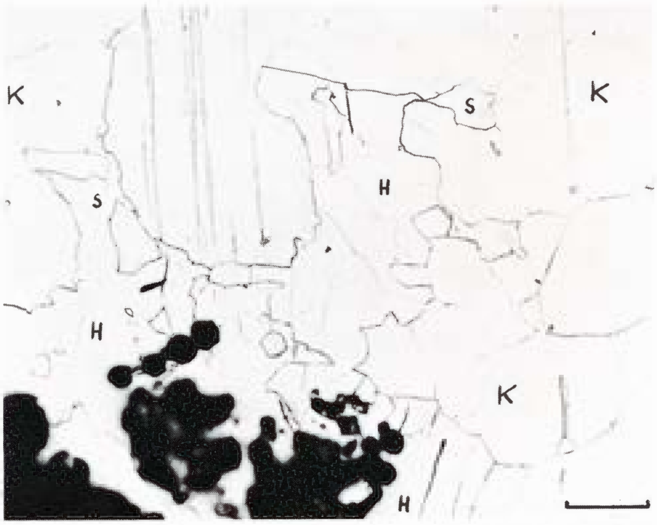

Figure 1877. Walker County (U.S.N.M. no. 379). Detail of the edge of another graphite nest similar to that in Figure 1876. A cluster of fine cliftonitic graphite crystals (black) are located in kamacite (K) with Neumann bands, and in haxonite (H) with small phosphide inclusion (S). Etched. Scale bar 50 μ.

Wallapai, Arizona, U.S.A.

Approximately 35°48'N, 113°42'W; 2000 m

Fine octahedrite, Of. Bandwidth 0.43±0.06 mm. Neumann bands/ε. HV 255±15.

Group IID. 11.4% Ni, 0.69% Co, about 0.9% P, 82 ppm Ga, 98 ppm Ge, 3.5 ppm Ir.

HISTORY

In 1927 two masses of 306 and about 124 kg were reported to the U.S. National Museum from the Wallapai Indian Reservation in Mohave County. They were lying on the slope of a limestone mountain, only about 1.5 m apart, and protruded with about one-fourth of their mass above the ground. The meteorites had been discovered by an Indian, Dick Grover, and the location was given as 10-12 miles southeast of the Music Mountain mine and six miles from the rim of the Grand Canyon of the Colorado River. It appears, however, that the exact locality is no longer known. The smaller mass was acquired by the University of

Figure 1878. Wallapai (U.S.N.M. no. 788). The 306 kg mass is in the Smithsonian Institution. It is covered by corrosion products that indicate that its terrestrial age is high. Wallapai cannot be an observed fall as believed by previous writers. S.I. neg. 6154B.

Arizona in Tucson while, in 1927, the larger mass went to the U.S. National Museum where it was described by Merrill (1927c) with photographs of the discovery site, of the exterior and of an etched slice. Merrill, who quoted an eyewitness to a fireball observed over the area in 1904, believed that the two masses were associated with that particular event. However, the state of corrosion, as described below, is of a degree that suggests a terrestrial age of many thousands of years. Nininger & Nininger (1950: plate 5) and Buchwald (1968b: 12) reproduced a figure of an etched section through No. 1.

COLLECTIONS

Washington (302.2 kg of No. 1; 743 g of No. 1; 501 g of No. 2); Tucson (about 123 kg of No. 2), Tempe (597 g of No. 1), New York (499 g of No. 2), London (74 g of No. 1).

DESCRIPTION

The 306 kg mass (No. 1) is a shapeless lump with the average dimensions of 50 x 40 x 37 cm. The 124 kg mass (No. 2) is also a roughly rounded lump, averaging 44 x 34 x 27 cm. There are no conspicuous fracture zones on the surfaces which could indicate where they were originally joined. The ablation time was evidently sufficiently long to largely eliminate any hackly surface. And still the masses were discovered close together indicating a long, completely parallel flight – but perhaps the Indians had moved the masses. They are only slightly weathered. Regmaglypts, 2-4 cm in diameter, are visible in many places and local bowl-shaped depressions, e.g., 12 x 11 cm in aperture and 7 cm deep, are also caused by the atmospheric ablation. Small amounts of weathered fusion crust are preserved in protected places. Straight "chisel marks" indicate where Brezina lamellae were partially removed by ablational melting. They are typically 30 mm long, 1 mm deep and 1-3 mm wide. It is estimated that, on the average, only 1-2 mm metal has been lost by weathering.

Etched sections display a fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 35$) kamacite lamellae with a width of 0.43±0.06 mm. The kamacite has subboundaries decorated with 1-2 μ phosphides. It is remarkable that the kamacite shows a marked hatched ϵ-structure in mass No. 1 but open Neumann bands only in No. 2, this apparently being the only difference between the two masses. Transition zones between ϵ- and Neumann band patterns may exist, but were not observed, since only a few kilograms have been cut from each of the masses. No traces of recrystallization were observed.

The kamacite of No. 2 has a hardness of 255±15; it shows distinct Neumann bands which are locally distorted – particularly around the hard and brittle schreibersite lamellae where flow structures and lenticular deformation bands are apparent in the kamacite. It is relatively rare that an iron meteorite displays this much variation in the

Figure 1879. Wallapai (Tucson). The smaller mass of 124 kg, is in the College of Mines, University of Arizona. Regmaglypts are indistinctly visible. Scale bar approximately 10 cm.

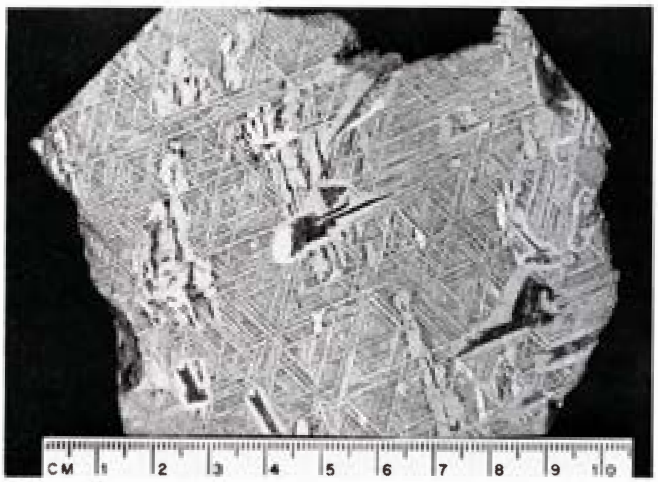

Figure 1880. Wallapai (Tempe no. 58bx). A fine octahedrite of group IID. Prominent schreibersite skeleton crystals with wide rims of swathing kamacite. Deep-etched. Scale in centimeters. (From Buchwald 1968b.)

WALLAPAI – SELECTED CHEMICAL ANALYSES

Hawley (1939) determined the platinum metals collectively and found 13.4 ppm. Goldstein (1967) examined the germanium distribution in the various phases.

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957		0.73				22	253		74	76		
Wasson & Kimberlin 1967	11.3								82.9	98.3	3.5	
Lewis & Moore 1971	11.42	0.64	0.23	120								

kamacite; however, it is known to occur in, e.g., Canyon Diablo, Campo del Cielo and Union County. The secondary structures were probably introduced by shock waves of varying intensity, either in cosmos or upon crater-forming impact. There are no indications that Wallapai should be a crater-forming meteorite, so the structural differences may indicate shock-attenuation in the parent body millions of years ago when the meteorite was released from its matrix, or perhaps dating from some later cosmic collision.

Taenite and plessite cover about 50% by area, particularly as dense, martensitic fields which display duplex and net plessitic development in the interior. The yellow or tarnished taenite rims (HV 400±20), are followed by platy martensite in $\{111\}$ directions (HV 450±20), and then by annealed martensites or unresolvable, duplex $\alpha + \gamma$ zones with hardnesses ranging from 350 to 280 – the lower, the coarser the grain size is. The easily resolvable, duplex structures have γ-blebs, 0.5-2 μ across, and are almost as soft as the kamacite lamellae (270±15).

Schreibersite is dominant as Brezina lamellae, which are developed as halberd-like skeleton crystals, for example 35 x 10 x 2 mm in size. Compact 5 x 5 x 5 mm masses and open rosette-like structures are also common. The schreibersite is enveloped in asymmetric, 1-2.5 mm wide rims of swathing kamacite; it is monocrystalline but slightly brecciated and has a hardness of 900±20. Schreibersite further occurs as 0.2-0.5 mm thick blebs centrally in the kamacite lamellae, as 10-50 μ wide grain boundary veins and as 1-50 μ blebs inside the plessite. Rhabdites proper were not seen, but numerous α-lamellae exhibit a significant background precipitation of phosphides, less than 1 μ across, and especially common in lines upon slip bands and dislocations. The bulk phosphorus content was found by point counting to be about 0.9%.

Troilite is conspicuous by its absence. On polished sections totaling 1,200 cm^2 the largest troilite crystal was 1 mm across, and inspection of the exterior surface of the two main masses also failed to disclose any pits which could be unequivocally attributed to troilite. It appears that the chemical group IID is characterized by, among other things, its low amount of troilite. The little troilite present is associated with schreibersite, forming monocrystalline blebs and elongated bodies, often with 15% daubreelite as parallel bars in the troilite.

The corrosion is mostly superficial – restricted to the exterior 1-5 mm and particularly following the schreibersite and the Widmanstätten boundaries as usual. Locally, the surface is distorted by hammering, and small fragments have been detached along the octahedral faces.

Wallapai is a fine octahedrite, which is closely related to Needles and Rodeo and further to Carbo and other irons of group IID as noted by Wasson (1969). It is particularly interesting in that it displays somewhat different secondary structures in the only two blocks known. This is probably the result of preatmospheric shocks.

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

302.2 kg main mass of No. 1 (no. 788, 50 x 40 x 37 cm)
735 g slice of No. 1 (no. 788, 17 x 9 x 0.5 cm)
501 g part slice of No. 2 (no. 1444, 13 x 10 x 0.5 cm)

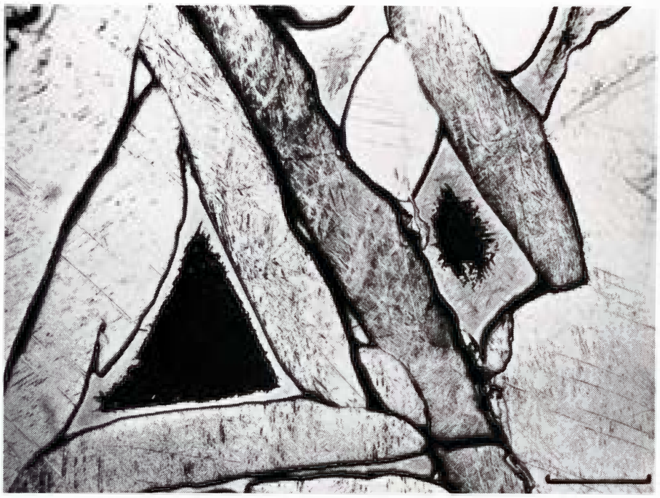

Figure 1881. Wallapai (Tempe no. 58bx). Shock-hatched kamacite and dark-etching plessite fields with cloudy taenite rims. Etched. Scale bar 400 μ.

Figure 1882. Wallapai (Tempe no. 58bx). Plessite field between two kamacite lamellae (K). The plessite shows cloudy taenite edges and martensitic interiors, with plates developed parallel to the bulk Widmanstätten pattern. Etched. Scale bar 50 μ.

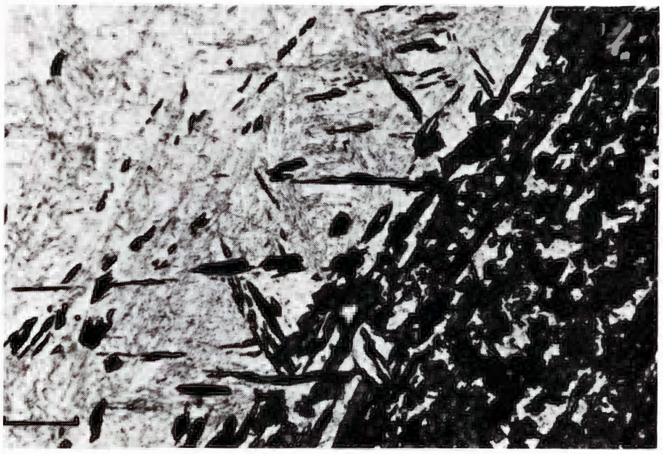

Figure 1883. Wallapai. Detail of the same field as Figure 1882. Transition from lightly etched to heavily etched (in reality brown, blue and black colors) martensite plates. Etched. Scale bar 20 μ. See also Figure 128.

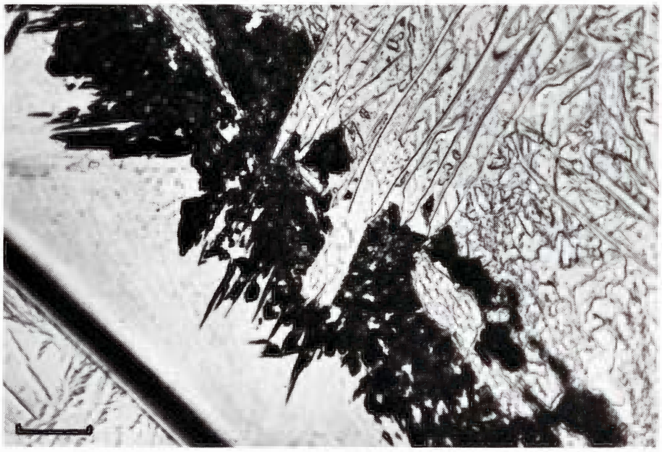

Figure 1884. Wallapai (Tempe no. 58bx). The edge of an acicular plessite field. Kamacite (K) is followed by a narrow yellow high nickel taenite edge. Then follows cloudy taenite and martensitic transition zones. The interior is shock-hatched kamacite needles between taenite lamellae. Etched. Scale bar 20 μ.

Warburton Range, Western Australia

26°17'S, 126°40'E; 600 m

Nickel-rich ataxite, D. α-spindles 8±3 μ wide. Rich in phosphides.

Group IVB. 18.00% Ni, 0.87% Co, about 0.10% P, 0.24 ppm Ga, 0.064 ppm Ge, 13 ppm Ir.

HISTORY

A mass of 125½ pounds (56.7 kg) was discovered in December 1963, or January 1964, about 12 miles south of the Warburton Mission. The finders, the prospectors H. Gill and G. Sims, made the discovery on sand amid broken outcrops of sandstone, and the meteorite was apparently resting on its flat "sole" on the surface, not buried. It was provisionally described as a nickel-rich ataxite, by McCall (1965b) and McCall & De Laeter (1965: 18), and then more fully, with photographs of the exterior, micrographs of etched sections and a map sketch by McCall & Wiik (1966).

COLLECTIONS

Perth (main mass of about 55 kg).

DESCRIPTION

In size and shape, the mass bears some resemblance to Signal Mountain, being a roughly triangular tapering cone. The height of the cone is 24 cm, while the flat or slightly concave sole measures 38 x 22 cm. The mass is well-preserved. On the conical sides it displays beautiful regmaglypts, 3-4 cm in diameter, with smooth crests in between. On the sole the regmaglypts are larger, shallower and indistinct, and somewhat altered due to terrestrial weathering. Fusion crust can be detected in protected places, albeit in a slightly weathered form, and heat-affected rim zones can be seen on sections of good quality. It is estimated that the mass has lost less than 0.3 mm on the average by exposure to the Australian climate.

Etched sections display a somewhat mottled ataxite appearance, only disrupted by the presence of scattered troilite inclusions. High magnification reveals a large number of kamacite spindles, distributed irregularly over the sections. One can distinguish between two kamacite types – one with and one without phosphide nuclei – occurring in about equal proportions, in a total number of 200-400 per mm^2. The first category is developed by heterogeneous nucleation and growth around early phosphide precipitates, generally 5-50 μ across, but ranging up to 250 x 50 in size. Typical spindles of this type, i.e., a schreibersite plus kamacite envelope, measure 30 x 120 μ and are arranged in numerous directions, apparently haphazardly.

The other category consists of Widmanstätten spindles which later presumably nucleated homogeneously and grew in octahedral directions. They are accordingly narrower, usually precipitate-free, typically 8±3 μ wide and about 10 times as long as wide.

Taenite and plessite cover 75-85% by área and usually etch very readily, creating a dark duplex optically unresolvable matrix upon which the kamacite spindles stand out clearly. Even in the matrix, which may be called bainitic,

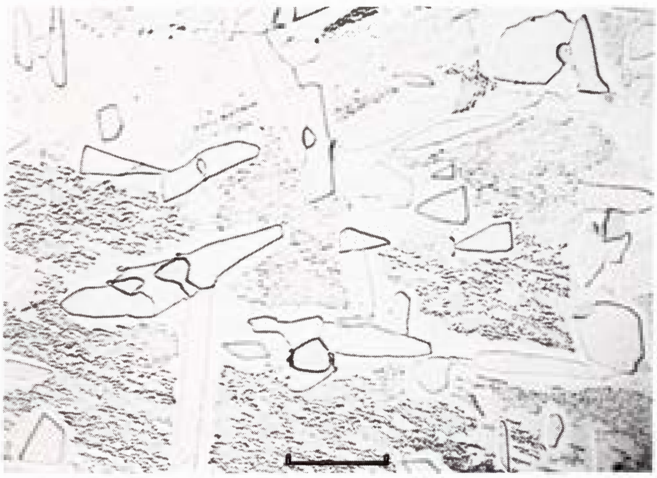

Figure 1885. Warburton Range (Los Angeles). A nickel-rich ataxite of group IVB. Kamacite spindles in an unresolvable duplex matrix. Fine schreibersite crystals inside several of the kamacite grains. Etched. Scale bar 50 μ.

WARBURTON RANGE – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
McCall & Wiik 1966	18.21	0.87										
Schaudy et al. 1972	17.80								0.244	0.064	13	
De Laeter 1972a									0.23			
Rosman 1972	18.14							0.026				

the octahedral Widmanstätten directions can be distinguished, indicating that at a higher temperature Warburton Range consisted of a single crystal of taenite. The development of the matrix corresponds to what is present in, e.g., Tawallah Valley.

As noted above, schreibersite occurs as discrete particles up to at least 250 x 50 μ in size. It is rare in the unresolvable duplex matrix. It is estimated that the bulk phosphorus content is 0.10±0.02%.

Troilite and silicates were reported by McCall & Wiik (1966); while the first observation may be supported – 0.1-1 mm troilite blebs occur with a frequency of one per 25 cm^2, – the other needs confirmation.

Warburton Range is a nickel-rich ataxite which is closely related to Skookum Gulch, Weaver Mountains and Tawallah Valley. In particular, its structural details are similar to those of Tawallah Valley and Weaver Mountains. Chemically, it is a normal member of the resolved group IVB.

The writer is indebted to Drs. E.P. Henderson and J.T. Wasson for permission to examine their small samples prior to analytical work being carried out.

Figure 1886. Warburton Range (Los Angeles). Two schreibersite crystals (white, with chipped portions) inside kamacite spindles. Two small sulfide particles (S) are associated with the larger schreibersite crystal. Etched. Scale bar 50 μ.

Washington County, Colorado, U.S.A.

39°42'N, 103°10'W

Ataxite, D. Polycrystalline kamacite with a grain size of 0.05 mm. No Neumann bands. HV 150±5.

Anomalous. 9.9% Ni, 0.6% Co, 0.39% P, 13 ppm Ga, 21 ppm Ge, 0.07 ppm Ir.

HISTORY

A mass of 5.75 kg was plowed up in a wheat field between 1916 and 1926 by Eugene King who stated that it had been buried about 30 cm deep. The location of the discovery was NE¼, Section 23, Township 4S, Range 52W, in Washington County, and has the coordinates given above.

The mass was acquired by Ward's Natural Science Establishment and was purchased in 1927 by Harvard University where it was described by Palache & Shannon (1928). They produced two photographs of the exterior and gave an analysis.

Čech (1962) reexamined the iron after it had been cut into two almost equal halves. He discussed the fusion crust and the heat-affected zones and presented several photomicrographs of the structures. These showed that the meteorite was apparently filled with microscopic voids to a degree unknown in any other iron meteorite. Further, he showed that a major part of the voids were arranged in subparallel bands with a slight curvature.

In order to reconciliate the results of the structural examination with the chemical analysis, Čech had to assume that the meteorite solidified as a body at approximately its present size and cooled rapidly by radiating its heat into a cold environment.

Schaeffer & Fisher (1960) noted an unusually low $^3He/^4He$ ratio. This was confirmed by Signer & Nier (1962) who further stated that five different adjacent samples showed an anomalous variation in total gas content. They also found a significant excess of neon. The ratio $^4He/^{20}Ne$ was nevertheless found to be nearly constant 420±40. They concluded that the anomalities might be explained if it were assumed that an inward diffusion of air had occurred after the meteorite landed. This would, however, require an elevated temperature. On the other hand, the anomalous rare gas could be of primordial origin. This last viewpoint was supported by Tilles (1962), who noted the remarkable agreement with the Suess & Urey (1956) value for primordial gases, $^4He/^{20}Ne$ = 400, deduced from spectral measurements of stars and planetary nebulas. Tilles further suggested that the discrepancies between values from adjacent samples might be caused by different concentrations of voids. The gases might conceivably have been particularly concentrated in the voids, since the solubility in the solid metal is negligible. However, as will be shown below, the voids are artificial.

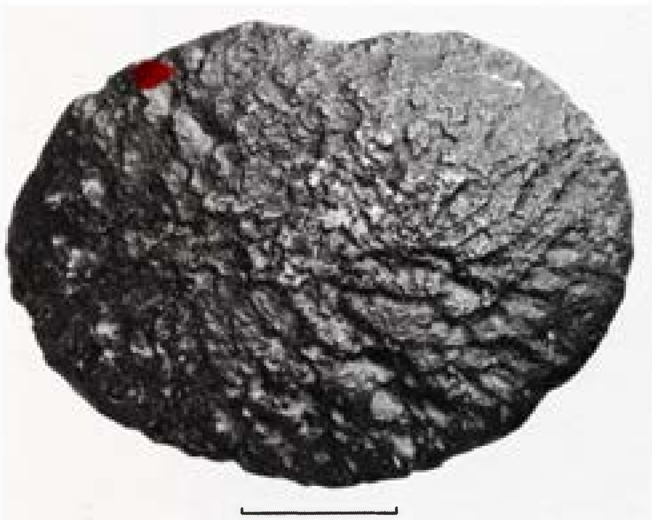

Figure 1887. Washington County (Harvard no. 565). The lenticular mass seen from the rather flat side. Irregular regmaglypts are indistinctly radiating from the apex. Scale bar 5 cm. S.I. neg. 1003C.

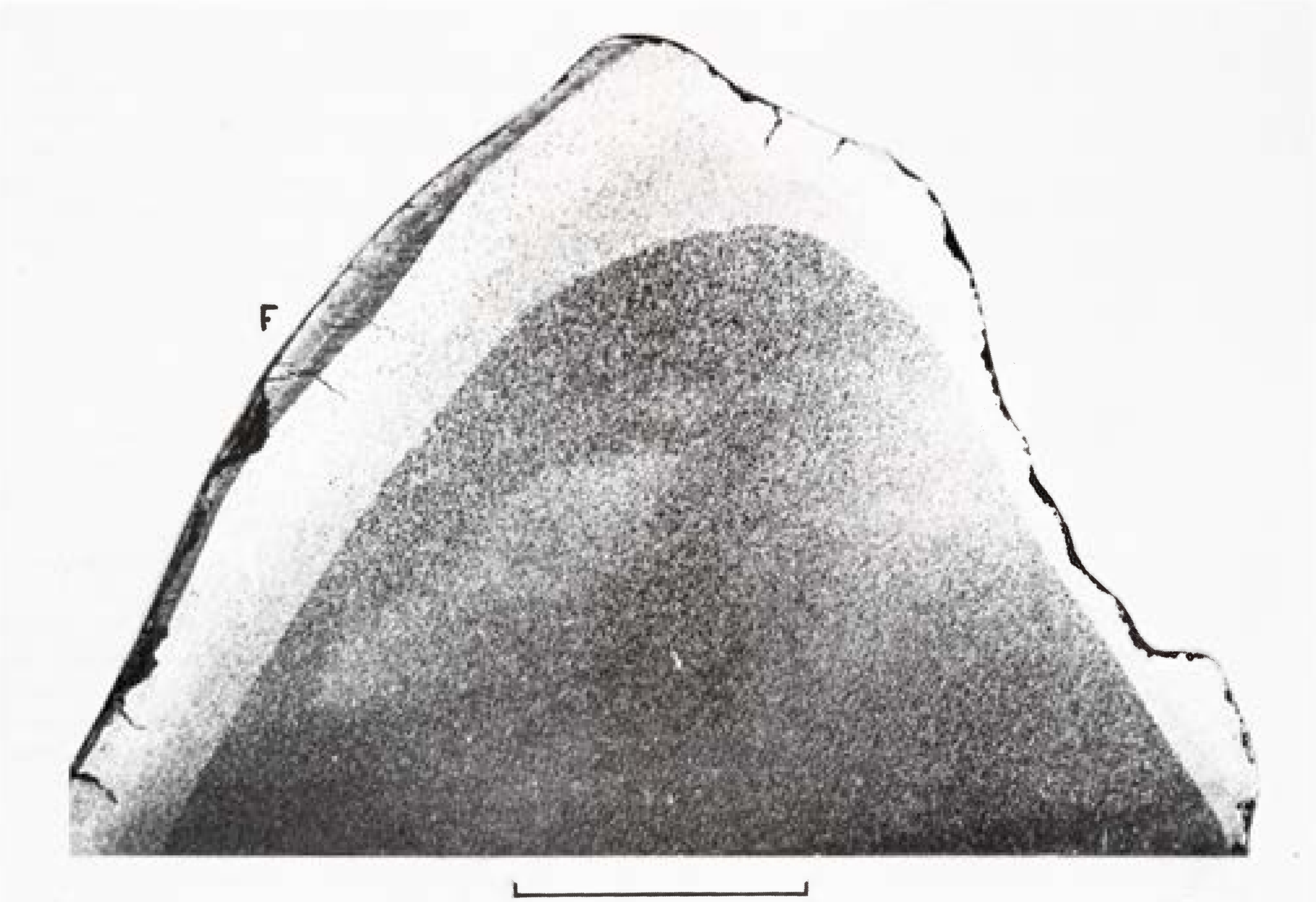

Figure 1888. Washington County (Harvard no. 565). A section taken where the flat regmaglypt-covered side (right) meets the smooth domed side (left). The width of the heat-affected α_2 zone is 3-4 times larger under the domed side, which is also covered with layered fusion crusts. Evidently the ablation rate was highest on the regmaglypt-covered side. Etched. Scale bar 10 mm.

Hintenberger et al. (1967) found the highest amount of excess noble gases ever recorded in an iron meteorite. The $^3He/^4He$ ratio was 0.044 and thus extremely low compared with normal values of about 0.25. They found that Washington County was similar to many stony meteorites with respect to the high content of primordial rare gases. They pointed out that the gases must come from the metal phase and not from any undissolved inclusions, such as silicates, troilite and schreibersite. They proposed that the meteorite formed by a sudden melting from a chondritic material which was rich in primordial gas. An immediate rapid cooling might produce the allegedly porous structure and trap the gases. A process of this kind could have taken place on a planetary surface due to the impact of another body.

Anders (1962) deduced from measurements by Fireman & DeFelice (1960) that the terrestrial age was low, of the order of 1,400 years. This is in line with the generally well-preserved state of the meteorite. Voshage (1967) estimated a cosmic ray exposure age of 575±80 million years.

COLLECTIONS

Harvard (main mass, divided into two halves each of about 2.5 kg), Copenhagen (50 g), New York (13 g).

WASHINGTON COUNTY – SELECTED CHEMICAL ANALYSES

Palache & Shannon (1928) found 0.30% P and 30 ppm S. While the noble gases have been examined by various authors, Čech (1962) analyzed for oxygen (0.0007%), nitrogen (0.0001%) and hydrogen (0.0000%). He commented, "The gas content is extremely low for a metal. It compares with or is lower than the most highly outgassed metal produced in modern vacuum melting facilities."

	percentage			ppm							
References	**Ni**	**Co**	**P**	**C**	**S**	**Cr**	**Cu**	**Ga**	**Ge**	**Ir**	**Pt**
Čech 1962	9.9	0.88	0.47	<100							
Cobb 1967		0.54					136	11		<0.6	
Wasson & Schaudy 1971	9.96							15.5	20.5	0.067	

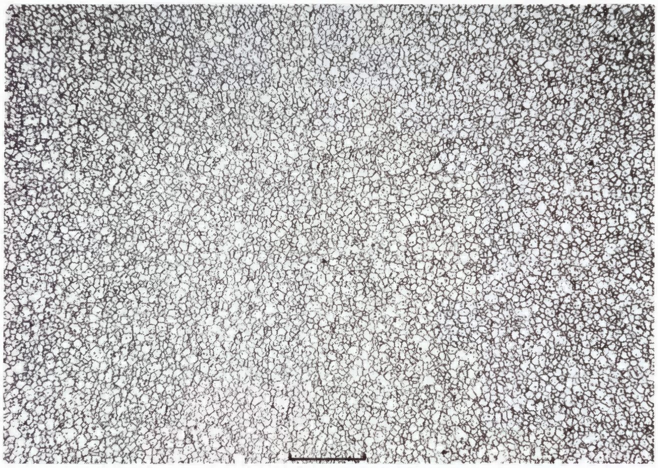

Figure 1889. Washington County (Harvard no. 565). Recrystallized even-sized kamacite grains with minute precipitates. Etched. Scale bar 500 μ.

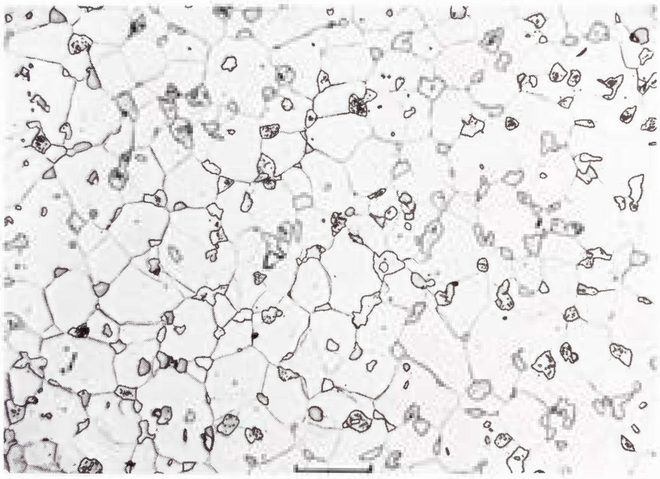

Figure 1890. Washington County (Harvard no. 565). Polycrystalline kamacite with amoebae-shaped taenite particles and angular phosphide particles. No Neumann bands. Etched. Scale bar 50 μ.

DESCRIPTION

The meteorite is an ellipsoid, measuring 20 x 15 x 6 cm along the three main axes. One of the convex sides is rather flat and displays shallow regmaglypts 1-2 cm across; some of them are arranged as indistinct grooves radiating away from the apex. The opposite side is more smoothly domed and from here a plane surface, 10 x 7 cm in size, was produced by shaping in 1927. Later, in the 1950s, the meteorite was divided by a vertical cut through the middle, and slabs were secured for gas analytical, chemical and metallographical work. The following is based upon a study of the main mass and of a slab (No. 565, 6.5 x 5.5 x 0.25 cm, about 50 g) which was kindly loaned to me by Professor C. Frondel of Harvard University.

Etched sections display an ataxite structure with no vestiges of Widmanstätten structure. The metal is a very homogeneous aggregate of almost equiaxial kamacite grains with an average size of 50 μ. There is a slight variation so that some 0.5 cm^2 patches may have grain sizes uniformly small – 25 μ – while others display grains about 75 μ across. It is not apparent what causes this variation. In the structurally related meteorites, Hammond and Seneca Falls, original Widmanstätten structures are visible, although severely altered by reheating. Possibly Washington County presents a still more extreme case, where a very thorough study will be required to prove the previous existence of a Widmanstätten structure.

Neumann bands are absent, and it seems that the kamacite phase is in a well-annealed state. This is confirmed by its low microhardness, 150±5. It is massive, without pores or cavities.

Taenite occurs as uniformly dispersed, cloudy-yellow particles, usually located in the kamacite grain boundaries. They are 1-15 μ across and cover an estimated 20% by area. They assume a very characteristic shape, being irregular, amoeba-like, with internal 0.5-1 μ windows of kamacite, and a nickel content of 28-34%.

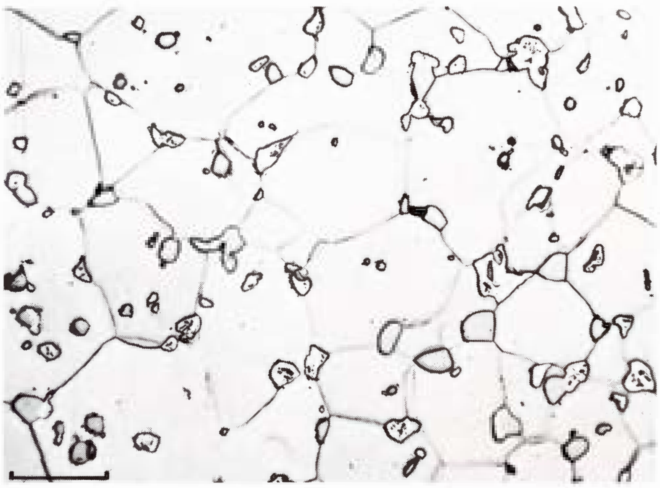

Figure 1891. Washington County (Harvard no. 565). A detail showing the irregular cavernous taenite particles and the angular, slightly darker phosphide particles. They are mainly located at grain boundaries, probably because these were pinned by the precipitates. Etched. Scale bar 40 μ.

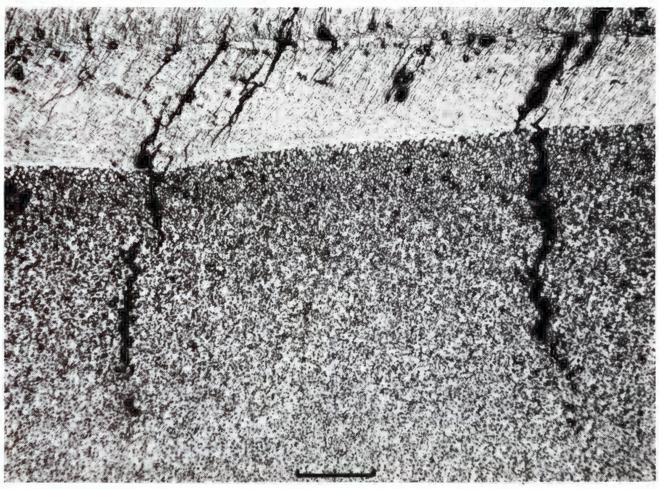

Figure 1892. Washington County. Detail of the fusion crust at F on Figure 1888 (inverted). The metallic fusion crust is composed of numerous layers of dendritic-columnar structure. Hot-cracks penetrate the crust and the heat-affected A zone (page 53). Compare Figure 51. Etched. Scale bar 500 μ.

Schreibersite is very common. It forms 1-15 μ anisotropic angular particles, which may easily be identified upon a polished, unetched section. Very often schreibersite and taenite particles are in contact, or intergrown, in the α-grain boundaries. Small spheroidized phosphides, typically 1-3 μ across, occur in the kamacite grain interiors. The phosphide quantity tallies with the analytical average value of 0.39%.

It is remarkable how pure the meteorite is otherwise. Silicates, troilite, daubreelite, chromite, carbides, nitrides and graphite are apparently completely absent. The bulk sulfur, chromium and carbon contents are correspondingly low. The absence of troilite and other sulfide minerals is very rare in iron meteorites and indicates that Washington County has had an anomalous cosmic story.

The meteorite is well-preserved, displaying fusion crusts locally, and having almost continuous heat-affected α_2 zones. Čech (1962), in his desription of the meteorite, referred to "an outer band, an outer-intermediate band and an inner-intermediate band," and it was perhaps not entirely clear what made the bands visible to the naked eye and what exactly was meant by the terminology. It turns out that the outer band is identical to the metallic, dendritic-columnar fusion crust; the outer-intermediate band is the outer half of the α_2 zone in which the phosphides are micromelted, while the inner-intermediate band is the inner half of the α_2 zone.

The fusion crust is composed of an outer oxidic part, which is now almost removed by corrosion, and an inner metallic part. The oxidic part is 50-100 μ thick and composed of wüstite and magnetite, significantly altered, however, by terrestrial corrosion and spalling.

The metallic fusion crust on the smooth, domed surface is up to 1.5 mm thick and composed of several layers, each 200-600 μ thick. The columnar dendrites are coarse, 15-25 μ wide, and the hardness is 270±15. On the opposite side, the metallic fusion crust is thin, below 0.2 mm, and the individual laminae are much thinner, 30-50 μ. Also, the columnar dendrites are much smaller, being only about 5 μ wide. The metallic layers on either side are crossbedded and wedge out irregularly, and terrestrial corrosion has locally penetrated them and created pits.

There are numerous minute (0.5-20 μ) globules of trapped oxides from the atmospheric flight included in the metallic fusion crust, but there are also limonitic oxides from later exposure to ground water. It is relatively easy to distinguish between them because the first variety solidified as globules from a melt; while the second formed by low temperature corrosion as irregular, layered oxides, mainly following the interdendritic boundaries and cavities.

Under the fusion crusts of the domed side, a 3-4 mm wide heat-affected α_2 zone follows. Its hardness is 172±10. In the recovered transition zone from α_2 to α the hardness drops to 137±5 (hardness curve type II). The individual α_2 units are ragged and slightly smaller than the original kamacite grains. The exterior half of the α_2 zone is rich in micromelted phosphides. Originally subangular, they have now dissolved part of the adjacent metal walls and solidified as rounded globules. The interior of the meteorite acted as a heat sink so that the primary solidification occurred from the inside of the walls. In the eutectic part of the phosphide, the last to solidify, there is often a 1-5 μ spherical cavity which was produced by solidification shrinkage. The large number of these pinholes gives a peculiar sheen to this zone which is visible to the naked eye. It is quite normal in the heat-affected zone of iron meteorites, but here seen to perfection, because the fine phosphides are evenly distributed. Microcracks penetrate from the exterior through this zone but rarely go deeper, since they are primarily hot-cracks following the micro-melted phosphides.

Under the thin fusion crusts of the opposite regmaglypt-covered side follows a thin α_2 zone, ranging from 0.3 to 1.0 mm in thickness. Its structure and hardness is as before, only its dimensions are smaller. The facts are consistent with the idea already advanced by Palache & Shannon (1928) that the regmaglypt-covered face was the

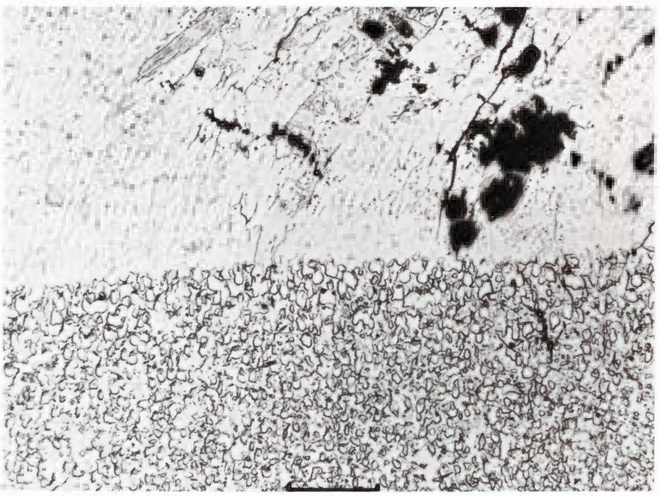

Figure 1893. Washington County (Harvard no. 565). The fusion crust (above) shows cellular-columnar growth with the crystals slightly tilted relative to the substrate. (Black denotes terrestrial corrosion products). The heat-affected α_2 zone is of a peculiar nature because it formed from a fine three-component mixture of α, γ and phosphides. Etched. Scale bar 200 μ.

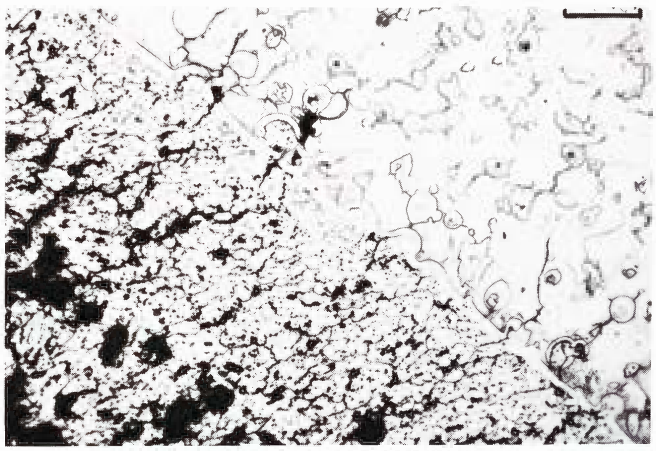

Figure 1894. Washington County (Harvard no. 565). Fusion crust (left) with terrestrial corrosion products at cell boundaries (black). The heat-affected α_2 zone shows globular phosphide melts with gas holes. Etched. Scale bar 50 μ.

anterior, rapidly devoured surface during a stabilized flight through the atmosphere. Similar cases are discussed under Jamestown and elsewhere.

Čech (1962) discussed at length some phenomena he had observed on a macroetched specimen. Most importance was attached to the presence of microscopic, angular (sic!) voids and non-metallic impurity particles which formed a striking pattern of subparallel "spiralling" striations. In another place he stated that "the black spots dispersed through the structure are a mixture of non-metallic inclusions and voids." It was assumed that the voids, 20-150 μ in size, were genuinely cosmic and had been produced by solidification shrinkage during rapid cooling.

The carefully prepared large section (No. 565) that went half way through the entire meteorite was examined. No voids and no nonmetallic impurities were detected nor were they to be found on the polished and lightly-etched section of the same sample. However, it was revealed that routine grinding and polishing, followed by a macroetch, developed numerous microscopic pits. They were 5-20 μ across, arranged in bands, and often quite angular. It is quite certain that they were artefacts which formed during the preparation. The meteorite itself is massive. The reason for the appearance of voids is not quite clear, but part of the explanation lies in the fact that the small angular phosphides are microcracked and pop out during preparation, so that their empty cavities become attacked by the acid during the following macroetching. The facets of the pinholes are probably caused by a slight variation in the rate of solution, when randomly oriented kamacite crystals are exposed to acids. Similar problems are discussed under, e.g., Kopjes Vlei, Hammond and Rafrüti.

While the voids are thus proved to be artificial, the indistinct striations appear to be real. They apparently reflect a rhytmic variation in phosphide population, but it is not clear how this formed. Perhaps large scale deformation could rearrange phosphides – which, in the primary structure, were present as Brezina lamellae – in subparallel bands.

Terrestrial corrosion has formed thin limonitic crusts locally. In these, the original γ-amoebae may still be identified as long-surviving particles. It is estimated that the meteorite has, on the average, lost less than 0.2 mm by weathering. There are no indications of artificial reheating by the finder or early owners.

Washington County is a unique iron. In its chemical composition it is anomalous without any near relatives. It appears, however, to be distantly related to the irons of group IIIB, such as Treysa, Chupaderos and Bear Creek, and it may have had a primary structure similar to these. The present structure may, under this assumption, be interpreted as the severely altered end stage of an iron similar to Bear Creek. The metamorphism probably involved severe shocking, shear-deformation and annealing. During the shear-deformation the low-melting sulfides may have acted as lubricants and finally have been entirely squeezed out and vaporized. In this treatise it has been proposed that several other iron meteorites form similar sequences of metamorphic development, such as Bartlett-Juromenha (IIIA), Hill City-Smithland (IVA), and Lombard-Mejillones (IIA). The anomalous gas contents of Washington County must be considered on the basis of this structural development.

Waterville, Washington, U.S.A.

47°45'N, 119°51'W

Anomalous. Polycrystalline aggregate with troilite and graphite. Deformed Neumann bands. HV 230±20.

Anomalous. 7.81% Ni, about 0.3% P, 0.5% C, 3% S, 65 ppm Ga, 196 ppm Ge, 0.3 ppm Ir.

HISTORY

A mass of 75 pounds (34 kg) was discovered in 1927 on the Fachnie farm in Douglas Dounty, 16 miles northeast of Waterville. Mr. Fachnie had plowed and harrowed the ground in the fall of 1926, and the meteorite was not encountered. But in August 1927, when the wheat was being harvested, the wheat binder struck the meteorite, which was exposed on the surface of the ground. It was, therefore, assumed that it had fallen between 1926 and 1927 (McMillan 1940). As shown below, the state of corrosion does not support this conclusion; the fall must be of a high terrestrial age. Nininger & Nininger (1950: 100, 138 and plate 5) showed that Waterville was

> "a unique iron with abundant small inclusions of troilite distributed in much the same manner as are the olivine crystals in pallasites, or still more closely resembling the arrangement of the silicate inclusions in the Weekeroo iron from Australia."

An enlarged photomacrograph of the same section was presented by Read et al. (1967) when they reported the discovery of a different iron meteorite, Withrow, only 8 km south-southeast of the Waterville mass. Read gave references to a paper on Waterville by O.W. Freeman (1948), which I was unfortunately unable to examine before this study was made. Wasson (1970a) noted a nonmagnetic, black residue, presumably of graphite, left from a wet chemical analysis. He considered Waterville to be remotely related to the resolved chemical group I.

COLLECTIONS

Ferry Museum, Tacoma, Washington (main mass), Washington (197 g), Tempe (146 g), London (135 g).

DESCRIPTION

The specimens in Washington, Tempe and London are thin slices through the meteorite. The Tempe and London specimens are two halves of the same slab, a figure of which was presented by Nininger & Nininger (1950: plate 5). The mass is weathered; no fusion crust and no heat-affected α_2 zones are preserved; and hardness traces perpendicular to the surface fail to indicate any hardness gradient. It appears that, on the average, more than 5 mm has been lost by weathering. Corrosion penetrates deep into the interior along α - α and α - γ grain boundaries and along brecciated

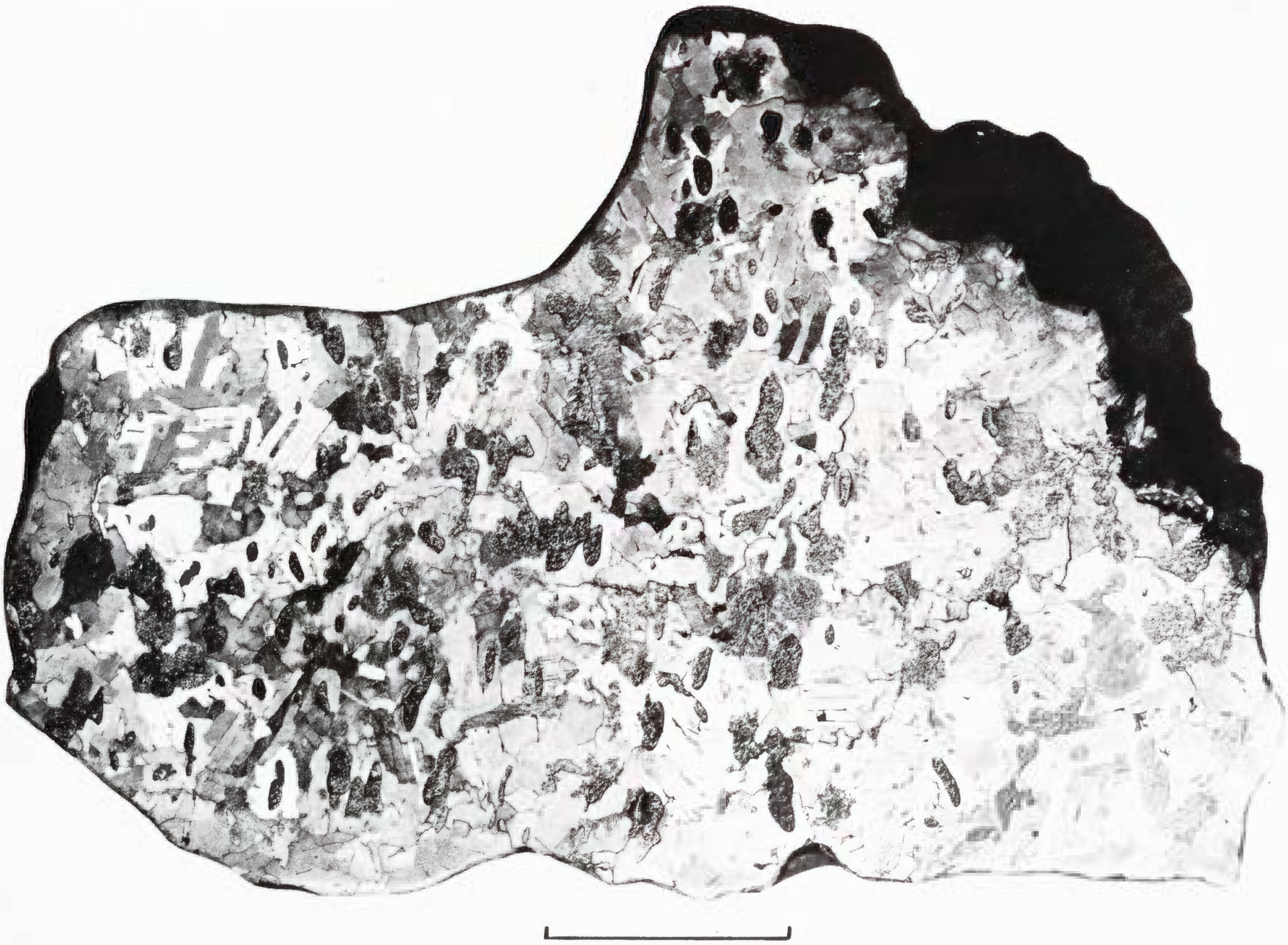

Figure 1895. Waterville (U.S.N.M. no. 1512; 149 g). An anomalous polycrystalline aggregate with abundant troilite and graphite. Deep-etched. Scale bar 20 mm. S.I. neg. 41117A.

troilite and schreibersite, forming 10-100 μ wide limonitic veins. Some pentlandite veining occurs in the near-surface troilite nodules. In the irregular 0.1-1 mm thick exterior limonitic crust, graphite aggregates survive longer than any of the other meteoritic minerals.

Polished sections show Waterville to be an anomalous iron meteorite with significant quantities of troilite and graphite. Point counting of a total area of 80 cm^2 yielded 15-17 volume percentage troilite plus graphite. It is estimated that 4/5 are troilite, corresponding to a bulk sulfur content of about 3%. The troilite forms ellipsoidal to sausage-shaped or irregular bodies, ranging from 0.5 x 1 mm to at least 3 x 7 mm in size, and they are apparently arranged subparallel. The evidence for this is, however, not sufficiently good because the few slices are thin and parallel. The troilite nodules were originally monocrystalline, but they are now brecciated by shear-deformation and display multiple twinning, undulatory extinction and – particularly along interface boundaries – recrystallization bands of 1-5 μ equiaxial grains. Shock melting, if at all present, occurs only to an insignificant extent, and the troilite displays smooth borders against the metallic matrix except where intergrown with graphite.

Graphite occurs in troilite, schreibersite and kamacite; its exact amount cannot be measured by point counting, because of its extreme variation in mode of occurrence and its tendency to flake out and leave pits, especially in the troilite. A rough estimate is 3-4 volume percentage graphite, corresponding to about 0.5 weight percent carbon. The graphite occurs in the kamacite in cliftonitic forms as cubes, octahedrons and imperfect varieties thereof, generally 25-100 μ across; and it also appears as clusters of spear-heads or wedges, or as large (1.3 x 0.3 mm) cakes, composed of numerous tiny crystallites grown in a basket

WATERVILLE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970a	7.81								64.8	196	0.30	

weave structure. A 0.5-1.5 mm wide kamacite zone around the troilite bodies is often loaded with irregular graphite particles. It suggests the previous existence of carbide crystals, nucleated upon the troilite and later decomposed to metal and graphite. The graphite in the kamacite must antedate the precipitation of schreibersite since these crystals have often grown around graphite sheaves and wedges.

Etched sections display an unusual polycrystalline nature. The precursor austenite grain size was apparently 5-15 mm, and the troilite was mainly located in the austenite grain boundaries. During the primary cooling, schreibersite and kamacite nucleated heterogeneously upon the troilite nodules, and the kamacite grew to irregular 0.5-1.5 mm wide rims (swathing kamacite). The retained austenite, squeezed between these troilite-kamacite islands, eventually transformed homogeneously in a Widmanstätten pattern. The Widmanstätten lamellae are straight and short $(\frac{L}{W} \sim 8)$, but they range widely in width, from about 0.5 mm to 1.5 mm. The kamacite displays Neumann bands and decorated subboundaries. The shear-deformation responsible for the brecciated troilite and schreibersite has bent the Neumann bands, particularly close to the inclusions. Some fine cubic cleavage cracks in the kamacite, from the same deformation event, now contain limonitic weathering products. The microhardness corresponds to cold-worked kamacite, HV 230±20. The kamacite in the graphite areas is softer, 200±15, either because this material is less cold-worked or because it is poorer in nickel (preexisting carbides?).

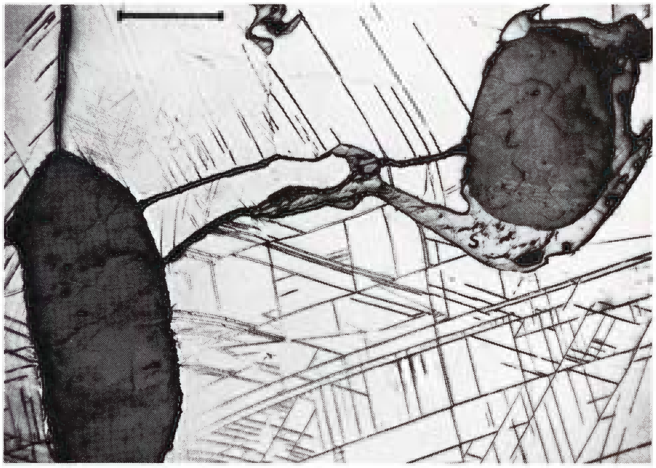

Figure 1896. Waterville (Tempe no. 453.2x). Two troilite nodules, the one at right having served as a substrate for precipitating schreibersite (S). Several differently oriented kamacite grains with Neumann bands. Compare Figure 163. Etched. Scale bar 400 μ.

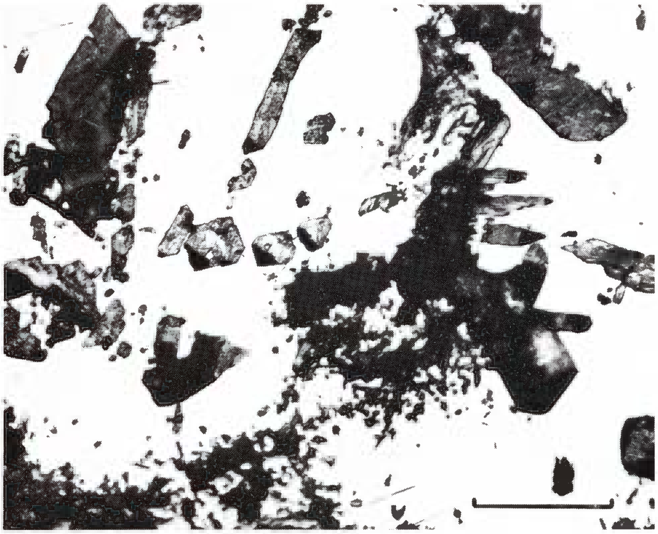

Figure 1898. Waterville (Tempe no. 453.2x). Kamacite (white) with a cluster of graphite particles typical for Waterville. Acicular and flaky particles occur besides irregular ones and some with cubic morphology. Polished. Crossed polars. Scale bar 100 μ.

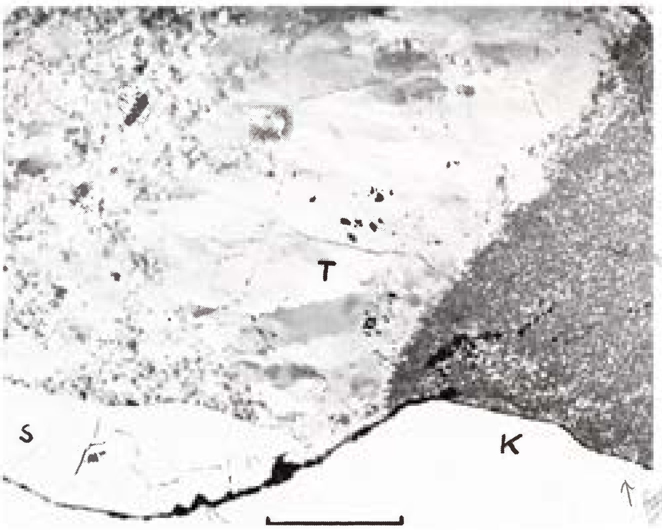

Figure 1897. Waterville (Tempe no. 453.2x). Troilite (T), schreibersite (S) and kamacite (K) with an unidentified component to the right. The troilite shows recrystallized portions (left) and portions with undulatory extinction (center). Polished. Crossed polars. Scale bar 100 μ.

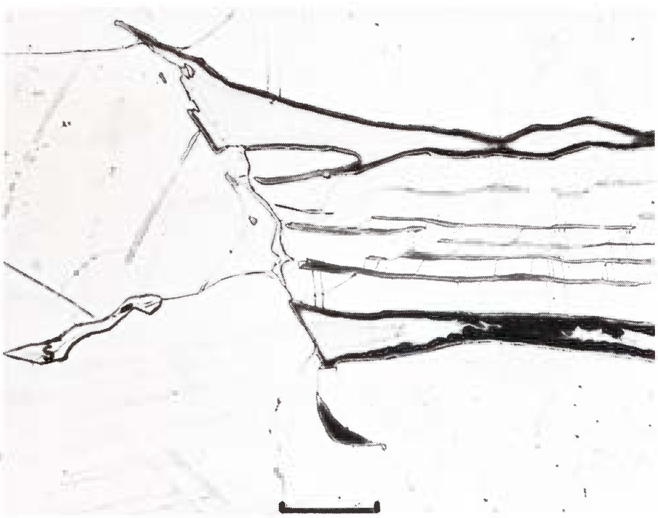

Figure 1899. Waterville (Tempe no. 453.2x). A comb plessite field and a schreibersite crystal (S) in a grain boundary. The plessite shows cloudy taenite edges and martensitic interiors. Etched. Scale bar 200 μ.

Figure 1900. Waterville (Tempe no. 453.2x). An unusual aggregate. Chromite (below) in contact with an unidentified black mineral, which contains unidentified light sparks. Troilite (T) with undulatory extinction, schreibersite (S) and graphite (black, scattered through troilite and schreibersite). Polished. Crossed polars. Scale bar 100 μ.

Taenite and plessite cover 4-8% by area. Comb plessite is uncommon, whereas individual 20-80 μ wide γ-lamellae and wedges occur in the Widmanstätten areas and in the grain boundaries. A typical wedge, 80 x 200 μ in size, will show a bluish-brown stained taenite rim with densely spaced slip lines from plastic deformation (HV 395±20), followed by a yellow transition zone and a central portion decomposed to martensite, etching distinctly and developed parallel to the $\{111\}$ Widmanstätten planes (HV 450±30). In other, smaller plessite fields the martensite displays a different morphology with numerous directions of the platelets, presumably due to a higher nickel content of 25-30%. The individual features are particularly distinct when examined on an etched section under crossed Nicols.

Schreibersite occurs as 0.01-1 mm wide but discontinuous rims on troilite, and as grain boundary veinlets of similar sizes. It is monocrystalline, but severely brecciated. Rhabdites occur locally as 1-2 μ prismatic needles; some ultramicroscopic precipitates are perhaps also fine rhabdites. The bulk phosphorus content is estimated to be 0.30±0.05%.

At least four rather unusual minerals occur in association with the troilite-graphite aggregates. One is a bluish, anisotropic sulfide which forms parallel, 1-50 μ wide bars or flames in troilite and in many respects resembles daubreelite. The second is an opaque black, isotropic mineral; it occurs in troilite as rounded blebs 50-150 μ across, often in contact with graphite. The third occurs as 1 μ wide creamy-yellow threads or idiomorphic crystals inside the above mentioned black one. The fourth is apparently imperfect chromite crystals, 50-250 μ across.

Waterville is a corroded, highly anomalous meteorite. In its troilite-metal intergrowth it particularly resembles Barranca Blanca, but the detailed development of the kamacite and taenite is quite different in the two irons. In both, the high temperature precursor taenite had a polycrystalline macrostructure in which the grain boundaries were pinned by the troilite inclusions. The subsequent incongruous development of kamacite and taenite is probably partly a result of the different troilite-metal ratio in the two meteorites and partly a result of a higher cooling rate for Waterville.

Chemically, Waterville has no near relatives, except perhaps Mundrabilla, which shows a very similar composition. The significant proportion of graphite is in line with this supposition.

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

149 g part slice (no. 1512, 11 x 7 x 0.3 cm; from O.W. Freeman)
48 g part slice (no. 1512, 8 x 4 x 0.2 cm; the same)

Wathena, Kansas, U.S.A.

39°49'N, 94°55'W

Hexahedrite, H. Shock-recrystallized to 0.5 mm kamacite grains. HV 146±12.

Group IIA. 5.54% Ni, 0.27% P, 60 ppm Ga, 184 ppm Ge, 7.0 ppm Ir.

HISTORY

A small mass of 566 g was found in 1939 by Russell C. Maag. It was lying in a ditch beside a country road running northwest from Wathena, Doniphan County, and about one mile outside the town. It was sent to the U.S. National Museum for identification and in 1941 was acquired and added to the collection by support from the Roebling Foundation. Henderson & Perry (1949c), who provided the above information, also gave a description, an analysis and two photomicrographs. They classified Wathena as a nickel-poor ataxite.

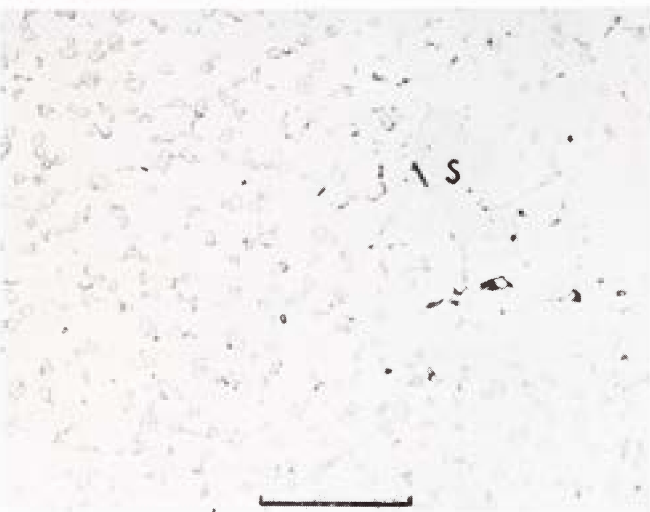

Figure 1901. Wathena (U.S.N.M. no. 1387). Originally a hexahedrite, this meteorite has been exposed to shock and has recrystallized. The schreibersite crystal (S) is partially resorbed and the rhabdites have transformed to irregular taenite-phosphide particles. Lightly etched. Scale bar 100 μ. (Henderson & Perry, 1949c.)

COLLECTIONS

Washington (428 g), Ann Arbor (12 g).

DESCRIPTION

The well rounded ovoidal mass weighs 566 g and has the dimensions of 8 x 4 x 4 cm in three perpendicular directions. No regmaglypts are visible on the surface and a crust of terrestrial oxides up to 1 mm thick covers it irregularly. The mass has been divided by two parallel cuts, producing two endpieces of 375 g and 53 g and a section which has been used for analyses and polished samples.

Etched sections reveal an unusual polycrystalline structure, similar to that of Mejillones and Kopjes Vlei. The kamacite phase is subdivided into numerous almost equiaxial grains, the smallest units generally being 20-50 μ across. Inside these grains some microrhabdites, $<0.5\ \mu$ thick, occur; they are secondary compared to the ordinary rhabdites discussed below. The kamacite grains often coalesce to larger units, 0.2-2 mm across, that are easily visible to the naked eye because they reflect the light uniformly. The small grains thus form either polycrystalline mosaics with high angle boundaries, or they form polycrystalline mosaics with low angle boundaries, in which case the small grains may be interpreted as unusually regular subgrains. Neumann bands were not detected in any of the forms. The microhardness varies between extreme values of 114 and 162, the normal being 146±12. There is no obvious correlation between the hardness and the structure. Perhaps the amount of nickel and phosphorus in solid solution in the kamacite is the decisive factor in the hardness level. The hardness is, however, low for a hexahedrite, corresponding to a recovered-recrystallized condition without subsequent deformation or Neumann bands.

Schreibersite was once present as 0.1-0.5 mm crystals in the kamacite, and as 0.1-0.2 mm wide, discontinuous precipitates on the troilite-daubreelite aggregates. Rhabdites occurred in profusion as 0.5-10 μ thick prisms.

All phosphides are now severely altered. The larger ones are decomposed to irregular blebs with numerous reentrant angles. They are surrounded by zones of varying grain size and composition in much the same way as observed in Mejillones. The dominant zone is 200-300 μ wide and composed of 10-50 μ kamacite grains, 1-10 μ taenite blebs and 1-10 μ phosphide wedges. The taenite and the phosphides are situated in the grain boundaries of the kamacite, and the taenite displays serrated borders and minute internal windows of kamacite. In these zones micropits usually do not develop.

The original rhabdites are almost unrecognizable because they are altered to unequilibrated structures that

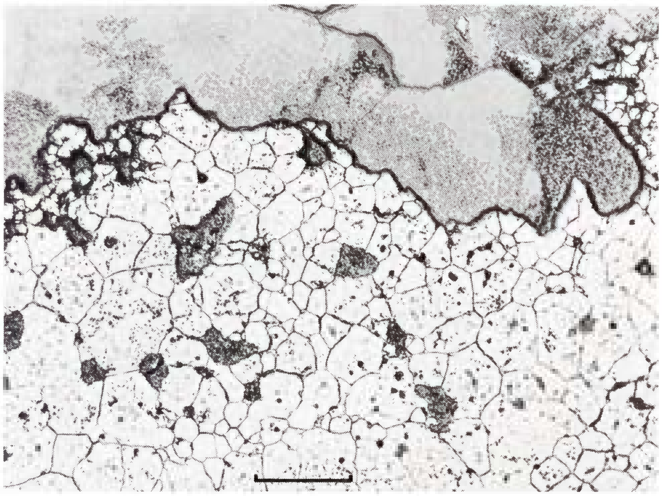

Figure 1902. Wathena (U.S.N.M. no. 1387). The edge of a shock-melted troilite nodule. Small sulfide blebs have in the process become detached and are now situated outside the serrated boundary. Recrystallized kamacite with minute phosphide particles. Etched. Scale bar 200 μ.

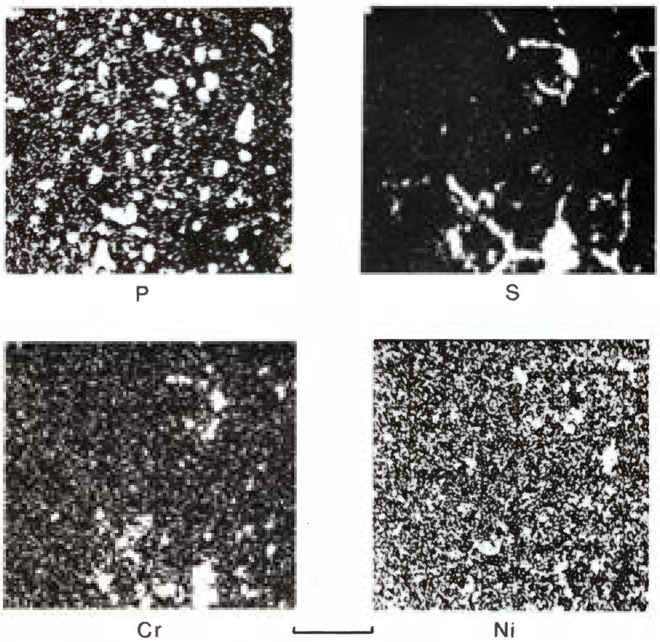

Figure 1903. Wathena (U.S.N.M. no. 1387). X-ray scanning pictures of shock-melted sulfide filaments outside a nodule similar to Figure 1902. The filaments are basically remelted troilite and daubreelite material, while phosphides occur as discrete particles. PK_α, SK_α, CrK_α, and NiK_α pictures at 15KV. Scale bar 50 μ. See also Figure 178.

WATHENA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson & Perry 1949c	5.56	0.60	0.27		1100							
Wasson 1971, pers. comm.	5.51								59.6	184	7.0	

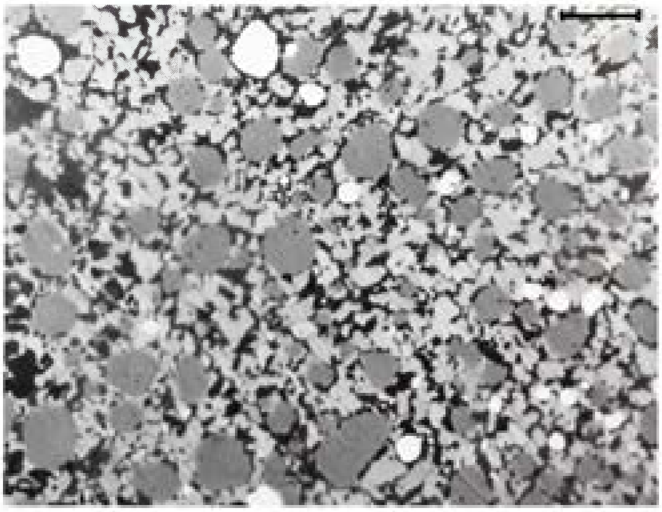

Figure 1904. Wathena (U.S.N.M. no. 1387). Detail of the massive shock-melted troilite. In a fine-grained eutectic of iron (black) and sulfide (gray) nearly molten particles of daubreelite (dark gray) and schreibersite (white) are dispersed. Etched (thereby the iron component was removed, leaving black grooves). Oil immersion. Scale bar 10 μ.

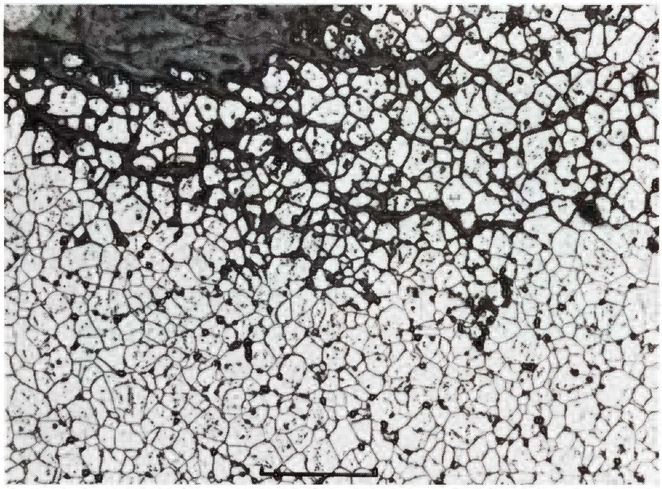

Figure 1905. Wathena (U.S.N.M. no. 1387). Near-surface section showing intergranular corrosion. The numerous black angular dots are sensitized loops that were preferentially attacked. Compare, e.g., Kopjes Vlei. Etched. Scale bar 200 μ.

form 5-15 μ loops. Upon routine etching and polishing, these loops are severely attacked and disappear, leaving black micropits. Careful repolishing discloses that the micropits are not an integrating part of the structure; in other words, the meteorite is not porous to any significant extent. The repolished surface appears just as massive as any normal hexahedrite or octahedrite. Upon slight etching with 2% Nital, the loops develop as heavily etching grain boundaries along which several minute, wedge-shaped phosphides are located. Within the loops there is an easily attacked metallic phase with no distinct structure. Microprobe examination revealed Fe and Ni as major, and Co and P as minor components. Si, Cr, S and C were absent. It remains a puzzle why this component is so sensitive to laboratory etchants. It is likewise sensitive to terrestrial corrosion, since it is the first to be transformed to limonitic products in near-surface regions.

Troilite occurs as irregular blebs, 0.2-5 mm across. They were apparently normal monocrystalline troilite crystals previously, with parallel daubreelite bars inside and with some schreibersite precipitates around the rim. The same event that altered the metallic matrix and the phosphides melted the sulfides. They now occur as fine eutectics of iron sulfide, chromium sulfide, kamacite, taenite and phosphides with a grain size of 1-10 μ. The interface in contact with the surrounding metal is violently serrated, and detached pockets of melts, 10-100 μ across, occur outwards to some distance in the metal. The kamacite grain boundaries of the surrounding metal are rich in micromelted sulfides, apparently injected there at high temperature.

Locally, with a frequency of about one per cm^2, a graphite nodule, 20-60 μ across, may be detected. The nodules are almost spherical and composed of crystallites, < 1 μ in size, that may be arranged in concentric shells. The graphite appears to be a decomposition product of preexisting cohenite. However, no carbide traces are left.

Wathena is weathered. No fusion crust and no heat-affected α_2 zones are preserved, and no hardness gradient towards the surface was detected. In the limonitic crust, which is up to 1 mm thick, daubreelite and phosphide wedges survive for a long time, distinguishable by their shape and color. Below the massive oxidation crust a grain boundary attack is developed to depths of 0.1-1 mm, and the loops are selectively corroded. It is estimated that the meteorite has lost, on the average, 4-5 mm by corrosion.

Wathena is a severely altered hexahedrite which originally may have had a structure like Richland, Gressk and Calico Rock. The structural components indicate that the alteration is due to intense shocks with associated reheating that led to recrystallization of the metal, decomposition of the phosphides and carbides, and complete melting of the sulfides. Similar structures are present in, e.g., Chico Mountains and Pima County, with which it is also chemically closely related.

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

375 g endpiece (no. 1387, 5 x 3.5 x 4 cm)
53 g endpiece (no. 1387, 4 x 3 x 0.8 cm)

Weaver Mountains, Arizona, U.S.A.

Approximately 34°15'N, 112°45'W

Nickel-rich ataxite, D. α-spindles 6±3 μ wide. Rich in phosphides. HV 300±15.

Group IVB. 17.72% Ni. 0.82% Co, 0.10% P, 0.21 ppm Ga, 0.05 ppm Ge, 17 ppm Ir.

HISTORY

A mass of 85.5 pounds (38.8 kg) was found in 1898 in the Weaver Mountains, Maricopa County, according to Ward (1904a: 27). He also stated that the locality was near

Wickenburg, but his coordinates and county are in error. Weaver Mountains is a range, 1000-2000 m high, in Yavapai County, about 40 km north of Wickenburg and 40 km southwest of Prescott, with the approximate coordinates given above. The mass was described and analyzed as an ataxite by Klein (1904a), and early analyses were, in addition, presented by Guild (1910). Henderson & Perry (1951a) confirmed the high-nickel content and gave a photomicrograph. Goldstein (1965) included the meteorite in his study of the kamacite composition and found the fine spindles to have a low average nickel content of 6.5%. Bauer (1963) measured the $^3He/^4He$ concentrations and estimated the cosmic ray exposure age to be 370 million years, while Voshage (1967) with the $^{40}K/^{41}K$ method found 385±50 million years. Helium determinations and further noble gas data were given by Schultz & Hintenberger (1967).

COLLECTIONS

Tucson (28.5 kg), Tempe (2.6 kg), Chicago (1.04 kg), Washington (773 g), London (155 g), Bonn (115 g), Berlin (97 g), Helsinki (90 g), Los Angeles (24 g).

Figure 1906. Weaver Mountains (Tucson). Two-thirds of the mass is preserved in the University of Arizona. A drill hole penetrates from the surface to the center of the mass. Scale bar approximately 10 cm.

DESCRIPTION

The main mass, in the Mineralogical Museum of the University of Arizona, Tucson, now measures 28 x 16 x 11 cm and weighs 28.5 kg. It is of an angular box-shape and presents some regmaglypts, modified by terrestrial weathering. No fusion crust and no heat-affected surface zones could be identified, so the mass has probably lost, on the average, more than 3 mm by corrosion. A drill hole, about 1 cm in diameter and 5 cm deep, indicates where early analyses were taken. The meteorite is undamaged, except locally from superficial cold hammering. It presents a cut face 22 x 10 cm in size.

Etched sections show an ataxitic structure with oriented sheen. A few of the largest kamacite lamellae may be seen as bright needles with the naked eye; and a number of troilite bodies, 0.5-4 mm across, also interrupt the otherwise very homogeneous structure. At high magnification the structure is seen to be composed of regularly distributed α-blebs in an unresolvable, plessitic matrix. The α-phase occupies 10-20% and occurs as (i) fine, short ($\frac{L}{W} \sim 10$) lamellae or spindles with a width of 6±3 μ and (ii) as irregular blebs, 5-30 μ across, normally developed around minute phosphide inclusions. The typical α-spindles are arranged parallel to the Widmanstätten planes. The two

Figure 1907. Weaver Mountains (U.S.N.M. no. 1427). A nickel-rich ataxite of group IVB. Many of the kamacite spindles contain tiny nuclei of schreibersite. Etched. Scale bar 200 μ. (Perry 1950: volume 7.)

WEAVER MOUNTAINS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lindner in Klein 1904a	17.92	0.84	0.12									
Hawley 1939												142*
Henderson & Perry 1951a	18.03	0.91	0.07									
Moore et al. 1969	18.11	0.70	0.10	35	100		10					
Schaudy et al. 1972	16.81								0.233	0.058	17	

*Includes all platinum metals, a surprisingly high value which needs confirmation.

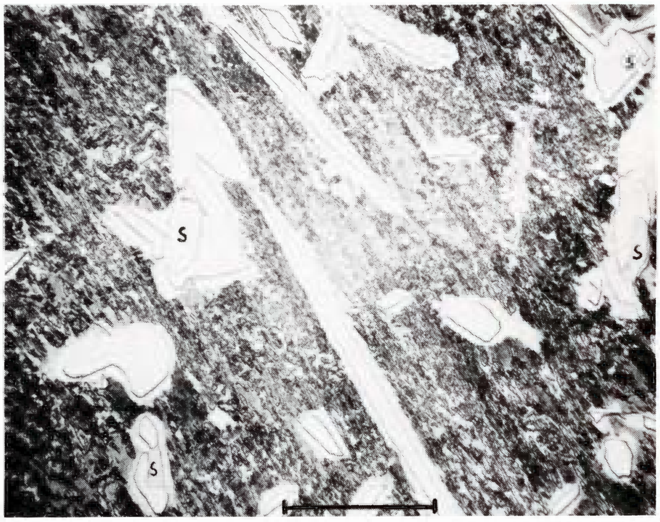

Figure 1908. Weaver Mountains (U.S.N.M. no. 1427). Kamacite grains with schreibersite crystals (S). Duplex, almost unresolvable matrix. Etched. Scale bar 50 μ. (Perry 1950: volume 7.)

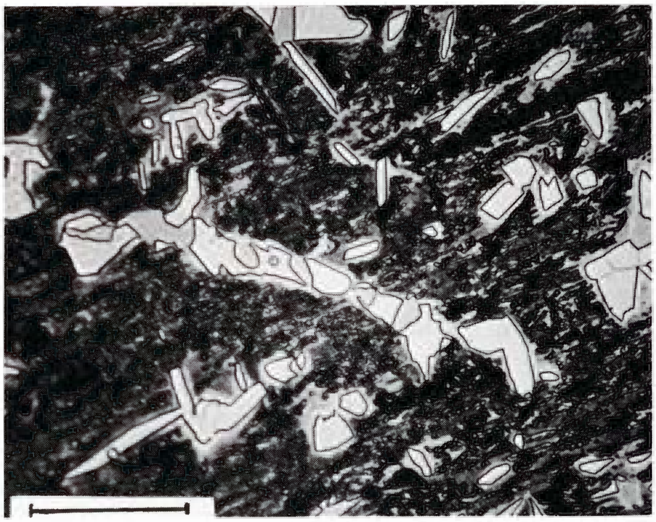

Figure 1909. Weaver Mountains (U.S.N.M. no. 1427). Kamacite grains with numerous schreibersite particles, usually in contact with taenite along at least one surface. Etched. Scale bar 40 μ. (Perry 1950: volume 7.)

forms together occur with a frequency of about 600 per mm^2. The α-phase has subboundaries, but neither Neumann bands nor hatched structures were observed.

The plessitic matrix appears to be of a bainitic, duplex type, but requires electron microscopy for any details to be seen. It appears striped at low magnification, apparently along the Widmanstätten directions, as defined by the scattered α-lamellae. The hardness is 300±15 and rather uniform right to the corroded edge of the specimens.

Schreibersite occurs as a few, "large" crystals, 40 x 60 or 120 x 20 μ in size, but most of the phosphides are present as evenly distributed blebs, 1-10 μ across. They have nucleated narrow rims of swathing kamacite, but the phosphide blebs are frequently still attached along one or two sides to the parent taenite. Because of this, the schreibersite is easily mistaken for taenite and is overlooked.

Troilite occurs with a frequency of about one per 15 cm^2. The individual nodules are small, 0.2-4 mm across, and have frayed edges against the metal. The troilite has been shock-melted and has dissolved part of the surrounding metal; the melts have solidified to fine-grained (~ 1 μ) eutectics of sulfide and metal.

Daubreelite fragments, 5-50 μ wide, are dispersed through the melts, and what appear to be tiny silicate or glass slivers are also present. The hardness of the troilite composites is 235±10.

Weaver Mountains is closely related to Tawallah Valley which it resembles structurally and chemically. However, its hardness is significantly different. Weaver is a member of group IVB but does not resemble the phosphorus-poor members very much because, when phosphides are precipitated, they tend to create blebs of swathing kamacite which conspicuously interrupt the monotonous ataxitic structure. Furthermore, the matrix of Tawallah and Weaver is bainitic and optically unresolvable, while the matrix of, e.g., Hoba and Kokomo, is easily resolvable.

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

546 g slice (no. 1427, 19 x 9 x 0.6 cm)
167 g part slice (no. 1427, 12 x 8 x 0.3 cm)
60 g part slice (no. 3145, 5 x 3.5 x 0.5 cm)

Wedderburn, Victoria, Australia

Approximately 36°26′S, 143°38′E

Nickel-rich ataxite, D. Numerous α-spindles 10±2 μ wide. Neumann bands.

Group IIID. 22.8% Ni, 0.57% Co, 1.5 ppm Ga, 1.5 ppm Ge, 0.05 ppm Ir.

HISTORY

A small mass of only 210 g was found on a road about 1951 by C. Bell, of Rushworth, while he was prospecting at a point three miles northeast of Wedderburn. It was acquired by the Mines Department, Melbourne, where it was described with four photomicrographs by Edwards (1953). He found it very similar to Tawallah Valley, and so did Lovering et al. (1960) who studied the ablation behavior during atmospheric entry. However, as noted below, the structure is different from Tawallah Valley in several important respects and rather resembles Föllinge and Freda, two other very small nickel-rich irons. Keil (1960: 269) reviewed the literature. Schultz & Hintenberger (1967) determined the amount of occluded noble gases, while Voshage (1967) estimated from these data a cosmic ray exposure age of 100-200 million years.

COLLECTIONS

Geological Museum, Mines Department, Melbourne (main mass, about 100 g), Sydney (17 g).