Stage four would be the penetration of the atmosphere. However, no remnants of the associated sculpturing are to be seen today. The fusion crust and heat-affected α_2 zones are all removed by weathering. Immediately after its landing, the external shape of Willamette may have resembled that of Morito rather closely.

Stage five is the final long-term exposure in the humid Oregon valley forest during which the deep cavities, partially penetrating and generally perpendicular to the topside of the mass, were formed. While no large-scale texture, such as silicate inclusions, can be considered responsible for the curious corrosion progress, it is possible that the very distinct troilite filaments have aided in the weathering. These lanes of fine-grained troilite, kamacite and taenite would probably provide easy diffusion paths studded with electrochemical cells and with dilute sulfuric acid from decomposed troilite, where the kamacite phase would provide the anodic areas and dissolve first. The final product, the deeply carved Willamette mass, must, however, be seen to be believed. A famous photograph by Ward (1904: plate 16) shows the fantastic sculpturing with a relief sufficiently large and deep to hide two children. Probably tens of thousands of years were required to bring about the amount of corrosion observed.

In summarizing, it may be stated that Willamette is a shock-altered medium octahedrite of the resolved chemical group IIIA. Its closest relatives are such irons as Cape York, Morito and Casas Grandes. Its shock history and resulting structure is unique but somewhat duplicated by the structures noted in Roebourne, Kokstad, Joel's Iron and Bingera, to name a few. Its terrestrial story, both with regard to corrosion features and law suits, is also unique.

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

397 g part slice (no. 333, 7 x 3 x 0.8 cm)
1,927 g part slice (no. 500, 31 x 19 x 0.6 cm; figured by Merrill 1916a: plate 36)
154 g on three part slices (nos. 1476, 2128, 3153)
242 g part slice (no. 3153)

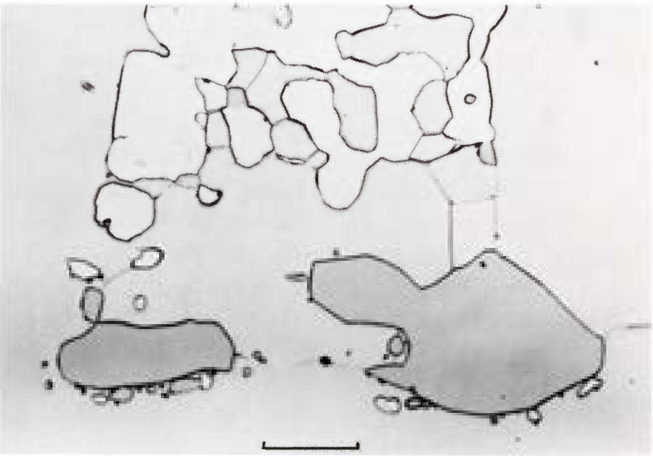

Figure 1959. Willamette (U.S.N.M. no. 333). The end of a similar taenite lamella and two adjacent annealed schreibersite crystals. Surplus nickel has been rejected in the form of minute taenite and phosphide particles along the periphery and they are all well spheroidized. Etched. Oil immersion. Scale bar 20 µ. See also Figure 225.

Williamstown. See Kenton County (Williamstown)

Willow Creek, Wyoming, U.S.A.

43°26'N, 106°46'W; about 1,800 m

Coarse octahedrite, Og. Bandwidth 1.40±0.25 mm. Partly recrystallized. HV 152±6.

Group IIIE. 8.76% Ni, about 0.35% P, 16.9 ppm Ga, 36.4 ppm Ge, 0.05 ppm Ir.

HISTORY

A mass of 112.5 pounds (51 kg) was found by John Forbes of Arminto, Wyoming, near Willow Creek, Natrona County, about 1914. For a long time it was in the possession of the Forbes family, but in 1934 the meteorite

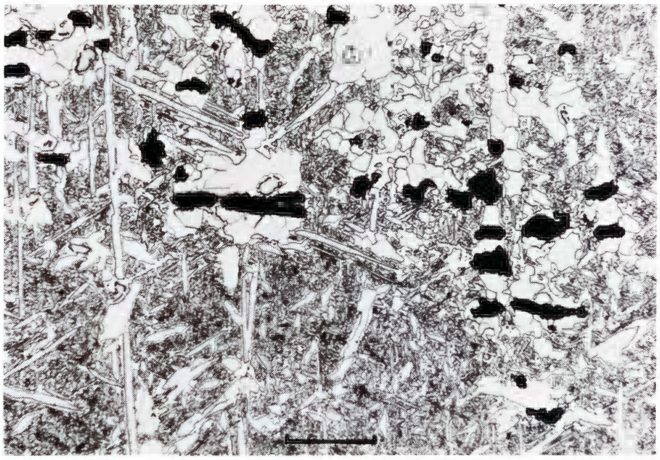

Figure 1960. Willow Creek (U.S.N.M. no. 900). Characteristic of this meteorite are the graphite flakes that occur inside several plessite fields. Compare Figures 145 and 146. Etched. Scale bar 40 µ.

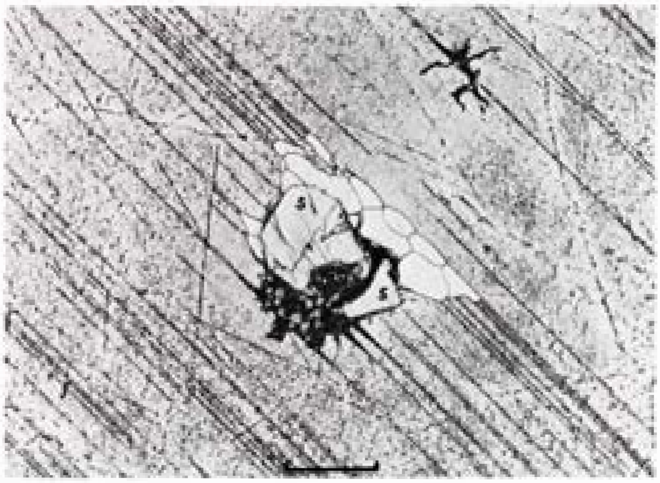

Figure 1961. Willow Creek (U.S.N.M. no. 900). Another characteristic of this meteorite is the shock-melted troilite nodules and the patches of recrystallized kamacite. One troilite nodule is transformed to a spidery shape, as in Willamette. Schreibersite (S) is brecciated. Etched. Scale bar 200 µ.

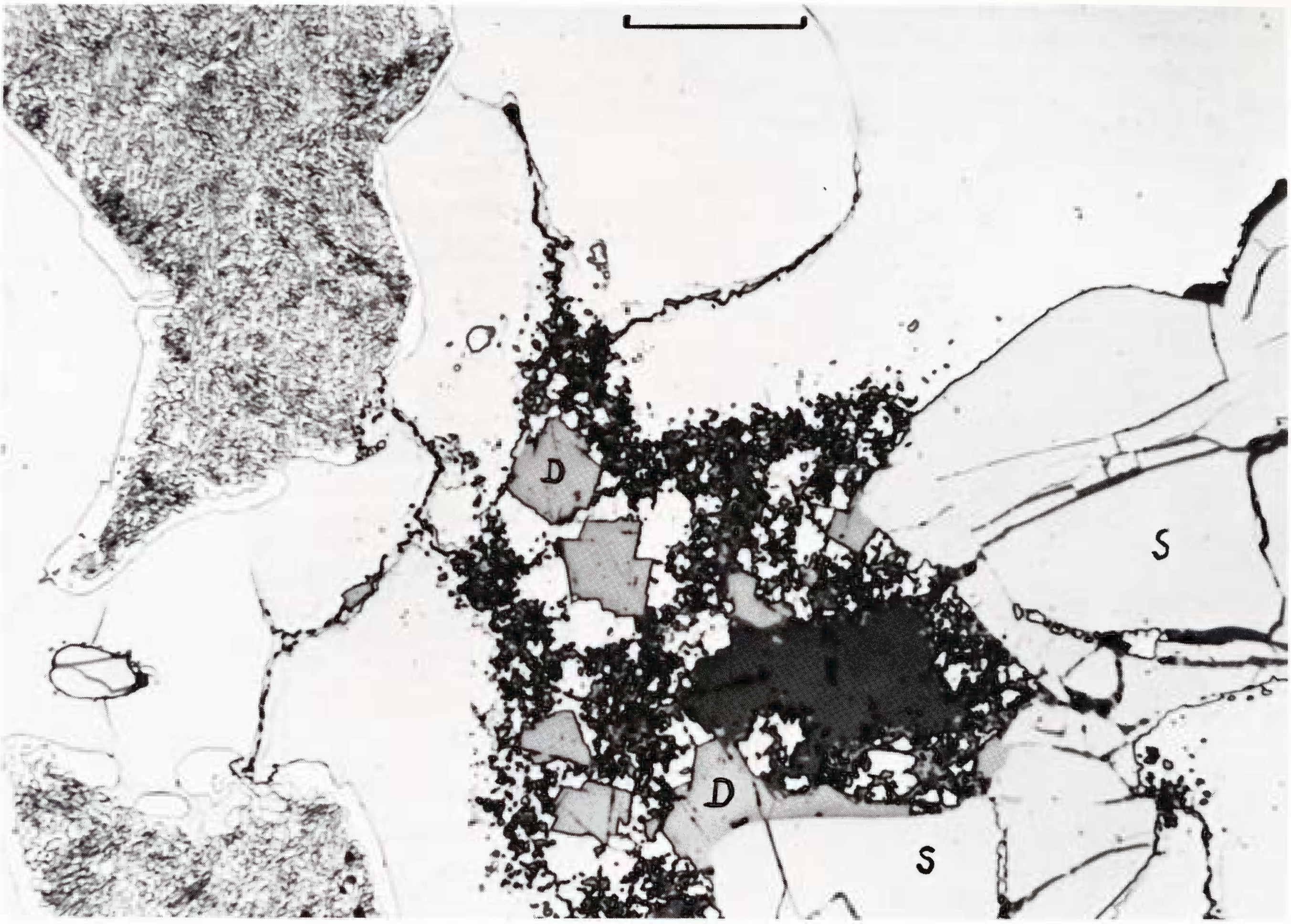

Figure 1962. Willow Creek (U.S.N.M. no. 900). Detail of another shock-melt. The mobile sulfide melt has penetrated into both kamacite and schreibersite (S). Angular daubreelite crystals (D) and chromite (black) are less altered. Etched. Scale bar 400 μ.

was reported to Nininger. He purchased it and described it with two photographs of the exterior and with one of an etched section (Nininger 1937b). The mass was said to have been found in Section 11, Township 40N, Range 83W, corresponding to the coordinates quoted above. Nininger & Nininger (1950: 102, 119 and plates 2 and 6) summarized the previously given information. A brief additional description appeared in Goldberg et al. (1951).

COLLECTIONS

London (17.1 kg), Tempe (16.8 kg), Washington (5.1 kg), Chicago (1.82 kg), Ann Arbor (1.40 kg), Harvard (1.00 kg), Amherst (939 g), Calcutta (83 g), Denver (slice).

DESCRIPTION

The 5 kg mass in Washington is a truncated endpiece with a large polished and etched section of 16 x 15 cm. The ultimate end point, approximately 9 x 5 x 5 cm in size, has been removed earlier by cold chiseling. Other parts of the surface are hammered; the mass has, however, not suffered by artificial reheating.

Etched sections display a coarse to medium Widmanstätten structure of spindle-shaped, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.40±0.25 mm. The oriented sheen is very strong and beautiful, and the spindle-shape of a significant number of the lamellae is quite characteristic, immediately suggesting a close relationship to Kokstad, Staunton and Rhine Villa. The kamacite is rich in Neumann bands; higher magnification shows, however, that the bands are degenerated by annealing. They are broken into shorter units, and rarely touch taenite and phosphides. In these Ni- and P-depleted zones diffusion has been sufficiently active to completely eliminate the Neu-

WILLOW CREEK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Goldberg et al. 1951	8.75								19.5			
Scott et al. 1973	8.76								16.9	36.4	0.054	

mann bands. Recrystallization to 5-100 μ new ferrite grains is common in these same areas. Otherwise, the kamacite is polygonized to densely spaced networks of subparallel cells, as present in, e.g., Kokstad and Uwet. The hardness is 152±6, corresponding to well-annealed kamacite.

Taenite and plessite occupy about 30% by area. Comb and net plessite are practically absent. All fields are well-annealed and decomposed to resolvable, duplex mixtures of α- and γ-particles. The individual γ-particles are 1-3 μ across, and the α-phase forms microcells, 5-10 μ across. The hardness is 190±10, somewhat dependent on the average nickel content. Martensite or bainite proper, otherwise so common as transitional zones between the taenite rim and the duplex interior, are not present but have been decomposed by annealing. A beautiful, somewhat unusual plessite type in which the α-phase forms evenly distributed bayonet-like sparks, typically 50 x 5 μ in size, is quite common.

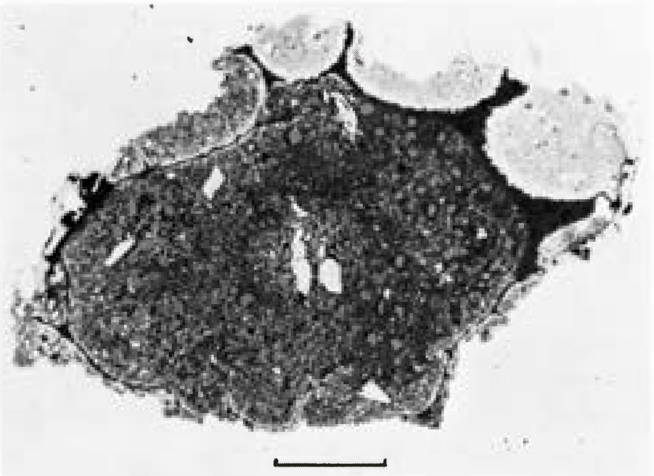

Figure 1963. Willow Creek (U.S.N.M. no. 900). A shock-melted troilite nodule with dispersed angular daubreelite fragments (dark). White fragments are schreibersite torn loose from the interface with kamacite which now appears irregular and fringed. Note the curvilinear cell walls in the shock melt. Polished. Scale bar 200 μ.

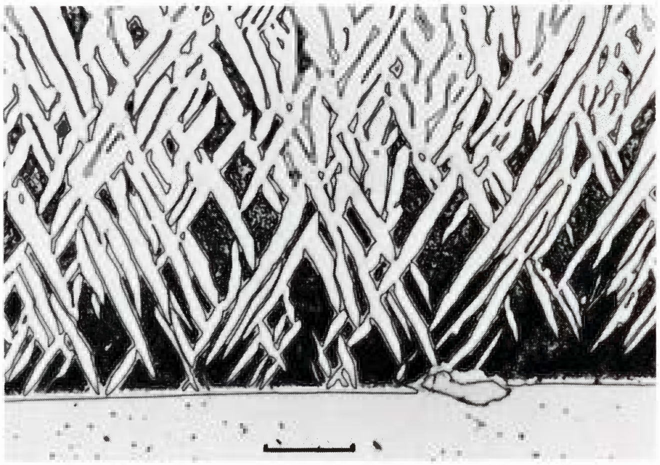

Figure 1964. Willow Creek (U.S.N.M. no. 900). Annealed acicular plessite field. Etched. Scale bar 200 μ.

About every third plessite field contains graphite. In clusters, 50-300 μ across, within the duplex plessite, numerous graphite laths or lamellae occur, each typically 25 x 5 μ in size. The morphology is identical to that of Kokstad. The location of the graphite clusters corresponds exactly to the carbide positions in, e.g., Rhine Villa, so there is no doubt that Willow Creek's graphite has formed by decomposition in situ of a preexisting carbide, probably haxonite. The hardness of the α-phase associated with the graphite is 160±10, indicating a significant (6-8%) nickel content in the area. This is in agreement with an origin from decomposition of haxonite, which is known to contain considerably more nickel than cohenite. Graphite occurs, in addition, as 2-10 μ spherulites located 20-50 μ from the taenite border in the plessite fields. They may be found in smaller amounts elsewhere, as in the plessite fields, on α - α boundaries and in the recrystallized ferrite adjacent to schreibersite. The spherulites consist of radiating sheaves of crystalline graphite but have no exterior crystal facets and

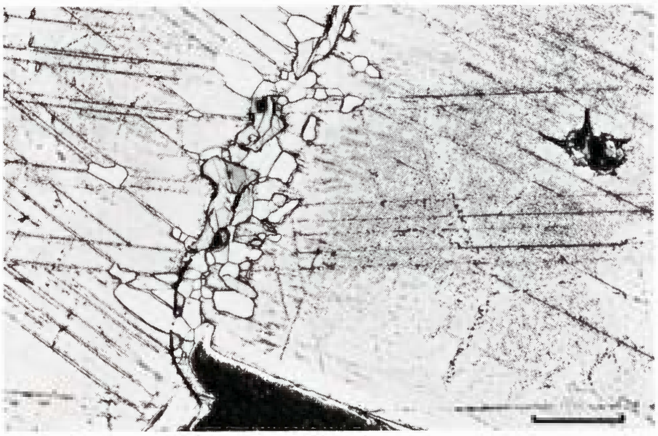

Figure 1965. Willow Creek (U.S.N.M. no. 900). A high angle α - α grain boundary with schreibersite crystals runs vertically through the picture. Recrystallization has started around the fissured schreibersite crystals, but not along the α - γ interfaces below. A shock-melted troilite nodule to the right. Etched. Scale bar 200 μ.

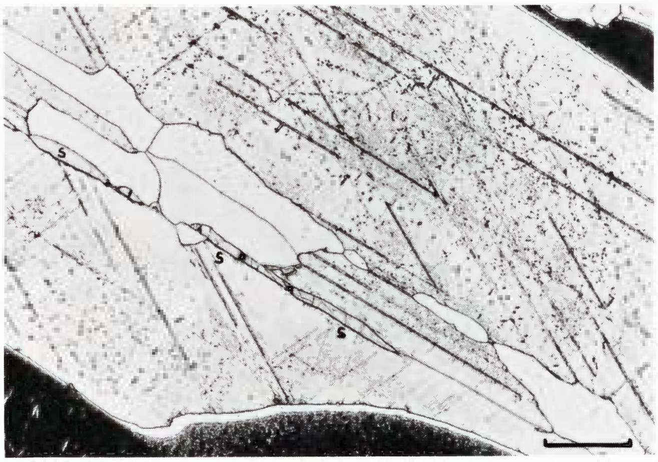

Figure 1966. Willow Creek (U.S.N.M. no. 900). Recrystallized grains elongated along Neumann band directions are very characteristic for the kamacite matrix. Schreibersite crystals are marked S. Etched. Scale bar 200 μ.

resemble somewhat the spherulites of nodular cast iron. Graphite finally plugs up numerous cracks, which follow cubic cleavage planes in the kamacite, often extending from the larger schreibersite crystals. The graphite fillings are typically 200 x 5 μ in size but may attain millimeter-length with only slightly larger widths. Corrosion, unfortunately, obscures many of the details.

Schreibersite is very common, both as irregular laths and rosettes, typically 10 x 0.8 or 3 x 2 mm in size, and as grain boundary veinlets 10-80 μ wide. The larger phosphides are apparently Brezina lamellae, oriented parallel to {110} of the parent austenite phase. They are enveloped in 0.5-1 mm wide layers of swathing kamacite. Schreibersite also occurs as numerous 1-10 μ blebs inside the plessite and as 1-10 μ particles on the kamacite subboundaries. Rhabdites proper are no longer present, but the kamacite is loaded with densely spaced, subangular particles 1-2 μ across which may represent original rhabdites, altered by annealing. The bulk phosphorus content is estimated to be 0.35±0.05%.

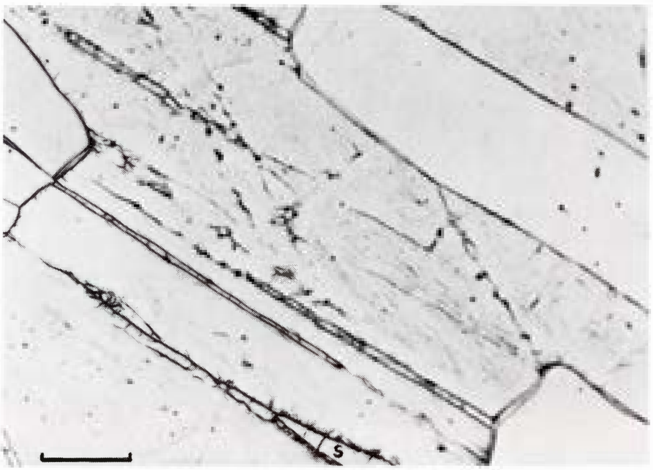

Figure 1967. Willow Creek. Detail of Figure 1966. Competition between grain growth of recrystallized units and recovery and polygonization in the kamacite matrix. Schreibersite marked S. Etched. Scale bar 40 μ. See also Figure 217.

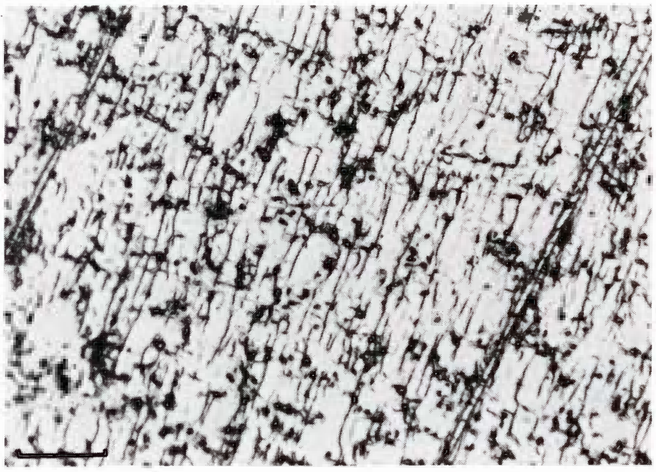

Figure 1968. Willow Creek (U.S.N.M. no. 900). The kamacite is polygonized and shows densely spaced networks of subparallel cells. Minute phosphide particles are also present. Etched. Scale bar 40 μ.

All the larger phosphide particles (> 5 μ) are surrounded by minute γ-blebs, only 1-2 μ across. This indicates that during late cosmic reheating the nickel-rich phosphides regulated their nickel content downwards, according to the Fe-Ni-P diagram. Similar reactions have occured in, e.g., Ballinoo and Willamette.

While troilite is normally agglomerated to a rather few large nodules, it is present in Willow Creek as a large number of small lenticular to globular bodies. They range from 0.1 to 11 mm in size and occur with a frequency of about one per cm^2. They are sometimes enveloped in 0.5-1 mm swathing kamacite but are frequently in direct contact with plessite. They previously contained parallel daubreelite lamellae and were surrounded by a little schreibersite.

However, they are all severely altered by shock. They are micromelted and have invaded the shattered schreibersite rims. The daubreelite is completely disintegrated into angular fragments, typically 5-25 μ across, and the troilite often penetrates along former Neumann bands out into the kamacite, thereby producing highly serrated interfaces against the metal.

The meteorite is corroded. On no sections could any fusion crust or heat-affected α_2 zones be detected, and no hardness gradient was revealed when traversing from the interior to the surface. It is estimated that, on the average, 3-4 mm has been lost by weathering. Laminated terrestrial oxides, 1-3 mm thick, cover part of the surface. The α-phase is selectively corroded and often removed in shallow grooves, making the Widmanstätten pattern clearly visible as a grid on the surface. Corrosion also penetrates

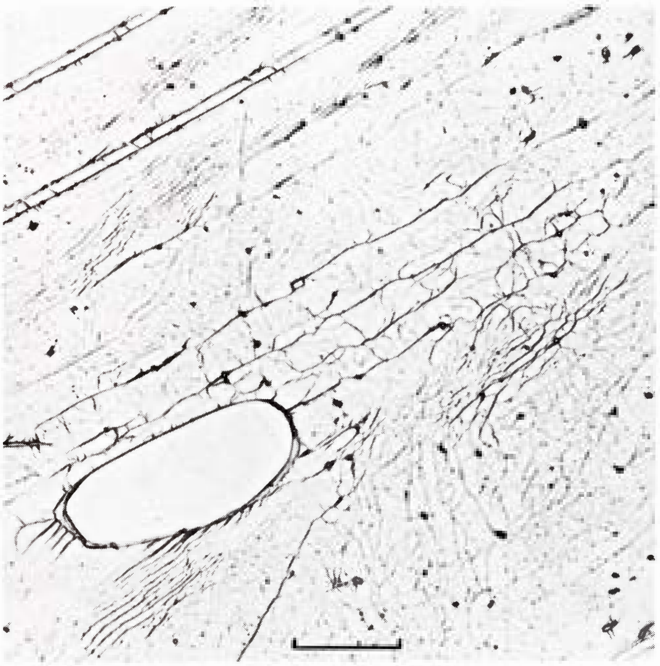

Figure 1969. Willow Creek (U.S.N.M. no. 900). A recrystallized kamacite grain for which grain growth is difficult because adjacent kamacite is already thoroughly polygonized. Etched. Scale bar 30 μ.

conspicuously along the Neumann bands which have been sensitized by phosphide precipitation.

Willow Creek is a coarse octahedrite, closely related to the small group IIIE of characteristic irons: Kokstad, Rhine Villa, Tanakami Mountains, Paneth's Iron and Staunton. The relationship to Kokstad is particularly well-defined, since both meteorites have suffered cosmic annealing.

The structure of Willow Creek, before it was exposed to cosmic annealing, may be visualized by the examination of Staunton which corresponds in almost all details of the primary structure. After the full development of the primary structure, Willow Creek was released from its parent body by a violent shock. The micromelted troilite, the brecciated schreibersite and the cubic cleavages in the kamacite probably formed at the time of this event. The mass circled from then on in an elliptical, probably asteroidal orbit, and was exposed to cosmic radiation. Gentle reheatings in the perihelion made the kamacite polygonize and partially recrystallize. Simultaneously, preexisting carbides decomposed to graphite; and taenite and kamacite – supersaturated with respect to carbon – exsolved graphite as "temper carbon," both at grain boundaries and in preexisting fissures.

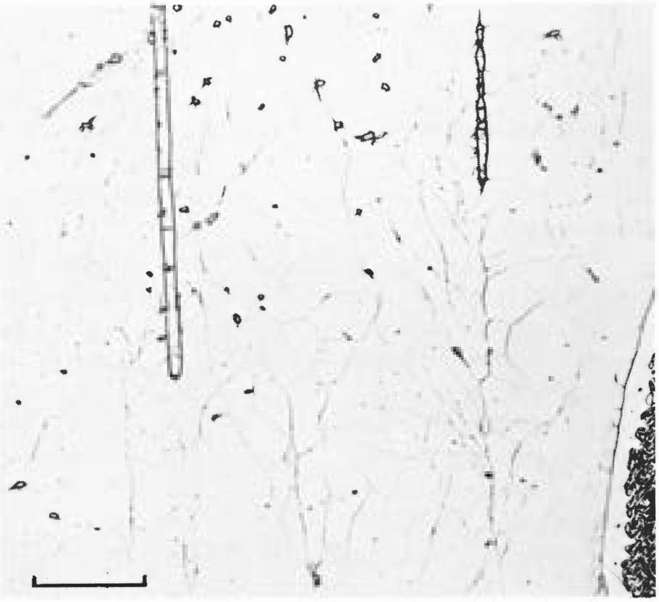

Figure 1970. Willow Creek (U.S.N.M. no. 900). Polygonized kamacite with several rhabdite particles. Two former Neumann bands (vertical) are almost eliminated by the cosmic annealing. Etched. Scale bar 30 μ.

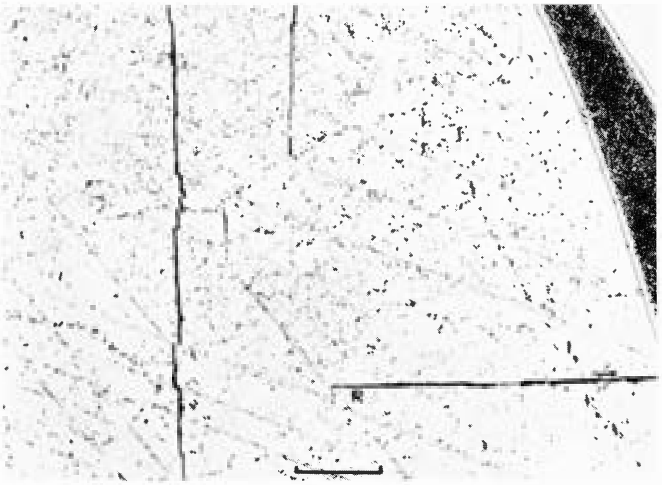

Figure 1971. Willow Creek (U.S.N.M. no. 900). In the kamacite several cracks follow cubic cleavage planes. To the right an annealed plessite field. At R a recrystallized kamacite grain at a Neumann band intersection. Etched. Scale bar 100 μ.

The plessite also spheroidized somewhat and martensite-bainite was annealed to resolvable duplex structures. The pair – Staunton and Willow Creek – appears to be a particularly well developed example of iron meteorites with identical chemical composition, yet different secondary and tertiary structures, as a result of different late-life histories.

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

4.5 kg	endpiece (no. 900, 16 x 15 x 7 cm)
515 g	slice (no. 900, 14 x 8 x 0.7 cm)

Winburg, Orange Free State
South Africa
28°30'S, 27°0'E

Medium octahedrite ?

Group unknown. About 6.9% Ni. Not an observed fall.

HISTORY

A mass of nearly 50 kg was said by natives to have been seen to fall in 1881. The place of discovery was on the Zeekoegat farm, belonging to Dr. Schneehage, in the Winburg district. Winburg has the coordinates given above. The meteorite remained on the farm for some years, then was described by Rudge (1914) who provided four photomacrographs of etched sections and also reported a chemical analysis and tension and compression tests. About 1923, the somewhat divided meteorite was acquired by the National Museum, Bloemfontein.

COLLECTIONS

Bloemfontein (about 40 kg and 0.5 kg), Copenhagen (about 3 kg), London (42 g).

ANALYSIS

Rudge (1914) recorded a partial analysis giving 6.91% Ni and about 0.15% C.

DESCRIPTION

Rudge stated that the meteorite measured 38 x 23 cm along the two greatest axes. The third dimension must have been about 15 cm, since the entire mass weighed 50 kg.

A cursory examination of the deep-etched specimen in London (B.M. No. 1915, 146) indicated that Winburg is a somewhat corroded mass. No fusion crust is present, and limonitic veins penetrate into the interior. The general appearance, therefore, does not support the history that it could have been an observed fall in 1881.

Otherwise, the deep-etched section allowed only few observations, and unfortunately, the sample could not be made available for a thorough metallographic study. It appears that Winburg is a medium or perhaps coarse octahedrite with 5-10% taenite and plessite, but the bandwidth could not be measured. It is recommended that the main mass be reexamined with modern methods, and that a full analysis be performed. For some additional information, please see the Supplement.

Withrow, Washington, U.S.A.

47°42′24″N, 119°49′48″W

Medium octahedrite, Om. Bandwidth 1.2±0.2 mm. Recrystallized. Probably group IIIA, related to Owens Valley and Ruff's Mountain.

HISTORY

A mass of 19¼ pounds (8.7 kg) was found about 1950 by Walter C. Nollmeyer, when he was walking across a newly planted wheat field. The site was one mile west of Withrow, in Douglas County, and only five miles south-southeast of the discovery site of the Waterville iron, which, however, is entirely unrelated. In 1956 the mass was deeded to the Waterville Museum and was thoroughly described by Read et al. (1967). They produced photographs of the exterior and of a macroetched section and discussed in particular the ablation sculpture of the well-preserved mass.

COLLECTIONS

Waterville Museum, Washington (main mass).

ANALYSIS

None has been recorded.

DESCRIPTION

The following is a commented summary of the paper by Read et al. (1967). The 8.7 kg mass measures 18 x 13 x 10 cm and is roughly hemispherical, or shaped somewhat like the upper part of a Neanderthal cranium. It is very slightly weathered and covered with fusion crusts which locally build up crossbedded layers of dendritic metal, up to 2 mm in thickness. The fusion crust displays the warts, ridges and thread lines associated with fresh falls. The circumstances of discovery indicate that the meteorite fell some years prior to the date given, perhaps during wintertime on a snow-covered frozen surface. Annaheim was discovered under similar circumstances, but that fall was well-substantiated by a number of eyewitnesses. No information of relevant fireballs is recorded in connection with Withrow, and the weathering on some parts of it suggests a somewhat higher terrestrial age than just a few years.

The domed side of the mass shows shallow regmaglypts, 1 to 2 cm in cross section. Some large depressions are apparently composites of numerous shallow regmaglypts. A gaping cavity, 5 x 3.7 cm across and 2 cm deep, was interpreted as the result of an explosion-like expansion of a troilite nodule which blasted out the overlying metallic plug and part of itself during the last part of the atmospheric flight.

The opposite rather flat side shows shallow regmaglypts, 3-5 cm across. Three of the depressions are unusually deep and have as bottoms circular cavities about 2.5 cm in diameter, presumably due to ablational melting of troilite nodules. The overall shape of the meteorite suggests a stabilized flight through the atmosphere with the domed surface being the anterior face.

An etched section shows Withrow to be a medium octahedrite with a bandwidth of 1.2±0.2 mm. Taenite and plessite cover 25-30% by area. Comb plessite and somewhat spheroidized varieties of comb and net plessite are common. All kamacite is recrystallized. The recrystallization has led to coarse grains in the kamacite lamellae, 0.1-0.3 mm in size, and to smaller grains inside previous plessite fields. The recrystallized grains are not arbitrarily oriented but are apparently elongated along preexisting Neumann bands, as repeatedly noted from other recrystallized meteorites, such as Indian Valley, Roebourne, and Durango.

Schreibersite occurs as platelets, up to 8 x 0.4 mm in size, situated along the midribs of many kamacite lamellae. It is also present as narrow grain boundary veinlets. The morphology resembles what is present in, e.g., Aggie Creek and Ruff's Mountain.

A Reichenbach lamellae, 2 cm long but paper-thin, was recorded and assumed to be composed of a fine-grained troilite backbone with precipitates of magnetite (?) and schreibersite.

Troilite occurs as nodules up to 2.5 cm across, but their structure is unrecorded. It appears, however, that they must be shock-melted fine-grained aggregates, estimating from the overall structure of the metal. It is also highly probable that fine fissures extend through the metal from the nodules. These would date from a remote cosmic shock event; but under the conditions of atmospheric entry and ablation, they would be very efficient in dislodging fragmental plugs of metal, such as described by Read et al. (1967).

The heat-affected α_2 zone is well preserved as a normal ±2 mm thick rim around the mass. In one place it stops abruptly, and it is possible that this is where a fragment became detached late in flight by fracturing along a Reichenbach lamella, parallel to the one which is preserved further inside the mass. This rather plane fracture surface is only insignificantly modified by sculpturing.

In describing the heat-affected rim zone Read et al. (1967) applied the term recrystallization. However, it should be pointed out that this term is metallurgically restricted to processes that occur during reheating after cold-deformation, without phase transformation. The 2 mm wide heat-affected zones on freshly fallen iron meteorites are the result of rapid phase transformations from α via γ back to unequilibrated α – the so-called α_2 phase – and they form irrespective of any previous cold-deformation.

The interior of Withrow is, on the other hand, a genuine cosmic example of recrystallization.

Withrow appears to be a medium octahedrite related to such irons as Aggie Creek, Baquedano and Ruff's Mountain. Chemically, it probably belongs to the resolved group IIIA or possibly to the transitional IIIAB irons. In its recrystallized and annealed structures, which are genuinely cosmic, it resembles Ruff's Mountain, Durango and Roebourne in particular. The surface morphology indicates that several small fragments are missing and might, with luck, be retrieved from the cultivated fields in the vicinity.

Wolf Creek, Western Australia

19°18′S, 127°46′E; 340 m

Medium octahedrite, Om. Bandwidth 0.85±0.15 mm. ϵ-structure. HV 265±25.

Group IIIB. 9.22% Ni, about 0.6% P, 18.4 ppm Ga, 37.3 ppm Ge, 0.036 ppm Ir.

HISTORY

A large circular crater – the most remarkable of the Australian craters – was first observed from the air in June 1947, on the edge of the essentially unexplored Great Sandy Desert. It is situated about 110 km south of Hall's Creek from where it may be reached by dirt track in a vehicle with 4-wheel drive. The coordinates above are from McCall & de Laeter (1965); White et al. (1967) recorded somewhat different coordinates, so the mapping of the region is evidently imperfect. The first descriptions by ground parties came from Reeves & Chalmers (1949), Guppy & Mattheson (1950) and Cassidy (1954). According to them, and to McCall (1965a), the crater is 850-900 m in diameter. The rim of the crater rises 18-30 m above the surrounding plain and 48-54 m above the floor of the interior basin. The crater may well have had a depth of 150-180 m prior to pervasion by gypsum and Aeolian sand which now form the existing flat floor, where a vegetation much more luxuriant than outside reflects the seasonal filling of the crater with rain water.

The crater is blasted into late Precambrian quartzite, scattered exposures of which are visible in the surrounding sand desert (see, e.g., map and cross sections in McCall 1965a). The quartzites exposed in the east side of the crater wall dip uniformly outwards at a moderate angle. The west wall, however, reveals steep dips, and inversion is present, alternating with zones of non-inversion. Single blocks, which must weigh many tons, have been thrown out onto the rim.

The crater must be of post-Miocene age because it penetrates the 15 m thick laterite capping of the area, generally assumed to be a Miocene deposit. The present Djaru tribes have no recollections or legends associated with the crater so, therefore, it is "prehistoric." Various physiographical characteristics suggest that it is Pliocene or, at the very latest, Plio-Pleistocene. It is no doubt considerably older than the Arizona Meteor Crater, around which so many tons of Canyon Diablo meteorites have been recovered. It is thought that the meteoritic material around Wolf

Figure 1972. Wolf Creek. The circular crater is 850-900 m in diameter and the rim rises 18-30 m above the surrounding plain.

Creek has weathered away to a much higher degree. However, little field work has at yet been carried out, compared to the Arizona crater, and core-drilling methods have not been employed.

Some authors have not entirely accepted the meteoritic hypothesis for Wolf Creek, or they point out that the structure is still open to question (Whipple 1952; McCall 1965a). No coesite, stishovite, lechatelierite, rock flour or shatter cones have thus been recognized. For further discussions of the origin and for references, the reader is referred to McCall (1965a), McCall & de Laeter (1965), Hey (1966: 523 and 561), Krinov (1966a: 42), Cassidy (1968), Short & Bunch (1968), and Yavnel (1971).

Samples of unweathered iron meteorite fragments are extremely rare. White et al. (1967), who examined specimens collected by Mason and Henderson in 1963, cut up some forty masses, including one weighing 250 kg, and found only a few metal particles, mostly microscopic in size. On the other hand, a large number of shale-balls weighing up to perhaps 300 kg each, and numerous severely weathered fragments have been recovered that are weakly magnetic and react to a mine detector. The shale-balls have been described by LaPaz (1954), and the many problems they pose have been discussed with the help of numerous photographs by McCall (1965a). Analyses of the iron-shales, in which scattered octahedral metal veins are sometimes present, yield 1.9-4.5% Ni (e.g., Buddhue 1957).

White et al. (1967) examined in great detail the secondary minerals produced by weathering. They found that the major minerals were goethite and maghemite, while hematite was absent. Accessory minerals were jarosite, apatite, lipscombite, reevesite (the nickel analog of pyroaurite), and cassidyite (the nickel analog of collinsite). A little opal was found in some cavities; other cavities were lined with reevesite. The "yellowish-green zaratite" recorded by LaPaz (1954) was discredited and shown to be a nickel serpentine, a nickel analog of clino-chrysotile.

Taylor (1965) discovered small masses of unaltered nickel-iron, not at the crater itself but about 4 km to the southwest. If this material were associated with the impact, the meteoritic body was a medium octahedrite with about 8.6% Ni. Knox (1967), on the other hand, examined a 280 g oxidized sample from the inside of the crater, and identified a 0.2 x 0.7 mm kamacite particle. He assumed that Wolf Creek was a hexahedrite, or alternatively a strongly segregated body displaying both hexahedral and octahedral compositions. He showed photomicrographs, suggesting a shock-hardened kamacite.

The present examination does not support the idea of a hexahedral component in the impacting body. All material examined by me was either of a medium octahedrite nature or too weathered to draw any conclusions. The "hexahedrite" of Knox appears to have been an unweathered kamacite lamellae, of the type normally present in shock-hardened medium octahedrites. Wasson (1967c) showed that the material collected by Taylor belonged to the resolved chemical group IIIB and was definitely different from those two other independent bodies that produced the Henbury and Boxhole craters.

COLLECTIONS

Numerous masses with a total weight of several thousands kg have been recovered (McCall & de Laeter 1965: 52). Almost all are shale-balls or iron-shales with specific gravities of 3.5-4. Large samples are in Albuquerque (about 300 kg), Adelaide (155 kg), Sydney, Washington (25 kg), University of Western Australia, New York (12 kg), Perth, Tempe (4 kg), Harvard (2.45 kg), London (2 kg), Belgrad (692 g), Moscow (151 g), Denver.

DESCRIPTION

For a description of the weathered material, particularly the shale-balls, the reader is referred to McCall (1965a), White et al. (1967) and LaPaz (1954). In this study I was fortunate enough to examine two – under the circumstances – large, metallic fragments of 37 g and 25 g, respectively, which had been collected by Ross Taylor in 1966 and donated to the Smithsonian Institution. In addition, I have had the opportunity to compare my observations with photomacrographs of four other deep-etched sections, each of 3-4 cm^2, provided by Dr. Taylor.

The 37 g fragment measures 25 x 25 x 20 mm; it is an angular slug of the type found around Henbury craters and around Meteor Crater, Arizona. It is covered with limonitic crust, 1 mm thick, and no fusion crust or heat-affected α_2 zone can be detected. Corrosion penetrates the mass as 0.01-1 mm wide limonitic grain boundary veins.

Etched sections reveal Wolf Creek to be a normal medium octahedrite with straight, long ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 0.85±0.15 mm. Locally, grain growth has led to almost equiaxial kamacite grains, 3-4 mm across. The kamacite displays subboundaries which are only indistinctly visible, however, because they are overlain by a hatched shock structure, indicative of peak pressures above 130 k bar. The microhardness is correspondingly high, 265±25, almost the same as in Narraburra and Bear Creek with which Wolf Creek has very much in common. There are several cubic cleavage fissures in the kamacite, presumably cogenetic with the impact and consequent break-up; the fissures are now lined with secondary minerals.

While the kamacite lamellae are usually straight, near-surface lamellae are occasionally distorted, indicating

WOLF CREEK – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Scott et al. 1973	9.22								18.4	37.3	0.036	

plastic deformation and necking associated with the disruption of the impacting body.

Taenite and plessite cover 35-45% by area. The plessite is of the type characteristic of Wonyulgunna and Narraburra, where a felt of pointed α-lamellae, 10-50 μ wide, intersect to form a micro-Widmanstätten pattern, leaving numerous rather homogeneous concave taenite islands in between. Another typical plessite variety displays strained taenite rim zones, followed by light-etching martensitic transition zones and central portions of dark-etching martensite, developed parallel to the bulk Widmanstätten pattern. Black taenite, i.e., unresolvable duplex $\alpha + \gamma$ structures, is also common.

Schreibersite occurs as cuneiform skeleton crystals, which reach sizes of 20 x 1 mm, and appear to be Brezina lamellae in the $\{110\}$ planes of the parent austenite crystal. It is monocrystalline but brecciated by shear deformation, and is enveloped in 2-3 mm wide rims of swathing kamacite. Schreibersite occurs as 20-60 μ wide grain boundary precipitates but is particularly characteristic as an island front of small particles, 10-20 μ wide, situated uniformly 10-20 μ outside taenite and plessite. Rhabdites are uncommon. Bulk phosphorus content is estimated to be 0.6±0.2%.

Large troilite nodules were not observed, presumably because the fragmentation proceeded along them and destroyed them. Troilite is, however, present as minor blebs, 50-100 μ across, associated with the Brezina lamellae. The troilite is a polycrystalline aggregate of 5-50 μ grains, apparently recrystallized without shock melting. Idiomorphic crystals of chromite, 100-200 μ across, are often associated with the troilite, possibly being the original nucleus upon which other minerals nucleated heterogeneously. White et al. (1967) suggested that the original meteorite contained an appreciable amount of lawrencite and that this could have aided in a rapid decomposition of surviving fragments. As noted under numerous descriptions, lawrencite does not appear as a primary, cosmic mineral in other iron meteorites; and since Wolf Creek is a normal IIIB iron, it is not believed to have been present here, either.

Since Taylor's fragments were recovered an appreciable distance from the crater, it has been suggested that they are from an independent fall. In my opinion, the fragments are clearly associated with the cratering impact: (i) The fragments are small slugs which, in other crater fields, such as Wabar, Henbury and Canyon Diablo, are unamimously attributed to impact fragmentation. (ii) The discovery of numerous small, partly deformed fragments of a single meteorite is difficult to explain without assuming a violent disruption. Terrestrial weathering cannot separate and distribute a single body as the field data indicate. (iii) The material examined by Knox (1967), presumably from the crater interior, is similar to what has here been examined, except for the degree of weathering. (iv) Sections through shale-balls, etc., recovered from the crater interior and immediate surroundings, occasionally display sparsely disseminated particles of metal and schreibersite. The remnants indicate that the unweathered material was a shock-hardened medium octahedrite with a bandwidth of about 1 mm and abundant schreibersite, i.e., similar to Taylor's fragments. (v) The finding of fragments 4 km from the crater itself may be surprising; fragments have, however, previously been discovered at large distances in other crater fields, such as Henbury (1.5 km), Boxhole (1.5 km) and Canyon Diablo (up to 7 km).

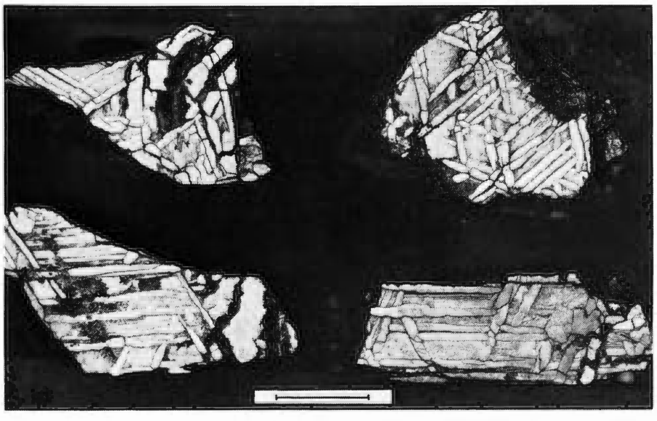

Figure 1973. Wolf Creek. Four weathered fragments which have been collected and photographed by Ross Taylor. They show that the Wolf Creek meteorite is a medium octahedrite of group IIIB. Deep-etched. Scale bar 10 mm.

Wolf Creek is a shock-hardened, unannealed medium octahedrite, closely related to Narraburra, Bear Creek, Bald Eagle, Knowles, Kouga Mountains, Smith's Mountain, and Wonyulgunna. I mention all these to indicate that Wolf Creek belongs to a group of well-known, and partly well-examined, iron meteorites, so that features present in these can be utilized when examining and evaluating the, as yet, sparse Wolf Creek material. Chemically, all the irons mentioned belong to the resolved chemical group IIIB.

The fragments so far examined apparently all possess their original cosmic structure, only insignificantly obscured by plastic deformation and fissuring from the impact. In particular, the shock-hardened ϵ-structure and the recrystallized troilite appear to be original and not associated with the impact with the earth. They probably date from a remote cosmic shock event.

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

37 g irregular metallic fragment (no. 2481, 2.5 x 2.5 x 2 cm)

25 g irregular metallic fragment (no. 2481). Both donated by S.R. Taylor

About 25 kg shale-balls and iron shale, collected by E.P. Henderson and Brian Mason in 1963 on an expedition sponsored by the National Geographic Society.

Wonyulgunna, Western Australia

24°55′S, 120°4′E

Medium octahedrite, Om. Bandwidth 0.95±0.20 mm. ϵ-structure. HV 325±15.

Group IIIB. 8.89% Ni, 0.51% Co, about 0.35% P, about 1% S, 19.5 ppm Ga, 39.6 ppm Ge, 0.03 ppm Ir.

HISTORY

A mass of 37.8 kg was found by an aborigine, Wally

Work, in 1937 on the Bald Hill (formerly Wonyulgunna) sheep station. The exact place was just west of the 485 mile post on No. 1 Rabbit Proof Fence and about 21 miles southeast of Mount Wonyulgunna. The whole mass was donated to the Western Australian Museum where it was described with four photographs by Simpson (1938). McCall & de Laeter (1965) gave some additional information and another photograph of the main mass.

COLLECTIONS

Perth (33.6 kg main mass), London (948 g), Washington (612 g), Sydney (260 g).

DESCRIPTION

The overall dimensions of the flattened, triangular mass are about 40 x 22 x 12 cm. It is covered by deep pits and shallow regmaglypts, created during the atmospheric entry. The typical pits are 5-25 mm in aperture and up to 40 mm deep, and they indicate the locations where troilite nodules wholly or partly burned out. The regmaglypts are irregular, 2-8 cm in diameter and frequently many centimeters deep, hollowing the mass from both sides. At the bottom of one such regmaglypt is a 10 mm hole through the mass, probably again the site of a lost troilite inclusion. The surface is apparently much corroded, since it is covered by reddish, rough, terrestrial oxides. Sections normal to the surface disclose, however, that the fusion crust is preserved, although altered somewhat. One section shows a 0.6 mm thick fusion crust consisting of an inner, laminated zone of metallic, columnar grains (HV 360±15) overlain by a confusing array of sintered, metallic droplets and intercalated, dendritic oxide melts. The metallic laminae here are 4 in number; they wedge out and disappear locally. The columnar grains are 2-5 μ in cross section and have grown normal to the cooling surface. The metallic spherules are 50-150 μ across and have concentric solidification structures. They are sintered to the substrate and to each other, and the interstices are partially filled with the latest ablation products, gray, dendritic iron oxides. Terrestrial oxides from weathering further complicate the structure of the original fusion crust. The heat-affected α_2 zone extends 1.2-1.5 mm under the crust, and micromelted phosphides are present in the exterior 50% of this zone. The α_2 zone has a hardness of 200±15 (hardness curve type I).

Etched sections display a medium Widmanstätten structure with an appearance that varies somewhat from section to section because of the irregular distribution of sulfides, phosphides and chromite. The kamacite lamellae are straight and long ($\frac{L}{W} \sim 15$) and have a bandwidth of 0.95±0.20 mm. In addition, there occurs a group of more irregular and somewhat broader lamellae, developed around the primary schreibersite and chromite crystals. The kamacite is due to shock, estimated to have been in the 130-300 k bar range, converted to a contrast-rich, hatched ϵ-structure, and it has a correspondingly high hardness, 325±15. Taenite and plessite cover about 40% by area. The plessite is developed as comb and net fields, where the individual taenite blebs are concave and 5-20 μ across. The more nickel-rich fields have martensitic structures, with platelets parallel to the overall octahedral directions. In many places the martensite grades over in duplex $\alpha + \gamma$ structures, sometimes easily resolvable.

Schreibersite is common as irregular skeleton crystals, typically 5 x 0.5 mm in size, but occasionally larger. It is further present as characteristic island-arcs of 10-30 μ thick crystals, situated about 10 μ in front of the taenite and

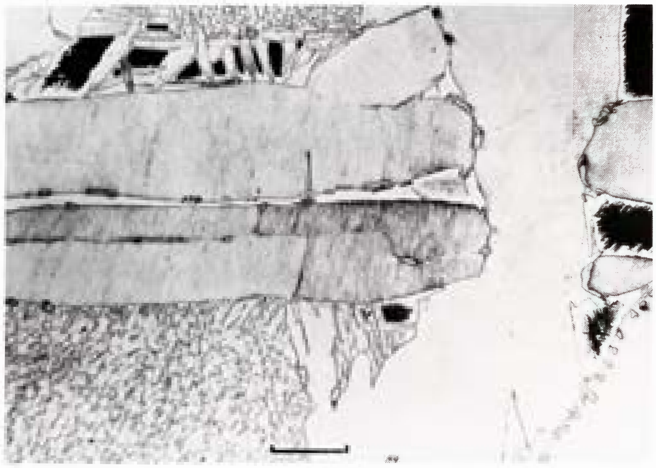

Figure 1974. Wonyulgunna (U.S.N.M. no. 1747). Shock-hatched medium octahedrite of group IIIB. Net and acicular plessite fields, and fields that are black and unresolvable under the optical microscope. Etched. Scale bar 500 μ.

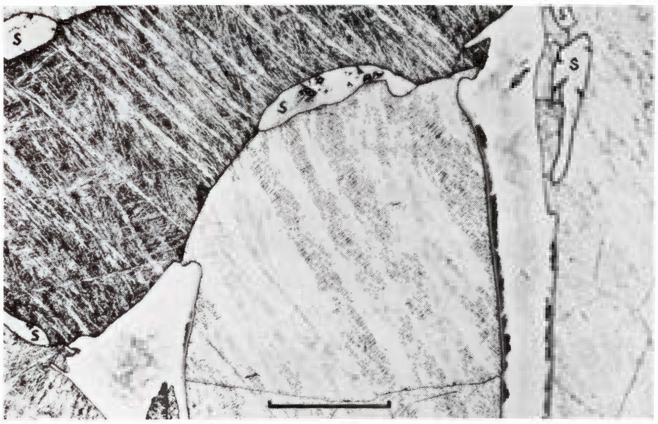

Figure 1975. Wonyulgunna (U.S.N.M. no. 1747). Shock-hatched kamacite lamellae in different orientations and shades. Plessite with cloudy taenite edges. The cloudiness is absent at grain boundaries and schreibersite precipitates (S). Etched. Scale bar 200 μ.

WONYULGUNNA – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Lovering et al. 1957	9.05	0.51				1.2	118		13	34		
Scott et al. 1973	8.72								19.5	39.6	0.028	

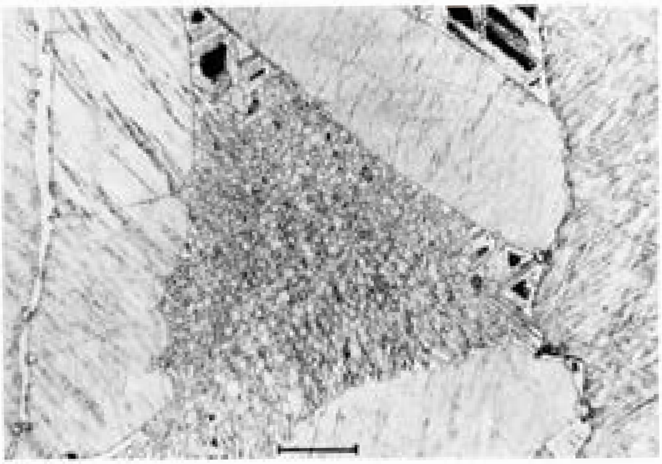

Figure 1976. Wonyulgunna (U.S.N.M. no. 1747). A large net plessite field amidst kamacite lamellae showing shock-hatching of various shades. Note the island-arcs of small schreibersite crystals. Etched. Scale bar 500 μ.

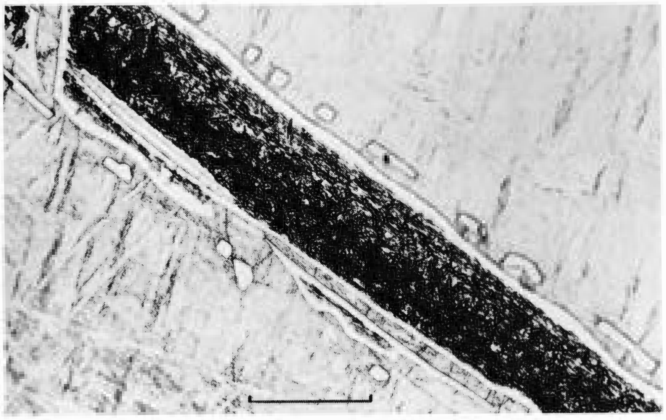

Figure 1977. Wonyulgunna (U.S.N.M. no. 1747). A taenite lamella with clear edges and unresolvable martensitic interior. On either side eminent island arcs of schreibersite. Etched. Scale bar 200 μ.

plessite. It is also present as 5-20 μ vermicular bodies inside the plessite, but rhabdites do not occur. The millimeter-sized bodies are enveloped in 0.5-2 mm thick ribbons of swathing kamacite. The bulk phosphorus content is estimated to be 0.35±0.05%. Cohenite has been reported by Simpson (1938) but apparently erroneously.

Troilite is common as 10-20 mm nodules that are sheathed in irregular, 0.4 mm thick schreibersite rims. Daubreelite is not present. The troilite is either monocrystalline or built up of an aggregate of 1-5 mm units, possibly conditioned by the easy access to growth substrates in the form of chromite crystals. The troilite contains numerous lenticular twins, probably as a result of shock loading. Simpson (1938), who examined several large sections, estimated the bulk sulfur content to be 1-1.5%.

Chromite (HV 1100±50) occurs as 0.5-2 mm angular, isotropic crystals, frequently surrounded by troilite and ferrite. They may also themselves contain pockets, 50-200 μ across, of troilite. Plates, 15 x 5 x 0.1 mm in size, are rather common, cutting across the regular Widmanstätten structure. Troilite and schreibersite have precipitated in various amounts and shapes on these plates.

The nonmetallic inclusions are somewhat sheared and brecciated, displaying relative movements in 1-10 μ steps.

Wonyulgunna is a shock-hardened medium octahedrite, rich in inclusions and resembling, in this and other respects, particularly Luis Lopez, Wolf Creek, Kouga Mountains, El Capitan and Grant. Chemically, it belongs to group IIIB.

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

82 g part slice (no. 1747, 4 x 3 x 1.2 cm)
530 g part slice (8 x 3 x 3 cm)

Woodbine, Illinois, U.S.A.

42°20′48″N, 90°10′6″W

Polycrystalline, fine octahedrite with silicate-troilite inclusions. Bandwidth 0.3±0.1 mm. Neumann bands. HV 176±6.

Group I – Anomalous. 10.6% Ni, about 0.5% P, about 0.1% C, 37 ppm Ga, 114 ppm Ge, 1.4 ppm Ir (for the metal phase).

HISTORY

A mass of 48.2 kg was plowed up in 1953 on Henry Albrecht's farm, about 2 km west of Woodbine, Jo Davies County. The circumstances of the find, a map and a description of the meteorite, have been given by Read (1963c; Meteoritical Bulletin, No. 24, 1962). A thorough description of the silicates and a photomacrograph of an etched section were presented by Mason (1967a), while Jarosewich (1967) presented an analysis. Goldstein & Short (1967a) included Woodbine in their discussion on cooling rates. Wasson (1970b) presented an analysis of the metal phase and discussed formation conditions of the iron meteorites with silicate inclusions.

COLLECTIONS

Washington (main mass), Chicago (1,826 g).

DESCRIPTION

According to Read (1963c) and the figures given by him of the exterior, the mass is a weathered, angular block measuring 30 x 27 x 17 cm in three perpendicular directions. In several places, relatively fresh surfaces indicate where the discoverer chiseled off pieces and distributed them as curios. Sections through the mass display an intricate mixture of metal, silicates, troilite, schreibersite and graphite. The volume ratio metal to non-metal ranges from 3:2 to 2:3 in different large sections. The silicate minerals are rounded and have grain sizes of 0.05 to 0.5 mm. They occur singly in the kamacite or in dense aggregates, cemented by troilite. The largest metal-free silicate aggregate is about 6 x 2 cm, while the largest silicate-free metal grain is about 3 x 2 cm in size. Corrosion penetrates grain boundaries forming 10-300 μ wide limonitic veins; the brecciated minerals are partly recemented by limonite.

Etched sections show the metal phase to be a polycrystalline aggregate of parent austenite grains, each 2-20 mm

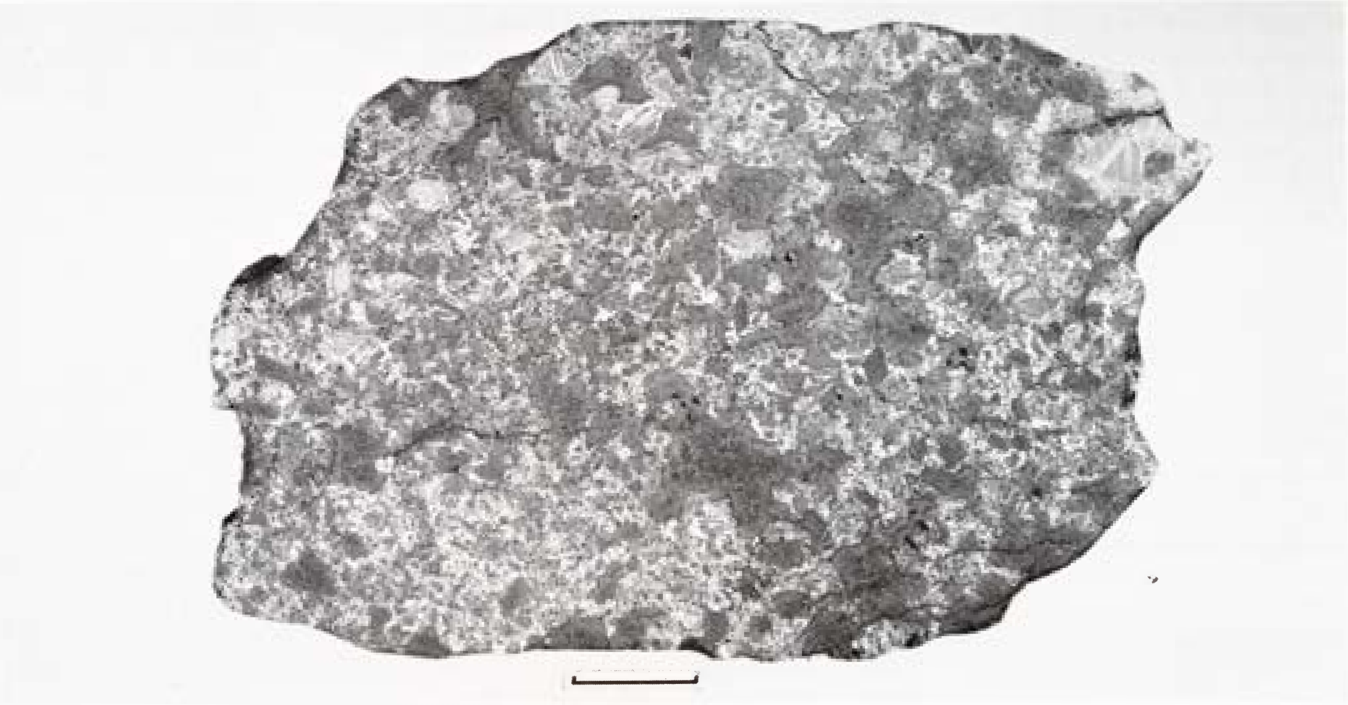

Figure 1978. Woodbine (U.S.N.M. no. 2169). A polycrystalline fine octahedrite with silicate-troilite inclusions. One of the largest precursor taenite crystals is situated near the upper right corner. Deep-etched. Scale bar 30 mm. S.I. neg. 1267.

across. The bulk of the silicates are situated at prior austenite grain boundaries, or as massive aggregates "substituting" for austenite grains of equivalent sizes. There are no flow patterns of the type visible in Tucson; apparently the metal-silicate mixture has only been insignificantly worked after its formation by mixing (?) from the constituents.

The prior austenite grains have – when inclusion free – independently developed a fine Widmanstätten structure of straight, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 0.3±0.1 mm. The kamacite displays lightly decorated subboundaries and numerous Neumann bands. The hardness is 176±6. In several places cold-deformation has been intensive; the Neumann bands here are distorted and the hardness increases to at least 205. Each prior austenite grain is enveloped in 0.3-0.5 mm wide kamacite that nucleated and grew upon the grain boundaries before the grain interiors decomposed by homogeneous nucleation. Impure austenite grains, i.e. grains with silicate inclusions, decomposed to a number of equiaxial kamacite grains, each nucleated by an inclusion.

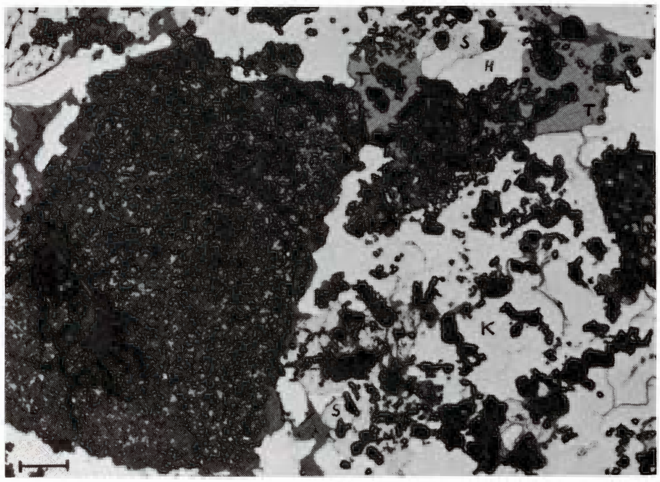

Figure 1979. Woodbine (U.S.N.M. no. 2169). To the right a complex aggregate of silicate grains (black) and troilite (gray). Irregular troilite (T) – schreibersite (S) – haxonite (H) intergrowths in other places. K is kamacite. Many silicate grains are enveloped in graphite, not clearly seen in the photo. Polished. Scale bar 1 mm. S.I. neg. 1044.

I. Metal

WOODBINE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970a	10.60								37.3	114	1.4	

II. Bulk analysis. Jarosewich (1967) and Mason (1967a) analyzed a 22 g sample and found 79.6 weight percent metal and 20.4% non-metal; the 20.4% was made up of 7.6% orthopyroxene, 4.2% olivine, 2.6% plagioclase, 1.1% diopside, 3.0% schreibersite, 1.7% troilite and 0.2% graphite. The schreibersite was found to contain 53.6% Fe, 30.8% Ni, 0.25% Co and 15.3% P. The density was determined on two thin slices as 5.96 and 6.34, averaging 6.2. Read (1963c) reported lawrencite, based only upon circumstantial evidence, however: exudation of small pustules on polished sections. The chlorine ions are probably mainly of terrestrial origin, introduced by the ground water.

Taenite and plessite cover 10-20% of the metallic areas. The taenite is of the comb plessite types, or displays martensitic interiors with decomposition parallel to (111) of the parent austenite grain (HV 360±20), or – in small nickel-rich fields – displays high-nickel feathery martensite developed in a multitude of directions (HV 410±20). The taenite rims are brown or blue-stained (HV 330±30) and are visibly cold-deformed. The dense grids of $(111)_\gamma$ slipplanes are plainly visible particularly on etched sections with crossed Nicols. In addition, unresolvable duplex $\alpha + \gamma$ fields ("black taenite") and small spheroidized plessite fields occur.

Schreibersite is present as up to 1 x 0.5 mm irregular patches which normally envelop silicate grains more or less completely. In the Widmanstätten parts only short 30-50 μ wide veinlets occur on the grain boundaries. Rhabdites were not observed. The phosphides are somewhat sheared and brecciated, but monocrystalline. The bulk analysis by Jarosewich indicated 3.0% schreibersite, or 0.47% P. It appears that a major part of the phosphorus was originally in solid solution in the metal phase but precipitated upon the silicate nuclei upon cooling.

Troilite is not present as individual nodules of the usual type. It occurs as an infill, cementing the more or less loosely packed silicate grains together. The troilite-silicate ratio ranges from 1:1 to 1:10 in these aggregates. All troilite is polycrystalline with grain sizes of 5-50 μ apparently due to a shock recrystallization. On this occasion, the troilite must have been in a semi-liquid state and has been squeezed into adjacent fissures in silicates and schreibersite. These minerals now often appear as sheared and brecciated grains in the troilite. Chromite, daubreelite and cohenite were not identified.

Graphite is a minor accessory, partly dispersed as 0.1-1.5 mm cakes with a feathery development in the troilite-metal interface, partly occurring as a lining around the silicate grains. The graphite lining is 5-20 μ wide and may easily be mistaken for corrosion on an inferior section. However, it occurs only on silicate grains and on preexisting graphite cakes, never on taenite or schreibersite, indicating that it is an early high temperature solid state precipitate from the decomposing austenite.

Some of the carbon is bound in the rather unusual mineral haxonite. It occurs almost equivalent to cohenite, as 0.1-0.3 mm wide discontinuous rims around troilite and as tongues, projecting from it, up to 1.5 x 0.8 mm in size. It is bright white, isotropic and contains 5-20 μ wide schreibersite blebs. Its hardness is significantly lower than that of cohenite, 790±30, as opposed to 1100±50, but – like cohenite – it is ductile and normally supports a load of 100 g upon the Vickers diamond pyramid, without fracturing. In this respect, cohenite and haxonite are different from schreibersite which is hard (HV 700-950) and brittle.

The silicates have been fully described by Mason (1967a). The orthopyroxene is an enstatite with about 6 mole% $FeSiO_3$. The olivine is a low-iron forsterite with 4 mole% Fe_2SiO_4. The clinopyroxene is a chrome diopside, and the plagioclase is a sodic anorthite. Mason noted that the principal minerals represented a near equilibrium assemblage, presumably determined by the slow cooling of the host nickel-iron. He noted further that the composition of the minerals was comparable to that of the ordinary hypersthene chondrites; the sodic nature of the plagioclase is especially characteristic and serves to distinguish the meteorite from the mesosiderites with which there might otherwise be some common features. Mason suggested that Woodbine – and other silicate-bearing irons as well – might have been formed by the injection of molten nickel-iron into a mass of chondritic silicates. He suggested, alternatively, that a mass of chondritic material could have been imperfectly melted in the weak gravitational field of a small asteroid, resulting in incomplete separation of metal and silicate.

Had the metal been in a completely molten state, I believe the overall morphology of metal-silicate would have approached pallasitic structures. I prefer to believe that Woodbine is the product of mixing, compression and sintering at moderate temperatures (1000-1100° C ?). Very little shear-deformation occurred and no flow pattern or other superstructures developed. Metallic grain growth, aided by molten sulfide and phosphide films, proceeded to a maximum grain size of about 2 cm, and the silicates acquired rounded shapes and drained, by capillary action, most of the troilite into these spongy aggregates. Small amounts of graphite were separated in the troilite.

Upon cooling, the austenite became supersatured with respect to carbon, and 5-20 μ wide microcrystalline graphite precipitated upon the silicates. Next, phosphides were precipitated, also upon available interfaces. Kamacite then nucleated upon the silicate and schreibersite crystals, and upon the γ - γ grain boundaries whereby the characteristic but rather confusing pattern of large and small equiaxial kamacite grains developed. Lastly, the austenite grain interiors decomposed in a typical Widmanstätten pattern by homogeneous nucleation and growth. A little schreibersite also precipitated on this occasion.

After complete cooling, a shock event dislodged the mass from its parent body. This event introduced Neumann bands, sheared the schreibersite and silicates, and for a moment held the troilite in a plastic state so that it could penetrate the brecciated minerals. Upon cooling, the troilite formed a polycrystalline aggregate that cooled too rapidly for grain growth to occur.

The meteorite penetrated our atmosphere under ablation and formation of fusion crust and heat-affected α_2 zones. No signs of these features were observed on the sections, so the mass must have been exposed to a terrestrial environment for countless thousands of years.

Woodbine has much in common with the inclusion-rich octahedrites of group I, particularly Mertzon, Mazapil, Shrewsbury and Toluca. Still closer relations are to be found with Mesa Verde, Four Corners, Pitts, Copiapo and Pine River.

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

820 g slice (no. 2169, 18 x 13 x 0.7 cm)

Wood's Mountain, North Carolina, U.S.A.

Approximately 35°45′N, 82°9′W; 600 m

Fine octahedrite, Of. Bandwidth 0.30±0.05 mm. Heavily distorted and recrystallized. HV 180-255.

Group IVA. 8.20% Ni, 0.37% Co, 0.04% P, 2.4 ppm Ga, 0.14 ppm Ge, 2.4 ppm Ir.

McDowell County is a fragment of Wood's Mountain.

HISTORY

A weathered mass of 850 g was found before 1923 in McDowell County and was briefly mentioned by Merrill (American Journal of Science 1923: Volume 5: 519). It was classified as a finest octahedrite and has figured as an independent fall, labeled McDowell County, ever since; see, e.g., Hey (1966: 298). Another mass, of 3.02 kg, had previously been found south of Wood's Mountain in 1918 by G.M. Bird but was first described – as Wood's Mountain – in 1939 by Perry who presented numerous photographs. This specimen was also classified as a finest octahedrite and was compared – although it was somewhat misleading – to Salt River and Tazewell.

While the location of the 850 g mass was only known before this study as "the hills near Marion," the location of the 3 kg mass has been known with better precision, and the corresponding coordinates are given above. It was picked up from shallow water at the edge of Little Buck Creek which is a 2 km long, north-south running stream 16 km west-northwest of Marion, and about 1 km east of the present Blue Ridge Parkway. While searching for more information on the 850 g mass, I found – in the Smithsonian Archives – some unpublished notes by S.H. Perry. These, together with a personal communication from H.T. Davis, Raleigh, indicate that the fragment was found by a forest ranger near Little Buck Creek, and thus, in fact comes from a place very near the 3 kg fragment.

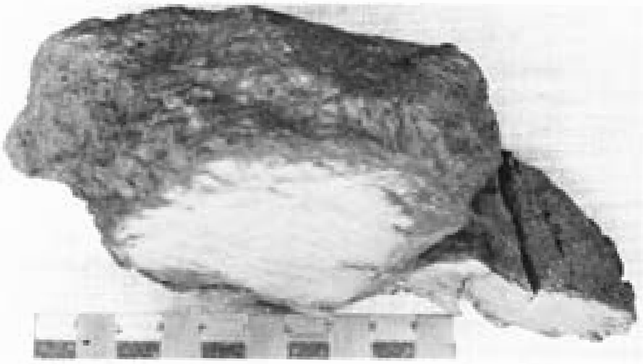

Figure 1980. Wood's Mountain (U.S.N.M. no. 1271). The Wood's Mountain mass is of a highly anomalous shape. It is approximately lenticular but shows a flat tongue-like projection to the right. When fitting the 850 g McDowell mass into the right part the whole mass assumes a normal slightly conical form. Scale in centimeters.

While the smaller specimen apparently has never been examined the 3 kg specimen has been analyzed and described by several authors. Nininger (1940b) noted the heavy plastic deformation of the kamacite lamellae, and Perry (1944) gave 8 photomicrographs, in addition to the first ones published in 1939.

COLLECTIONS

North Carolina State Museum, Raleigh (400 g, half of the 1923 mass), Washington (322 g, other half). Washington (1,780 g of the 1918 mass), Chicago (240 g), Ann Arbor (119 g), Harvard (79 g), New York (68 g), Tempe (60 g) London (51 g).

DESCRIPTION

The 3 kg specimen is turtle-shaped with a thickness of 5 cm and a width and length both equal to 15 cm. At one edge there is a flat, flange-like projection, about 6 x 8 cm in area and 1 cm thick. Interestingly enough, the 850 g mass, which is about 11 x 6 x 3.5 cm, fits fairly well into the 3 kg specimen's wedge and flange, whereby the full mass becomes considerably more regular and shaped as a low, flat cone. It is difficult to determine whether the mass fragmented late during the atmospheric entry or was split by the finder. If the latter is the case, it was not recorded; and the individual fragments reached collections through different channels and at somewhat different times, as mentioned above. That the original finder of the 3 kg mass did make an attempt to split it is evidenced by the 8 cm long and 5 mm deep heavy chisel mark in the flange. Estimating from the corrosion present on the cleavage faces, the present author is inclined to conclude that the two masses were found independently at some distance and that only the larger mass was somewhat scarred by hammering and chiseling.

While all the natural surfaces and the cleavage faces are covered by 0.5-2 mm thick oxide-shales and display exfoliation along some of the octahedral planes, the flat rear side is less weathered and still preserves the deepest layers of the fusion crust. As Perry (1939b; 1944) pointed out, there are several 1-5 mm wide pockets of dendritically solidified metal. Their detailed structure is complex; they consist of incomplete spherules, 1-5 mm in diameter, which in irregular ways protrude into the meteoritic material and normally show concentric solidification structures. The spacing of

WOOD'S MOUNTAIN – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Gonyer in Perry 1939b	8.27	0.34	0.02		300		200					
Moore et al. 1969	8.22	0.40	0.05	425	100		170					
Schaudy et al. 1972	8.13								2.39	0.143	2.4	

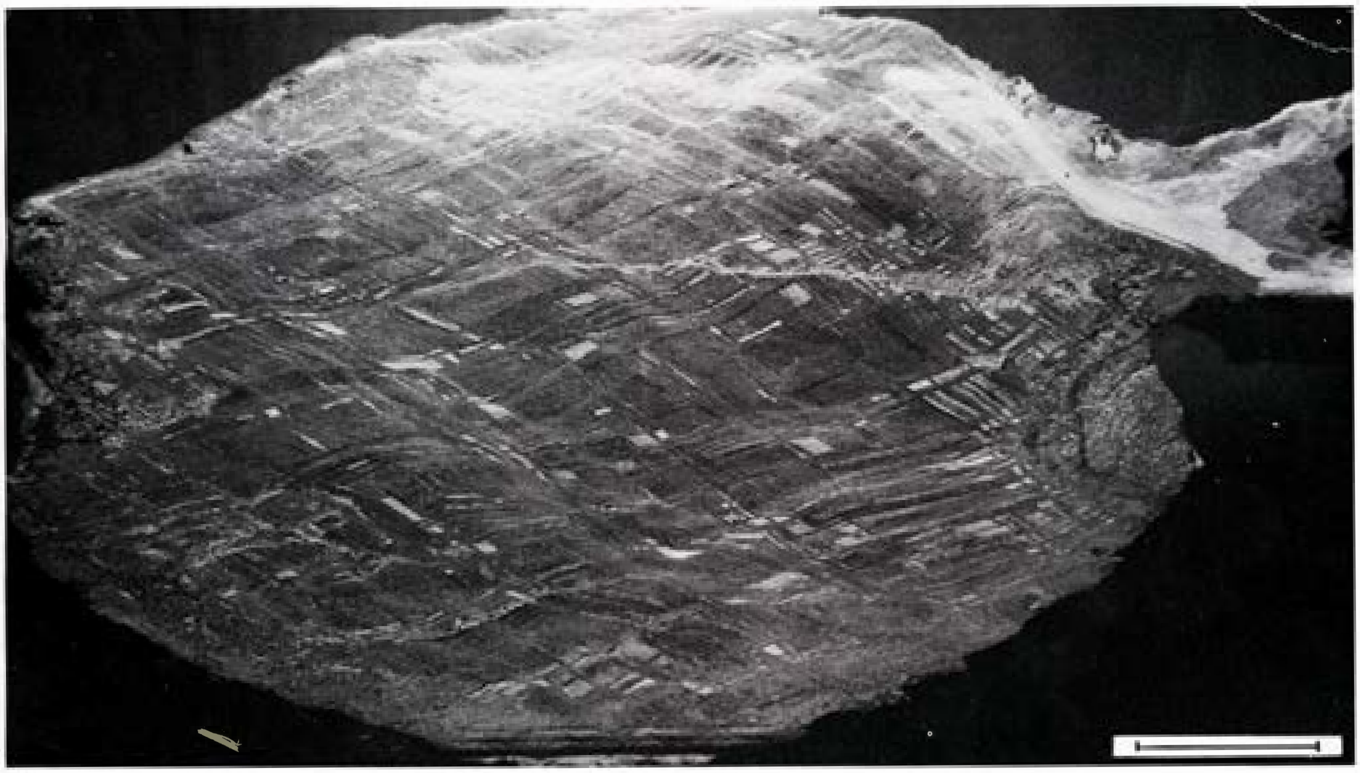

Figure 1981. Wood's Mountain (U.S.N.M. no. 1271). Full section through the 3 kg mass. The meteorite is violently worked by cosmic forces. Etched. Scale bar 20 mm.

the dendrite arms is 2-5 μ, indicating a rapid solidification. There are intercalated layers, and spherules of magnetic oxides; but in addition, various terrestrial corrosion products occur and blur the picture. It appears, however, that the structures represent ablated metal deposited on the relatively well-protected rear side of an oriented meteorite, similar to those discussed under Arlington, Durango, Jamestown, Sandtown, Seneca Township and others. The heat-affected α_2 zone is irregularly preserved as up to 2 mm thick rims which, at low magnification, stand out as light-etching areas. The hardness of the α_2 phase is 205±15. It drops to 180 at the transition to the interior, which shows a wide range in hardness, 180-255 (hardness curve type IV).

Etched sections display a fine Widmanstätten structure of distorted, long ($\frac{L}{W} \sim 30$) kamacite lamellae with a width of 0.30±0.05 mm. The pattern belongs to the most undulating known in meteorites, and the lamellae are displaced by shear in many places. The kamacite is recrystallized to an aggregate of 25-100 μ ferrite grains. Where the shear has been most violent, long subparallel zones, 100-200 μ wide, have recrystallized to grains only 2-10 μ in diameter. In all grain boundaries there are numerous 0.5-2 μ wide taenite blebs, and the boundaries themselves resemble double-lined ditches at high magnifica-

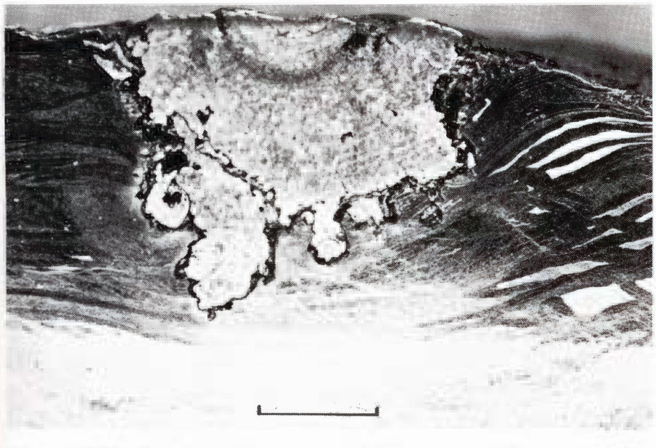

Figure 1982. Wood's Mountain (U.S.N.M. no. 1271). A typical whirlpool intrusion developed on the rear side during atmospheric flight. Part of the deformed Widmanstätten pattern was already present, caused by an earlier cosmic event. Etched. Scale bar 2 mm. (Perry 1939b: plate 5.)

Figure 1983. Wood's Mountain (U.S.N.M. no. 1271). Detail of a whirlpool intrusion, showing dendritic metal solidified in concentric rings. Black denotes terrestrial corrosion products. Etched. Scale bar 200 μ. (Perry 1939b: plate 6.)

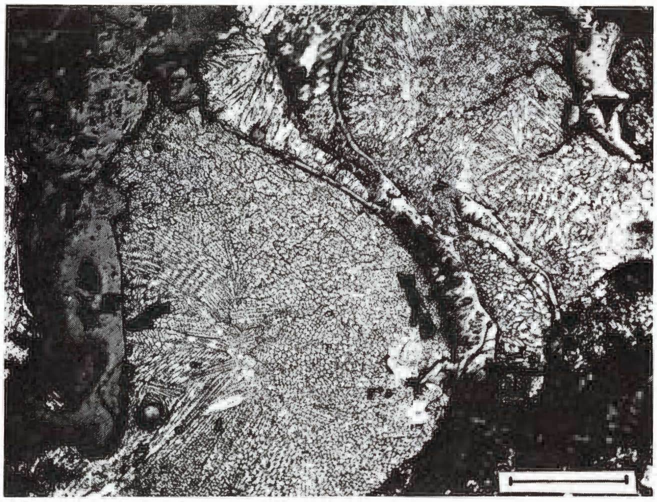

Figure 1984. Wood's Mountain (U.S.N.M. no. 1271). Detail of a whirlpool intrusion showing rapidly solidified metal with dendritic-columnar growth. Magnetite and wüstite are also present; most of the black oxides are, however, colloform limonite from terrestrial corrosion. Etched. Scale bar 80 μ. (Perry 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±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 microscale. 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 centimers 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 loccated 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 μ 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.

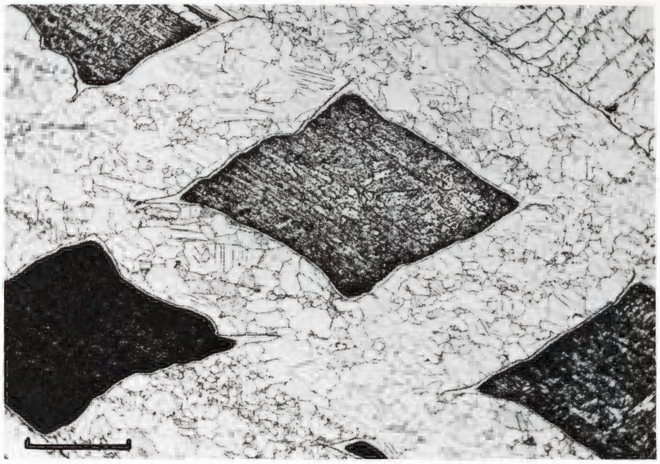

Figure 1985. Wood's Mountain (U.S.N.M. no. 1271). A fine octahedrite of group IVA. The plessite fields are annealed and the kamacite lamellae are recrystallized. In the recrystallized grains is a new generation of Neumann bands. Etched. Scale bar 200 μ. (Perry 1950: volume 5).

Daubreelite occurs as 10-100 μ wide, brecciated bars in the troilite. Rhythmic intergrowths of troilite and daubreelite in parallel 1 μ 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)

Wooster, Ohio, U.S.A.

40°46'N, 81°57'W; 300 m

Medium octahedrite, Om. Bandwidth 1.00±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