the genuine Widmanstätten kamacite spindles; and (iv) decomposition of the remaining austenite to a well defined, duplex $\alpha + \gamma$ mixture, probably via an intermediate martensitic stage, as suggested by the appearance of the plessite areas under low magnification. After the full formation of all structural details a shock event created the Neumann bands and micromelted the shock-absorbing, compressible troilite inclusions.

Cowra is a well preserved, plessitic octahedrite which somewhat resembles Ballinoo, Perryville, Wiley, and Corowa. The details of the structure are, however, different, which is in harmony with the fact that the Ni-Ga-Ge determinations of Lovering and Wasson have also placed Cowra apart from the others. As discussed on page 583, Cowra also resembles Gay Gulch but the two irons turn out to have somewhat different chemical composition.

Specimen in the U.S. National Museum in Washington:
61 g slice (no. 733, 6.5 x 5 x 0.3 cm)

Coya Norte, See North Chile

Cranberry Plains, Virginia, U.S.A.
37°13′N, 80°44′W; 550 m

Fine octahedrite, Of. Bandwidth 0.35±0.05 mm. α_2 structure. HV 200±10.

Probably group IVA, related to Duel Hill (1854). About 9.5% Ni and 0.2% P.

All specimens in collections have been artificially reheated to about 1000° C.

HISTORY

Nothing is known of the history and original size of this meteorite. It was briefly listed as Cranberry Plains, Poplar Hill, Virginia by J.L. Smith (1876b: 4), who reported the discovery year as 1852. It was further listed by Meunier (1884: 116) as "Poplar Camp" and by Brezina (1885; 1896) as "Cranberry Plains, Popolar Hill, Virginia." The present "Poplar Hill" in Giles County, which probably is the same locality, has the coordinates given above. Cranberry Plains was a small village of 75 inhabitants, which is marked on Rand McNally's Atlas (1882: 468) in Carroll County about 9 km northwest of Hillsville. The date of find is variously given as 1877 (French catalogs) and 1852 (Smith 1876b; Brezina 1885; Huntington 1886). Only 89 g was known when Wülfing compiled his catalog (1897).

Huntington (1886: 300; 1888: 70 and plate 2) discussed the distorted Widmanstätten structure of the Harvard specimen. He assumed that the kamacite lamellae crystallized from a melt and that the peculiar morphology reflected some original, high temperature stress and flow conditions. Cohen (1905) concluded on the basis of Huntington's descriptions that Cranberry Plains was a fine octahedrite related to Putnam County and Chupaderos. Farrington (1915) reviewed the literature.

COLLECTIONS

Very little is known. Harvard (29 g), Yale (22 g), Paris (16 g), Washington (7 g), New York (7 g), Amherst (7 g), Chicago (1 g).

ANALYSIS

None is available. Based upon structural observations, the author would estimate the nickel and phosphorus content to be 9.5±0.2% and 0.2±0.02%, respectively, with trace elements placing it in group IVA.

DESCRIPTION

The Washington specimen is a small hammered fragment with no visible fusion crust or regmaglypts. It has suffered so much beating that it is partially split along octahedral, schreibersite-filled lamellae.

The etched section displays a fine Widmanstätten structure with slightly curved long ($\frac{L}{W} \sim 40$) α-lamellae which have a width of 0.35±0.05 mm. It is no longer possible to state whether Neumann bands or ϵ-structure originally were present, since all ferrite is converted to 25-50 μ serrated α_2 grains, due to artificial reheating above 800° C. Original subboundaries in the lamellae are still faintly visible because they were decorated by $<1\ \mu$ phosphide precipitates.

Plessite occupies 40-50% by area. The taenite is diffuse and has blurred, scalloped edges with thorns protruding into the present α_2 phase. The taenite has evidently been heated to a temperature of about 900-1000° C, whereby it started to dissolve in the matrix. Before complete resorption took place the iron was again cooled.

Schreibersite was originally present as 20-50 μ grain boundary precipitates, as 5-20 μ angular bodies in the plessite interior, and as an occasional 100 x 200 μ crystal. All phosphides have been remelted and partially resorbed, which means that the temperature has been about 1000° C for some time.

Troilite and other meteorite minerals were not observed.

One more indication of artificial reheating is found by examination of the surface zone. Instead of normal corrosion products there are complex pearlitic intergrowths of metal, oxides and sulfides. An oxidation attack, which has penetrated about 50 μ along the high temperature austenite boundaries, can only be interpreted as having taken place while the specimen was in the austenite region (above 800° C) under oxidizing conditions. It appears thus that Huntington's observations may better be interpreted as the result of a blacksmith's work than of some cosmic event.

Cranberry Plains is a fine octahedrite of the Chinautla type. Its structure is severely damaged by man and apparently only little survived the forging, when a blacksmith divided the mass in the nineteenth century. A remote possibility that it is a fragment of Duel Hill (1854) should be checked on some occasion.

Specimen in the U.S. National Museum in Washington:
7.5 g fragment (no. 1005, 22 x 20 x 2mm)

Cranbourne, Victoria, Australia

38°9'S, 145°17'E; 30m

Coarse octahedrite, Og. Bandwidth 2.2±0.5 mm. ε-structure and Neumann bands. HV 305±15.

Group I. 7.02% Ni, 0.50% Co, 0.26% P, 85 ppm Ga, 358 ppm Ge, 1.8 ppm Ir.

HISTORY

Since the first two large masses of 3.5 and 1.5 tons were found about 1853 in the coastal, swampy lowlands 50 km southeast of Melbourne, at least nine other masses have been added, bringing the total known weight of the Cranbourne shower up to 8.5 ton.

The first reports in European journals (Hochstetter 1861; Haidinger 1861a, b) aroused considerable interest, since the irons were considerably larger than anything hitherto known (the Otumpa iron of the Campo del Cielo shower and the Pallas iron, Krasnojarsk, both about 700 kg, were, until then, the largest in collections). The former mineral dealer A.T. Abel from Hamburg acquired the 1,500 kg mass (No. 2) and sold it to the British Museum. A few years later it was donated to the National Museum in Melbourne in exchange for the larger mass (No. 1) which, eventually, had been removed from its finding site through the efforts of the owner, James Bruce, and the Geological Survey of Victoria. Several small pieces of the order of kilograms had been detached at an early date from the large masses and came into circulation under various synonyms such as Dandenong, Yarra Yarra River and Western Port, all referring to nearby place names. One protruding edge on the 3.5 t mass had been chiseled off by Fitzgibbon in 1854 and forged into one or more horseshoes (Haidinger 1861a,

Figure 678. Cranbourne (Prague no. 93). A weathered sample which, however, exhibits the coarse octahedral structure very well. Perhaps cut from the 75 kg Beaconsfield mass. Deep-etched. Scale bar 30 mm.

Meteorite	Original Mass kg	Year Found	Approximate Place of Find °S	°E	Present Location of Main Mass
Cranbourne No. 1	3,500	1853	38°9′	145°17′	British Museum, London
Cranbourne No. 2	1,500	1853	38°7′	145°20′	National Museum, Melbourne
Cranbourne No. 3	6.8	1857	38°9′	145°17′	Lost
Cranbourne No. 4	1,250	1923	38°8¾′	145°17′	National Museum, Melbourne
Cranbourne No. 5	350	1923			Victorian Mines Department, Melbourne
Cranbourne No. 7	150	1923	38°8¾′	145°17¼′	Geology Department, University of Melbourne
Cranbourne No. 8	24	1923			Victorian Geological Survey, Melbourne
Cranbourne No. 6 = Pakenham	40.5	1928	38°3′	145°26′	Victorian Geological Survey, Melbourne
Beaconsfield No. 9	75	1876	38°4′	145°24′	Probably widely distributed
Langwarrin No. 10	914	1886	38°11½′	145°14′	National Museum, Melbourne
Pearcedale No. 11	750	1903	38°10½′	145°13½′	U.S. National Museum, Washington

b; Walcott 1915). Flight (1882) described the minerals with several analyses and photographs of the exterior of the masses, and Haidinger also presented several pictures.

Cohen (1897b) described with excellent analyses a new mass of 75 kg, called Beaconsfield. Walcott (1915) gave the history up to his time with many new details and suggested that the five irons then known were all part of a shower falling along a line trending S30°W.

The Pearcedale mass of 750 kg was found in 1903 by E.W. Monro just below the surface in sandy, saline soil, 2 km north-northwest of Pearcedale, 5 km east-southeast of Langwarrin Station. According to the accession papers in the U.S. National Museum, it was bought from Mr. Monro in 1938 and for about 5 years was stored in the basement of the Smithsonian Institution. Although it "was in splendid physical condition" during the years 1903-1938 in its native country, it soon started to disintegrate in Washington. In an attempt to stop the decay the mass was moved into the open court about 1945. The several years outside may have helped to wash out the superficially absorbed chlorine compounds. Upon inspection in 1970, the mass showed large flaky shales, 0.5-3 cm thick, which could be peeled off by hand, but it appeared that the major attack had been checked. The mass measures 65 x 60 x 52 cm, and shows several reentrant portions; a large cavity is 8 cm deep and 14 cm in diameter.

Many other large Cranbourne specimens are violently corroded and very special precautions have been taken in some cases to preserve them (Bannister 1937).

Edwards & Baker (1942) gave a thorough description of the 40.5 kg Pakenham meteorite, and in 1944 they issued a review paper with a detailed map of the distribution of the then-known 10 masses. They reported that the No. 2 mass rusted considerably less than other specimens they knew of, although the chemical composition and structure were the same. They further stated that the general area "is distinctly swampy during some periods of the year, as evidenced by the records of the Victorian Mines Department, and the subsoil is saline, carrying as much as 0.1% of sodium chloride."

In the table above a summary of the distribution of the masses is given. Based upon the descriptions in previous papers (Haidinger 1861a, b; Walcott 1915; Edwards & baker 1944) a complete set of coordinates has been worked out with the aid of modern maps. The opinion of Walcott and others as to the linear distribution is fully confirmed, except that the line has widened to a narrow ellipse 23 km long and about 2 km wide. The distribution is interesting because the original localities for numerous other shower producing-irons, like Chupaderos, Coahuila, Gibeon and Arispe, are only known approximately because of man's early removal of the masses. The distribution may perhaps best be explained if we imagine a large, plate-shaped mass (4 x 3 x 0.5 m ?) coming obliquely into the atmosphere. The decelerating forces will create a momentum that will break up the plate; and, while the main central portion will continue more or less as the center of gravity, the peripheral parts may land in front of or far behind the central part because of slight differences in momentum and rotation. The distance between the cluster of large and small chunks (Nos. 1, 3, 4, 5, 7, 8, totaling 5.3 t) and the front runners (Nos. 10, 11, totaling 1.7 t) is about 5.5 km, while the distance between the cluster and the rear mass (No. 2 of 1.5 t) is about 6.5 km. Far back are Nos. 6 and 9, totaling 115 kg, about 18 km northeast of the main cluster. This interpretation is, of course, very tentative, if for no other reason than because we do not know how much more material will be found when systematic investigations with mine-detecting devices are commenced.

Lovering & Parry (1962) included Cranbourne in their thermomagnetic phase analysis, and Reed (1965a, b) reported the detailed composition of kamacite, taenite and schreibersite. Chang & Wänke (1969) measured the pair $^{10}Be/^{36}Cl$ and found the high terrestrial age of 180,000 years presented, however, with a very high uncertainty limit. The cosmic ray exposure age was found to be 45±15 million years by the $^{36}Ar/^{10}Be$ method.

COLLECTIONS

Apart from the large masses, the following material is in collections. Of Beaconsfield: Chicago (nos. 499 and 1159, 1,028 g), Paris (681 g), Vienna (670 g), Vatican

CRANBOURNE – SELECTED CHEMICAL ANALYSES

Reliable analyses of isolated inclusions of schreibersite, rhabdite, troilite, cohenite and taenite were performed by Sjöström (Cohen 1897b), and this work has been confirmed by modern microprobe techniques. Further analytical work is summarized by Edwards & Baker (1944). The data in line 2 above are averages of their determination on Nos. 4, 5, 6, and 7.

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Cohen 1897b, No. 9	7.34	0.48	0.26	500	400		200					
Edwards & Baker 1944	6.74	0.53	0.25									
Lovering et al. 1957,												
No. 9	7.18	0.48				4	119		79	262		
No. 10	7.05	0.51					194		80	343		
Smales et al. 1967						8.3	123		74	316		
Wasson 1970a	6.80								85.4	358	1.8	

(555 g) Prague (509 g), Uppsala (412 g), Copenhagen (365 g), Ottawa (244 g), Berlin (236 g), Washington (124 g). Of Cranbourne Nos. 1 and 2: Sydney (4,300 g), London (3,400 g), Budapest (3,360 g), Vienna (1,100 g), Washington (230 g). Of Cranbourne unspecified: New York (1,600 g), Harvard (1,170 g), Leningrad (680 g), Göttingen (360 g), Yale (257 g), Oslo (218 g).

DESCRIPTION

Most of the irregular, angular blocks were covered with heavy limonitic crusts. For example, the Beaconsfield mass weighed 75 kg when found; but, when all scales had been removed by chiseling, the weight had decreased to 53 kg (Cohen 1897b). The original fusion crust and heat-affected α_2 zone are, therefore, probably lost on all specimens.

Etched sections vary considerably in appearance. First of all, it appears that the masses are, in fact, polycrystalline, since boundaries between original 20-30 cm austenite crystals may be seen in some sections, e.g., Prague no. 93. The individual austenite grains, particularly the cohenite-rich portions, show a well-developed Widmanstätten structure with bandwidths of about 2.0 mm. Other inclusion-poor sections are rich in bulky, short, irregular lamellae of widths increasing to 3 and 4 mm. The ferritic grain growth has even locally produced equiaxial grains 6-10 mm in diameter. Heavy shock has produced the hatched ϵ-structure (in a Beaconsfield specimen), typical of shock intensities above 130 k bar and similar to the ϵ-structure observed in Magura. The ϵ-structure is shock-hardened to 305±15. But other individuals appear to be unshocked, since Jaeger & Lipschutz (1967b) found only unshocked kamacite in the unspecified Cranbourne specimen they studied. Perhaps they inadvertently examined some of the artificially reheated specimens known to exist; see, e.g., page 511.

Plessite occurs in varying amounts from about 1 to 5% by area. It is developed as comb plessite or it may have acicular or martensitic interiors. The 40 μ wide, tarnished taenite ribbons have hardnesses of 480±20.

Schreibersite is common as scattered hieroglyphic and skeleton crystals, 1-5 mm in size. They are monocrystalline and somewhat brecciated; further as 20-60 μ wide grain boundary precipitates and as inclusions of the same general size in the cohenite. Rhabdites 1-25 μ in diameter are ubiquitous.

Troilite is irregularly distributed as 1-5 cm nodules. One lenticular nodule isolated from Cranbourne No. 1 or No. 2 measures 5 x 3 x 2 cm. The nodules display various proportions of troilite and graphite and are sheathed in 1-2 mm schreibersite rims and a little cohenite. A 20 x 11 x 5 mm nodule (U.S.N.M. no. 89) shows a monocrystalline troilite that, along fracture zones, is recrystallized to 10-200 μ units. A 0.4 mm broad fissure is filled with angular fragments of schreibersite, cohenite and graphite. The nodule is enveloped in successive shells of 250 μ graphite, 200 μ schreibersite and 200 μ cohenite, but corrosion has destroyed part of the rim. The graphite is composed of sheaves with horsetail extinction which locally approaches a cliftonitic shape. In other places the troilite is intimately mixed with graphite and 5-10 μ angular daubreelite grains, as if remelted by shock heating. Terrestrial corrosion has created a dense net of 2-5 μ wide pentlandite veinlets everywhere in the troilite. The troilite has a hardness of 245±15.

Cohenite occurs as 3 x 0.8 mm irregular, lobed bodies centrally in the α-lamellae. They are monocrystalline and have the usual inclusions of α- and γ-phase and schreibersite. The cohenite crystals always appear in clusters of several cm^2 closely associated with taenite. No graphite was detected in the cohenite. Its hardness is 1150±30.

The four phosphide types described by Edwards & Baker (1942; 1944) are, in fact, schreibersite, rhabdite and cohenite in various configurations with each other and with troilite.

Cranbourne is one of those iron meteorites that deteriorates rather rapidly under room conditions, while it evidently may survive for thousands of years in nature. Traditionally the cause has been ascribed to the presence of the allegedly cosmic mineral lawrencite, $FeCl_2$, first mentioned by J.L. Smith (1855). However, to my knowledge the solid lawrencite mineral has not been adequately described. Whenever lawrencite is mentioned, it appears to be an extrapolation from the observation of small, greenish droplets on freshly prepared surfaces. I have examined many irons in search of the mineral, have dry-cut specimens supposed to contain lawrencite and polished them under kerosene in order not to wash out the mineral; but I have never been able to find it, neither under the microscope, nor under the microprobe, and I have gradually become convinced that the cosmic mineral lawrencite does not exist in iron meteorites. That chlorine is present on a high level in Cranbourne and many other rapidly deteriorating meteorites is, however, beyond reasonable doubt. Cohen (1897b) thus found 0.51% Cl in solution after having washed 457 g Beaconsfield fragments with water. Many other reports testify to the same result on other corroded meteorites. Now, as stated on page 509 the sandy, swampy soil southeast of Melbourne is very rich in chlorine, and it appears to me that the chlorine found in the analyses might be derived from saline ground water that has gradually penetrated the meteorite, particularly along grain and phase boundaries in the coarse-grained octahedrites. A heavily corroded iron, therefore, is either an old fall or was buried in a particularly strongly saline soil, or both. The depth of burial, the local humidity and other climatic conditions, as well as the porosity and substance of the various soils and rocks in direct contact with the iron mass, will, of course, play a significant role in the corrosive attack. The local availability of oxygen, which may vary on the iron from one face to another, may be expected to have a decisive influence on the corrosive attack. Although we are far from understanding the details of the destruction of the irons, it is probably wiser to think in terms of terrestrial salinity than invoking a hypothetical cosmic iron chloride which has never been isolated.

Cranbourne is an inclusion-rich coarse octahedrite with the usual variation in structure between cohenite-rich and -poor parts. The analyses do, in part, reflect this variation. Cranbourne appears to display both Neumann bands and ϵ-structure in different specimens of the shower. It is similar to such well known group I irons as Canyon Diablo, Magura and Youndegin.

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

25 g fragments, heated in hydrogen (no. 88)
71 g troilite nodule (no. 89, 5 x 3 x 2 cm)
123 g slice, Beaconsfield (no. 537, 7 x 4 x 0.7 cm)
Various fragments, shales, heated pieces (nos. 814, 1006, 2737, 3394)

Cratheus (1931), Ceará, Brazil

Approximately 5°10'S, 40°39'W

Fine octahedrite, Of. Bandwidth 0.30±0.05 mm. Reheated and showing an anomalous, duplex $\alpha + \gamma$ structure. HV 200±15.

Group IVA. 7.72% Ni, about 0.05% P, 2.19 ppm Ga, 0.11 ppm Ge, 2.3 ppm Ir.

HISTORY

The name Cratheus has been applied to two different meteoritic irons; they will here provisionally be called Cratheus (1931) and Cratheus (1950), referring to the date when they were first described in the literature.

Cratheus (1931) was briefly mentioned by Oliveira (1931) in his catalog of Brazilian meteorites. He noted that a mass of 27.5 kg had been purchased in 1914 by the Geological Survey in Rio de Janeiro, and he gave a photograph of a deep-etched section, which serves to establish the identity of the meteorite. The only other information is by Andrade (1931), who presented an analysis and stated that the mass came from Cratheús, in the state of Ceará. Cratéus is a town with the coordinates given above.

COLLECTIONS

Geological Survey, Rio de Janeiro (27.5 kg), Canberra (74 g), London (47 g), Washington (42 g).

ANALYSES

Andrade (1931) found 7.41% Ni and only traces of other elements, defining Cratheus as a very pure iron-nickel alloy. From structural observations, the present author would expect 7.8±0.2% Ni, 0.4% Co and about 0.05% P with a trace-element composition corresponding to group IVA. When I discovered that there were two different meteorites hidden under the name Cratheus, I asked Dr. Wasson to perform analyses on selected specimens of material which I had already examined. His results confirmed my conclusion: see below.

DESCRIPTION

The small specimens in U.S. National Museum and London are slices with original surface. There are no fusion crusts and no heat-affected α_2 zone. Corrosion appears to have attacked the mass rather evenly and consequently has removed at least several millimeters of the surface. There are no definite indications that the mass has been artificially reheated as might be suspected from the very unusual microstructure described below.

An etched section displays a regular, fine Widmanstätten structure of straight, long ($\frac{L}{W} \sim 40$) α-lamellae 0.30±0.05 mm wide. Plessite occupies about 50% by area and is mainly developed as comb plessite, repeating the gross Widmanstätten pattern, and as fine-grained, duplex $\alpha + \gamma$ structures.

Schreibersite does not occur, not even as minute grain boundary precipitates, and rhabdites were not observed. The total phosphorus content must, therefore, be well below 0.1%, and possibly similar to that of Charlotte or Gibeon.

Troilite is not present in the U.S. National Museum specimen but occurs as a few 1-2 mm blebs on the London sample. They are apparently shock melted. Tiny, 25-50 μ, angular, bluish chromium sulphides occur scattered in the α-lamellae.

Most interesting are the indications of a late cosmic reheating. The normal kamacite phase of the lamellae has given way to a duplex, fine-grained structure of 1-3 μ slightly oriented γ-grains in a matrix of α. The α appears to have "recrystallized" to serrated 10-25 μ wide irregular grains, and no trace of original Neumann bands, if ever present, can be found. The hardness is 200±15.

The taenite rims of the plessite fields have scalloped, blurred edges, and the interior of the plessite fields displays the same duplex structure as the Widmanstätten lamellae. It is, in fact, often difficult to distinguish the fine structure of the lamellae from that of the plessite interiors. The taenite lamellae, 30-50 μ wide, have a hardness of 230±8.

A possible interpretation of the very unusual structure seems to be that, after an initial normal cooling, a cosmic reheating to 600-700° C occurred, whereby "isothermal" taenite could nucleate. Before excessive growth could take place the heat source disappeared and rather rapid cooling prevented the original structure from reappearing. Similar structures have been experimentally produced by Brentnall

CRATHEUS (1931) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Schaudy et al. 1972	7.72								2.19	0.108	2.3	

& Axon (1962) and Staub et al. (1969). Similar reheated structures are also present in a few other meteorites, notably Karasburg.

The Cratheus material in the U.S. National Museum is thus a Gibeon type meteorite (group IVA), with anomalous "isothermal" taenite from a late reheating event. The London specimen appears to be similar.

The specimen, which Curvello (1950b) described and analyzed as Cratheus, is very diffferent and will be treated separately as Cratheus (1950).

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

42 g part slice, now subdivided (no. 1295, 4 x 3 x 0.3 cm) Received in 1938 from Dr. E. de Oliveira, Museu Nacional, Rio de Janeiro.

Cratheus (1950), Brazil ?

Coordinates unknown

Plessitic octahedrite, Opl. Spindle width 60±15 μ. Neumann bands. HV 175±5.

Group IIC. 8.96% Ni, about 0.3% P, 36 ppm Ga, 91 ppm Ge, 9.5 ppm Ir.

HISTORY

No historical data are available. When Curvello (1950b) described the metallography of the meteorite he assumed that his material came from the Cratheus mass of 27.5 kg listed by Oliveira (1931: 49). During this study, I discovered that Curvello and Oliveira's photomicrographs must be from two different masses and asked permission to borrow Curvello's material. He had only 20 g left which he lent me and Dr. J.T. Wasson, who performed an analysis. The reexamination establishes beyond doubt that Cratheus of Oliveira and Cratheus of Curvello are widely different, one being a Gibeon-type, the other a Ballinoo-type. Whether a mix-up has occurred can not be disclosed at this date. It is proposed to call Curvello's material Cratheus (1950) until more information becomes available. Whether an old report by Berwerth (1916: 271) refers to this material is uncertain. Berwerth's informer, Jorgo de Arayo-Ferraz, assumed that the mass was found in 1909 in the state of Espirito Santo and was preserved in Museu Nacional in Buenos Aires, in Brazil (sic!).

COLLECTION

About 20 g in Curvello's possession. On a brief visit to the Museum of Natural History in Rio de Janeiro in March 1973, I reidentified at least one major piece of this meteorite: it weighs 347 g and carries the number 64 Mt. Further, the label states, "Found in 1909," and indications are that the (unspecified) main mass is presently in the collection of the Brazilian Geological Survey.

DESCRIPTION

The examined specimen is a corner, 14 x 14 x 13 mm in size, with some crust. It is slightly weathered, and the fusion crust and heat alteration zone are lost. The etched section shows that the mass belongs to the rather rare group of plessitic octahedrites comprising, among others, Ballinoo, Kumerina and Unter Mässing. The alpha phase forms discrete spindles with a width of 60±15 μ, and the length:width ratio is about 15. The kamacite has subboundaries and Neumann bands, and the hardness is 175±5.

Schreibersite occurs evenly dispersed as 20-50 μ wide, branching, frequently polycrystalline crystals. The largest seen was 2 x 0.04 mm in the section. Schreibersite is also common as 1-10 μ blebs in the plessite. Troilite is rather common as 20-400 μ monocrystalline units. They show fine twinning due to slight plastic deformation. Pentlandite is absent. Chromite occurs as 50-150 μ euhedric crystals that have served as a substrate for troilite and schreibersite precipitates. Zones of swathing kamacite, 50-200 μ wide envelop the troilite, chromite and larger schreibersite crystals.

The plessitic matrix covers about 60% by area, mainly as an easily resolvable, but dense-meshed net plessite. There are 10-50 μ black-etching, unresolvable plessite wedges and islands and, also, numerous 10-25 μ wide crisscrossing α-spindles. The annealing effects present in Ballinoo are not seen in Cratheus (1950).

A comparison with the other plessitic octahedrites reveals with certainty that Cratheus (1950) is different from Ballinoo, Britstown, Perryville, Salt River and Wiley. On the present evidence it could not be distinguished from Unter Mässing and Kumerina. These irons are, however, very little distributed, so it appears unlikely that Cratheus

CRATHEUS (1950) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Curvello 1950b	8.94											
Wasson 1970, pers. comm.	8.97								36.3	91.4	9.5	

(1950) is a mislabeled fragment from one of these. The most plausible solution is that Cratheus (1950) is an independent iron of which we have, for the time being, lost track of the main mass and the early history.

Cruz del Aire, Nuevo Leon, Mexico
26°33'N, 100°10'W

Fine octahedrite, Of. Bandwidth 0.48±0.08 mm. Partly recrystallized. HV 175±10.

Anomalous. 9.11% Ni, 0.50% Co, 0.31% P, 38.2 ppm Ga, 186 ppm Ge, 5.9 ppm Ir.

HISTORY

A mass of 15.1 kg was found 1911 near the Cruz del Aire mine in the state of Nuevo Leon. It was acquired by the American Museum of Natural History in 1912, and briefly mentioned by Hovey (1912). Mac Naughton (1926) assumed it to be a Coahuila mass. Another mass of 7.8 kg was found in 1930 in Cerro Chico de Santa Clara, and was acquired by the University of Arizona and described with figures by Heineman (1932). He correctly pointed out that the two masses belonged to the same parent mass, a fine octahedrite. Reeds (1937) agreed and gave a few additional notes. The place of find is "near" Sabinas Hidalgo, which has the above given coordinates. It is not clear how far apart the two individual fragments were found.

COLLECTIONS

The 1911 mass is almost undivided in New York (15,010 g). The 1930 mass has been somewhat distributed: Tucson (5.84 kg main mass), Tempe (660 g), Washington (350 g), Chicago (217 g), Harvard (198 g), Ann Arbor (146 g).

DESCRIPTION

The 15.1 kg mass has the approximate dimensions 28 x 21 x 8 cm, but it is very irregularly lobed in shape, as seen from Heineman's Figure 5. The 7.8 kg mass is irregular, angular and has the overall dimensions of 27 x 12 x 8 cm. Both fragments are coated with 0.1-1 mm oxides. Adhering caliche is found on the underside in several places. The overall morphology with 2-5 cm regmaglypts of varying depths is, nevertheless, mainly the result of atmospheric sculpturing, as evidenced by the heated α_2 zone which is partially preserved as a 0.1-1.0 mm rim along some edges. It has a hardness of 190±10. The hardness decreases to about 155 in a recovered transition zone and then increases to the true interior value of 175±10 (hardness curve type II).

Etched sections show a beautiful Widmanstätten pattern of long ($\frac{L}{W} \sim 25$) isolated lamellae with a width of 0.48±0.08 mm. While the lamellae are generally straight, they are slightly bent in some portions near the surface. These areas, no doubt, indicate where the torsional fracture occurred, with some necking, during the atmospheric breakup. The schreibersite crystals are brecciated and show boudinage structures, and the plessite fields are distorted. The kamacite hardness increases correspondingly to 240±10. Plessite occupies about 40% by area, particularly in form of comb plessite with well-spheroidized interiors. In the plessite there are numerous 5-20 μ irregular schreibersite bodies which display diffuse 1 μ wide taenite rims gradually merging into adjacent massive taenite.

Neumann bands are present in varying amounts. They are partly resorbed, since recrystallization to 20-100 μ new ferrite grains are in progress everywhere, but especially around the schreibersite inclusions. In the ferrite phase are numerous rosy 0.5-1 μ particles which may be a nickel-rich austenite phase, left when former rhabdite crystals decomposed upon reheating by sending phosphorus out in the matrix in solid solution. In the grain boundaries of the recrystallized ferrite there are numerous vermicular 0.5 μ wide and 2-5 μ long phosphide precipitates.

Schreibersite is abundant centrally in the α-lamellae as 0.5 mm wide irregular nodules of varying lengths. Indications are that several, apparently independent, bodies belong to the same aggregate as fingers upon a hand. They are monocrystalline but brecciated. Schreibersite is further common as 10-30 μ grain boundary precipitates and as irregular 5-30 μ bodies inside the plessite fields. The amount of phosphides corresponds well to the analytical value of 0.3% P. Most of the schreibersite bodies have quite irregular edges, mainly because some of the phosphide has been dissolved and redeposited as irregular blebs during a short reheating plus cooling cycle.

Troilite is fairly common as small scattered nodules 0.1-0.5 mm in diameter. They have irregular rims of 100-200 μ schreibersite precipitates. Some daubreelite is present in the troilite. Sometimes a 1 mm zone of swathing kamacite is developed around the whole aggregate. The troilite itself is an aggregate of 1-2 μ grains in which

CRUZ DEL AIRE – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore & Lewis 1968	9.15	0.49	0.31	45	150		230					
Jarosewich 1969, pers. comm.	9.19	0.50	0.30									
Wasson 1970, pers. comm.	9.00								38.2	186	5.9	

numerous 1-2 μ rounded schreibersite bodies from the fragmented schreibersite rim are embedded.

The combination of rather unusual microstructures suggests that Cruz del Aire was subjected to shock followed by some reheating to about 600° C. Hereby the troilite, acting as shock absorber, melted and trapped some of the surrounding schreibersite. The kamacite started to recrystallize and resorb the rhabdites and the schreibersite edges. But, before recrystallization and resorption gained momentum, a cooling period made phosphides reprecipitate upon existing schreibersite and in the new α-grain boundaries. These events were all preatmospheric. In the atmosphere the breakup resulted in local flow structures and boudinage schreibersite, effects which also locally cold worked the kamacite phase.

Cruz del Aire has a structure that deviates from that of most fine octahedrites by having a larger bandwidth, a smaller $\frac{L}{W}$ ratio and a significant proportion of phosphides. It is assumed that the schreibersite bodies in the center of kamacite lamellae are primary precipitates from the austenite phase from before the Widmanstätten formation. The Ga-Ge-Ir analyses show that the meteorite is anomalous.

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

223 g slice (no. 1441, 12 x 5 x 0.5 cm)
121 g endpiece (no. 1441, 6 x 5 x 1 cm)

Cuba, West Indies

Approximately 20°N, 76° W

Coarse octahedrite, Og. Bandwidth 1.30±0.30 mm. Neumann bands.

No analysis available, but evidently a group I iron similar to Toluca.

HISTORY

Very little is known of this small iron which was briefly and insufficiently described by Solano y Eulate (1872). It appears that a fragment, weighing 1,327 g, from a somewhat larger mass was found in the eastern part of Cuba a long time before 1872 when it was listed as part of the collection of the Museum of Natural History in Madrid. In Navarro's list (1923) of meteorites in Madrid it still figures with 1,297 g. The specimen of 23 g in the U.S. National Museum was acquired through W.W. Pinch, Rochester, N.Y., in 1963 and appears to be authentic material. Ward (1904a) listed 3 g in his own collection; this material is listed as 2.6 g oxidized fragments by Horback & Olsen (1965).

ANALYSIS

The analysis of 1872, showing 3.24% Ni, is erroneous.

DESCRIPTION

The small specimen in the U.S. National Museum allows only a preliminary description. It is a normal octahedrite with well-developed Widmanstätten structure with oriented sheen. The lamellae are irregular and bulky ($\frac{L}{W} \sim 10$) and have an average width of 1.30±0.30 mm, placing the iron in an intermediate position between the classification groups medium and coarse octahedrites. If anything, the true lamella width is larger than 1.3 mm because the tendency is to underestimate the width on small specimens.

Neumann bands are common, and no recrystallization has occurred. The hardness, 210±15, indicates some slight cold-deformation. Taenite and plessite occupy about 15% by area. The plessite has either comb-like, or martensitic, or pearlitic or acicular interior, which is a constellation frequently met with in Group I irons, such as Toluca. The pearlitic decomposition of the austenite to about 0.5 μ subparallel, vermicular lamellae is seen exceptionally well in Cuba. A few of the pearlitic fields have small (100 μ) and imperfect carbide roses, i.e., complex intergrowths of haxonite, taenite and kamacite.

Schreibersite is common. It occurs as 1 x 0.2 mm subangular grains centrally in the α-lamellae, as 25-50 μ grain boundary precipitates and as 5-20 μ irregular bodies in the plessite fields. The schreibersite is somewhat brecciated but monocrystalline. Rhabdites occur everywhere as 1-10 μ tetragonal prisms. The total amount of phosphorus appears to be 0.2-0.3%.

Other minerals were not seen but would probably be found if larger sections were available.

Corrosion has removed all traces of the heat-affected α_2 zone. It has also been active sufficiently long to penetrate deep into the interior and, for example, selectively dissolve the α-iron from the pearlitic plessite fields. The tendency to continued deterioration under museum conditions is pronounced.

It is cautiously concluded that Cuba is a fragment of a larger unidentified mass which has all the characteristics of group I meteorites, particularly Toluca. A reinvestigation and a detailed analysis of the main mass is recommended. The history should be checked in order to confirm that the meteorite really was found on Cuba and is not a transported Toluca mass.

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

23 g part slice (no. 2213, 3 x 1.2 x 0.5 cm).

Cuernavaca. See Chupaderos (Cuernavaca)

Cumpas, Sonora, Mexico

30°0'N, 109°40'W

Medium octahedrite, Om. Bandwidth. 1.20±0.20 mm. ϵ-structure. HV 270±15.

Group IIIA. 8.04% Ni, 0.47% Co, 0.18% P, 0.35% S, 22.0 ppm Ga, 41.4 ppm Ge, 2.2 ppm Ir.

HISTORY

A mass of about 28.5 kg was found in 1903 by a gold prospector in a gulch of Montezuma River between the peaks of the Christobal Mountains east of Cumpas. It was but slightly embedded in soil on land which long ago had been terraced for cultivation and showed ancient Indian ruins. The mass was acquired by the Foote Mineral Company from whence, in 1904, it came to Harvard University. It was, however, first described by Palache (1926a), with an erroneous analysis by Shannon. Palache suggested that Cumpas and Moctezuma were paired falls, but could give no conclusive evidence. Cumpas was included in the study of Thode et al. (1961) on the geochemistry of the sulfur isotopes.

COLLECTIONS

Harvard (24.2 kg), Washington (2.21 kg).

DESCRIPTION

Cumpas is an elongated, loaf-like mass with the average dimensions of 33 x 18 x 17 cm. It is somewhat corroded and has up to 1 mm limonitic crusts locally. Its overall smooth morphology, with a large shallow cavity about 8 cm in diameter at one end, is, however, a result of atmospheric sculpturing. The heat-affected α_2 zone ranges from 0.1-2 mm in thickness, mainly because the exterior part has been removed by weathering. Laminated, metallic ablation melts are present locally as, e.g., 15 x 1 mm shallow pockets of fine-grained dendritic material.

The Widmanstätten structure is beautifully developed with straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae averaging 1.20±0.20 mm in width. A group of broader, swollen bands mentioned by Palache (1926a) is merely the fourth direction of the Widmanstätten lamellae, caused by the meteorite being cut almost parallel to a $\{111\}$ plane. The lamellae are generally fingers with the relative proportions between length, width and height 20:1:3. Therefore, the fourth direction in this case appears as irregular, wavy ribbons, about 25 mm long and 3.6 mm wide.

The kamacite is converted by shock above 130 k bar to the hatched, acicular ϵ-structure with a microhardness of 270±15. No recrystallization has taken place. The hardness ranges from 270±15 in the interior through a minimum of 205 to 220±10 in the heat-affected α_2 zone (hardness curve type I).

Taenite and plessite cover about 30% by area. The comb plessite repeats the Widmanstätten directions as usual. In other fields the taenite appears as angular, often concave, 5-20 μ islands. Schreibersite blebs of the same dimensions frequently substitute for taenite inside the fields.

Schreibersite is further common as 25-50 μ wide grain boundary precipitates. It is heavily brecciated and often displaced 2-5 μ along many subparallel shear zones. Rhabdites are not seen. The overall phosphorus content in the structure is in harmony with the analytical value.

Troilite is conspicuous in the four sections known to the author. On a total of 308 cm^2 there were three nodules larger than 1 cm in diameter and 13 between 1 and 10 mm. The bulk content of the meteorite was calculated to be 0.35% S. Some of the nodules contain angular inclusions of 1-2 mm chromite crystals which are lightly sheared. One 11 mm nodule was surrounded by small satellites of 0.1-1 mm troilite bodies, as is, for e.g., also seen in Gibeon. The troilite is monocrystalline yet densely populated by lenticular twins caused by plastic deformation. Daubreelite covers about 10% by area, most frequently as 1-20 μ wide, parallel lamellae. Shear zones with crushed troilite are common. Locally, fissures, which extend several millimeters into the surrounding metal, are seen to be partially filled with a microbreccia of 1-10 μ angular troilite and schreibersite fragments. Terrestrial corrosion has had easy access along such fissures, so they are now partially converted to hydrated iron oxides.

Short discontinuous rims of schreibersite, 10-20 μ thick, are precipitated on the troilite.

Reichenbach lamellae, 20-50 mm long, less than 50 μ wide, and gently curved, are characteristic for Cumpas. Some have nucleated irregular 1-1.5 mm wide α-rims as have the troilite nodules. The Reichenbach lamellae consist mainly of troilite with some precipitates of schreibersite. It appears that, at a late shock event, they were distorted and microbrecciated.

Cumpas is a shocked, medium octahedrite with Reichenbach lamellae, and it closely resembles, e.g., Bagdad, Cape York, Drum Mountains and Kayakent. It is different from Moctezuma in bandwidth, Reichenbach lamellae and phosphide morphology, so the two masses must be independent falls.

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

1,790 g slice (no. 775, 13 x 12 x 1.5 cm)
422 g corner (no. 1591, 8 x 5.5 x 1.5 cm)

CUMPAS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Smales et al. 1967						18	141	<1	22.9	40		
Jarosewich 1968, pers. comm.	8.14	0.47	0.18									
Crocket 1972											1.7	12
Scott et al. 1973	7.94								21.0	42.8	2.7	

Dadin, Neuquen, Argentina
38°55'S, 69°12'W

A mass of 37.3 kg was found before 1949 near Campamento Dadin, 12 km from the railway station Plaza Huincul. It was acquired by the La Plata Museum and described, with an inadequate analysis, by Ducloux (1949). It appears to be a medium octahedrite, but material for examination was unfortunately not available for the present study.

From the dimensions of the almost untouched main mass, 21 x 19 x 19 cm, presently (March 1973) exhibited in the La Plata Museum, I estimate the original weight to be 27-28 kg. I assume that 37.3 kg (Ducloux 1949) is a printer's error for 27.3 kg.

Dakota. See Ainsworth

Dalton, Georgia, U.S.A.
Approximately 34°54'N, 84°51'W; 225 m

Medium octahedrite, Om. Bandwidth 1.10±0.15 mm. Shocked and partly recrystallized. HV 155±10.

Group IIIA. 7.47% Ni, 0.10% P, 0.3% S, 18.4 ppm Ga, 33.1 ppm Ge, 9.6 ppm Ir.

Only one mass, Shepard's from 1879, will be accepted as Dalton.

HISTORY

A rounded individual of 117 pounds (53 kg) was plowed up in 1879 by Francis M. Anderson on his farm about 22 km northeast of Dalton, Whitfield County. The whole mass was acquired by Shepard who gave the exact location and described it with two figures under the name "Dalton" (1883b). Another mass, of 254 pounds, had been found half a mile from this one about the year 1862; it was sent to Cleveland and described by Genth under the name "Cleveland" (1886). A third mass of 13 pounds was discovered in 1877 on a farm about 32 km northeast of Dalton; it was described by Hidden (1881) under the name "Whitfield County." In most later works, e.g., Hey (1966: 128), Hidden's iron has more or less arbitrarily been accepted as a part of the Dalton (Shepard) fall, while Cleveland has been considered a separate fall. For morphological and structural reasons Hidden's iron, however, will be considered here as part of Cleveland, while Dalton is a separate fall of a rather unique structure. Already its exterior shape suggests that it is a complete, unfragmented individual. Merrill (1916a: plate 39) gave a photograph of the main mass after it had been acquired by the U.S. National Museum, and, a little later (1916b), he discussed the problems connected with the three irons mentioned above, reaching, however, a conclusion different from the one here exposed.

COLLECTIONS

Authentic Dalton (Shepard) material: Washington (49.2 kg main mass), Ann Arbor (500 g), Georgia Department of Mines (405 g), London (no. 61995 of 131 g), Chicago (no. 1967 of 91 g), Tempe (no. 396.1 of 35 g).

DESCRIPTION

The somewhat pear-shaped mass originally weighed 53.1 kg. It now weighs, after a few slices have been cut from the pointed end, 49.2 kg and has the average dimensions of 25 x 25 x 20 cm. It is covered with a 1-3 mm thick coating of iron oxides. Another 1.2 kg of platy, 0.5-5 mm thick shales are preserved in the collection. However, the corrosion has particularly attacked the surface and only penetrated slightly into the interior. On etched sections it is seen that all fusion crust and heat-affected α_2 zone have been removed by the terrestrial exposure, but it is interesting to note that the attack first dissolves the matrix and leaves the strain-free, recrystallized α-grains unattacked for a long time. Such recrystallized, 50-100 μ, grains may still be found intact in the shale when all other constituents are gone.

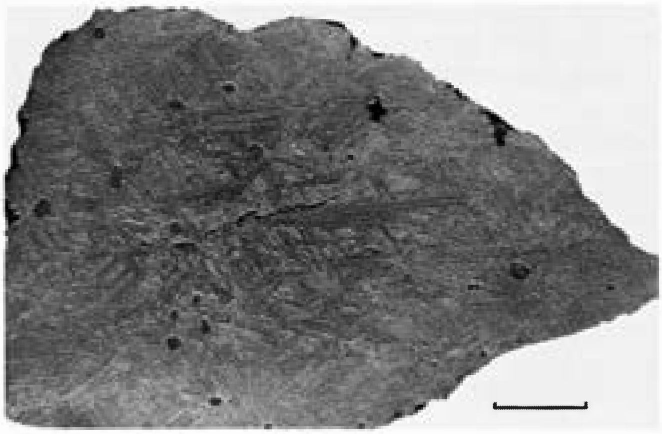

Figure 679. Dalton (U.S.N.M. no. 1010). Deep-etched section showing about twenty troilite inclusions, all with diffuse edges against the metal, and significantly attacked by the etchant (nitric acid). The reason for this is that they were in a shock-melted state. Scale bar 20 mm. S.I. neg. M-73. See also Figure 172.

DALTON – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Whitfield in Merrill 1916b	7.58	0.55	0.10	40	250		160				20	
Scott et al. 1973	7.35								18.4	33.1	9.6	

Whitfield's analysis is remarkable for its day; he was a very able analyst, both here and in most of his other published iron meteorite work.

Etched sections display an indistinct Widmanstätten structure of long ($\frac{L}{W} \sim 15$) lamellae with a width of 1.10 mm. While 95% of the surface for a superficial inspection contains Neumann bands that sometimes are slightly curved, the rest is recrystallized to irregular shiny aggregates of 50-400 μ ferrite grains. The recrystallized patches occur scattered all over the surface and give it a peculiar streaky, spotty sheen, related to the structure seen in Cedartown and Indian Valley. The recrystallization has taken place particularly inside and around comb plessite fields, around schreibersite and along grain boundaries. The nucleation sites were especially intersections of preexisting Neumann bands with inclusions, γ-phase and grain boundaries, and low-nickel areas ($\sim$ 6%) recrystallized before high-nickel areas ($\sim$ 7%). Before the recrystallization proceeded very far, the energy source disappeared.

Another important feature of Dalton is the Neumann bands. They are heavily decorated with tiny oriented plates, typically 3 x 1 x 0.3 μ. The matrix in between is similarly decomposed, almost on a submicroscopic scale, to platy oriented precipitates in an α-matrix. Wherever recrystallized α-grains have grown and engulfed the platy precipitates, these have become spheroidized. On the subboundaries are many 5 x 2 μ "flags," apparently of the same precipitate. Although it will be difficult to prove directly, by an analytical technique, that the precipitate is a high-nickel γ-phase and not a phosphide or carbide or something else, there are several indirect observations that point to the γ conclusion. First, they are most numerous where the nickel concentration of the α-phase was highest, and almost absent where nickel was low, e.g., near plessite fields and phosphides. Second, the bulk phosphorus and carbon content is too low to explain the heavy population of precipitates. Third, they have readily spheroidized to a metallic rather than an intermetallic phase. – The microhardness of the kamacite lamellae is 155±10, varying only little with the actual size and spacing of the precipitates.

Plessite occupies about 25% by area and is usually in the form of partly resorbed, open-meshed comb and net plessite with discontinuous taenite rims. Often the vermicular taenite of the comb and net plessite is well spheroidized. A very peculiar "grid" plessite is developed in the swollen part of the taenite ribbons. It is an annealed taenite.

Schreibersite is rare, which is in harmony with the analytical value. When present, it is as short, 5-20 μ wide, grain boundary veinlets, substituting for γ.

Troilite occurs as scattered, diffuse nodules 1-12 mm in diameter, in much the same way as in, e.g., Cape York and Henbury. Point counting leads to an estimate of 0.3% S. The troilites probably were originally well defined spherical and lenticular bodies with 10-30 μ wide daubreelite lamellae and thin discontinuous schreibersite rims. They are, however, now completely transformed to fine-grained aggregates of 50 μ metallic cells embedded in eutectics of 1-5 μ sulfide-phosphide-metal grains. The shock event that melted the troilite and schreibersite shattered the daubreelite. The daubreelite fragments became dispersed in the melt and, upon cooling, nucleated the iron, which then

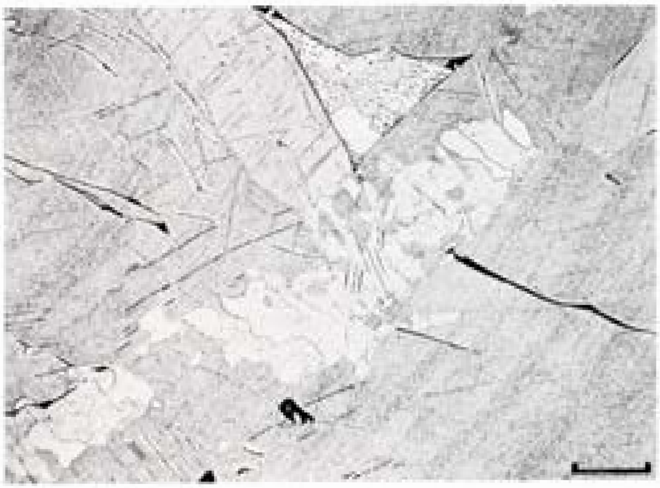

Figure 680. Dalton (U.S.N.M. no. 1010). A shocked and partly recrystallized medium ocathedrite. Due to low bulk nickel content the taenite (black) and plessite fields are almost resorbed. Etched. Scale bar 500 μ.

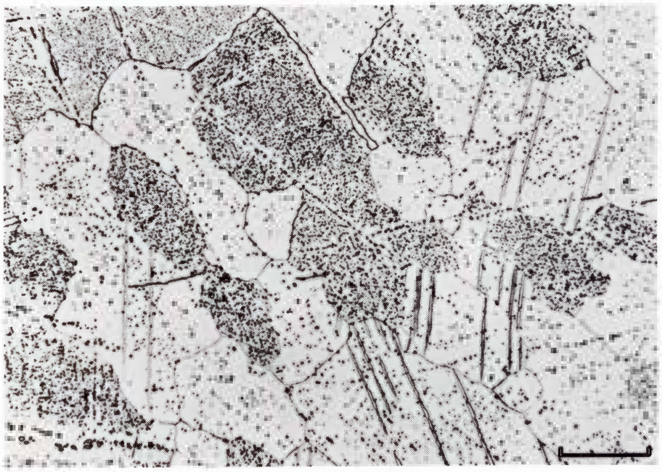

Figure 681. Dalton. Detail of center of Figure 680. Recrystallized kamacite grains with new Neumann bands. Old Neumann bands are decorated by numerous γ-particles. Etched. Scale bar 100 μ.

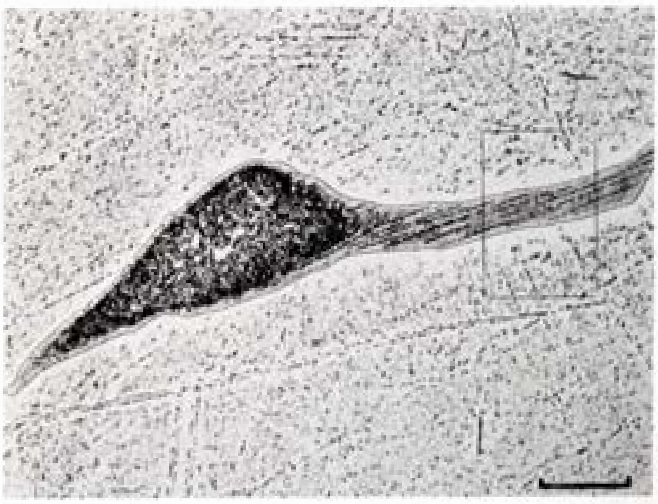

Figure 682. Dalton (U.S.N.M. no. 1010). Duplex plessite field. The taenite rims are decomposing and exhibit fine grids at this magnification. See also Figure 683. Etched. Scale bar 100 μ.

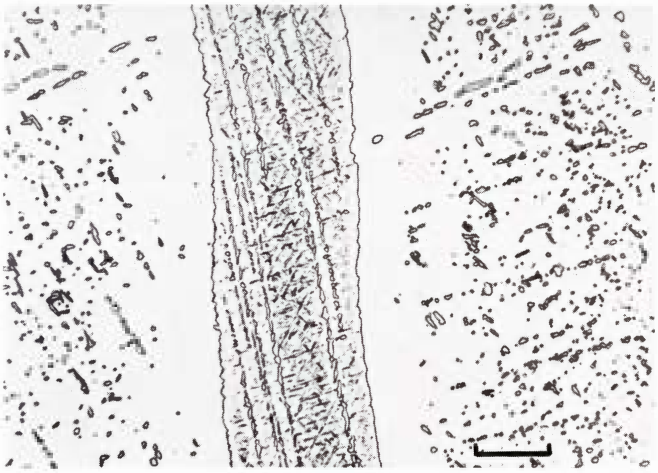

Figure 683. Dalton. Detail of Figure 682 as indicated. The γ-particles in the kamacite and the α-particles in the taenite are now clearly resolved. Etched. Scale bar 20 μ. See also Figures 222-223.

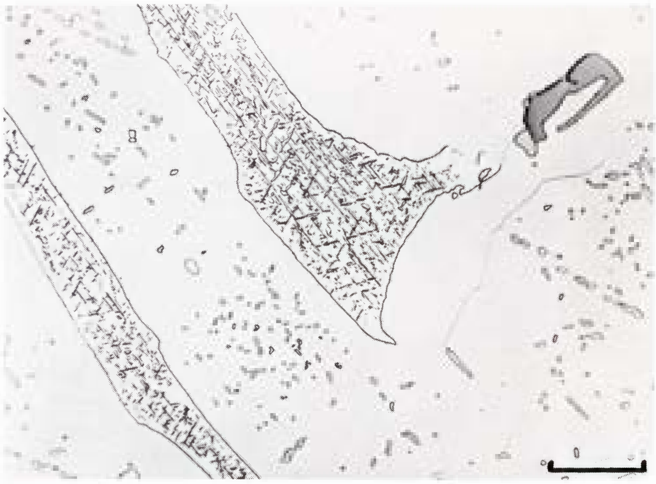

Figure 684. Dalton (U.S.N.M. no. 1010). Two other plessite fields under decomposition along (111) γ planes. To the right, a carlsbergite skeleton crystal (dark) and several phosphides (gray). Etched. Oil immersion. Scale bar 20 μ.

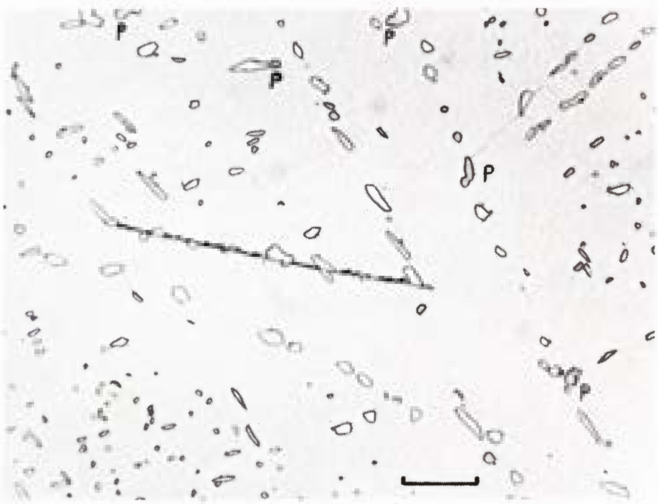

Figure 685. Dalton (U.S.N.M. no. 1010). A very fine platelet, probably of troilite or chromite, upon which several γ-particles have precipitated. A few phosphide particles (P) are also present. Etched. Oil immersion. Scale bar 10 μ.

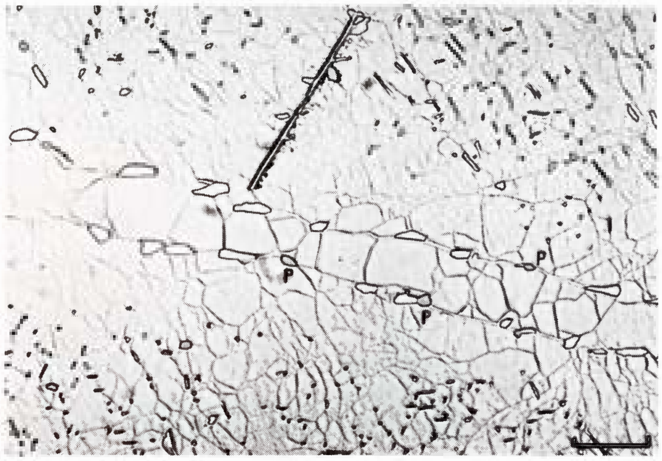

Figure 686. Dalton (U.S.N.M. no. 1010). A former Neumann band runs across the field. It is annealed and subdivided in kamacite cells, as is the kamacite matrix on either side. Numerous large γ-particles have precipitated on the Neumann band walls. a troilite (or daubreelite) platelet is also seen. Etched. Oil immersion. Scale bar 10 μ.

formed envelopes around each scalloped daubreelite grain; the remaining melt solidified to a fine-grained eutectic. An estimated maximum temperature of the troilite region immediately after th‹ shock would be 1100° C, many hundred degrees higher than the surrounding metallic matrix.

A few match-like carlsbergite inclusions, typically 6 x 1 x 0.2 μ, which were also mentioned in, e.g., Cape York, Costilla Peak and Boxhole, are present in the ferrite phase, apparently uninfluenced by shocks and heating events.

Summing up, Dalton displays an unusual combination of structures that may perhaps best be explained by assuming a "normal" cooling like, e.g., Boxhole, followed by a Neumann-band-forming event. Reheating to about 600-700° C led to precipation of fine γ plates in an oriented pattern; the plates grew first and largest upon the Neumann bands, but later the whole matrix started decomposing. A considerable shock with residual heat followed, enough to melt and shatter the troilite nodules and recrystallize some percent of the metal phase. All the shock and heating events may possibly be part of the same short event, it we assume that the combination of temperature and pressure led to γ-formation instead of ϵ-formation; confer the P-T diagram for iron. It is interesting to note that Dalton seems to represent a first step towards the creation of the fully crystallized structure of Willamette; Willamette is chemically, and in its primary structure, closely related to Dalton.

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

49.2 kg main mass (no. 1010, 25 x 25 x 20 cm with a polished face of 15 x 10 cm)
150 g part slice (no. 1010, 6 x 5 x 0.7 cm)
1.2 kg shales (rusty 4 x 3 x 0.3 cm plates, etc.)

Damaraland. See Gibeon

Davis Mountains, Texas, U.S.A.

Approximately 30°55'N, 103°55'W; 1200 m

Medium octahedrite, Om. Bandwidth 0.95±0.15 mm. ϵ-structure. HV 250±15.

Group IIIA. 7.41% Ni, 0.1% P, 17.4 ppm Ga, 33.7 ppm Ge, 14 ppm Ir.

HISTORY

A shield-shaped mass of almost 700 kg was found in the northern end of Davis Mountains, Jeff Davis County, in 1903. It was discovered on the surface by a seven-year-old boy, George Duncan of Toyah, and was later hauled away by his father; but it was not recognized as a meteorite until Professor G.M. Butler of the Colorado School of Mines saw it exhibited in Fort Worth 10 years later. It was immediately acquired by the Field Museum in Chicago, where it was described by Farrington (1914) with discussion and photographs of the exterior shape.

COLLECTIONS

Chicago (main mass, 693 kg, complete except for the removal of about 3 kg; 390 g slice), Tucson (780 g, 172 g, 47 g and 40 g; specimens received from Professor G.M. Butler), Washington (117 g), London (41 g), New York (28 g).

DESCRIPTION

The mass has the overall dimensions 78 x 68 x 38 cm. It is an irregular low cone with a flat base. As Farrington (1914) pointed out the shape is probably due to a rather uniform ablation during stabilized entry through the atmosphere. The front is covered by irregular indentations and grooves, and some narrow ridges extend from the apex of the low cone to the rim. The rear side is more uniformly and deeply pitted than the front side. The pits are broad, irregular, shallow depressions 3-8 cm in diameter and 1-2 cm deep. There are no striations. Farrington also observed a triangular late fracture surface, with a deviating surface morphology, which he attributed to a late breakup in the atmosphere whereby a small portion was dislodged.

A reexamination of the main mass confirmed Farrington's observations. The dislodged surface specimen may have been as much as 10 cm thick, but, unfortunately, it has never been found. In places the surface is quite damaged, both by gouging and by plastic overfolding and ear-formation. This damage may well have been inflicted when the meteorite was dragged across the uneven and rough surface of the ground.

The meteorite is covered with 0.1-2 cm oxide crusts, and the original fusion crust is lost. Also the heat-affected α_2 zone seems to have disappeared due to corrosion, but the general exterior morphology is well preserved. In one place near the edge of the front surface is a conspicuous cavity, 8 x 2 cm and 5 cm deep, which is due either to burning out of a large troilite nodule or to an unusual local carving by vorticing air.

Etched sections display an indistinct Widmanstätten structure of slightly undulating, long ($\frac{L}{W} > 20$) kamacite lamellae 0.95±0.15 mm in width. The kamacite has subgrain boundaries decorated by 1-2 μ phosphides. A shock has converted the α-phase to the hatched ϵ-type, but it appears that the matrix is also duplex on a submicroscopic scale. Fine particles, less than 0.5 μ across, decorate in large numbers the shear zones in the ϵ-structure. The particles are probably almost submicroscopic taenite beads. A later stage, where they have grown to larger, easier recognizable units, is found in, e.g., Jamestown. The microhardness of the kamacite lamellae is 250±15. It drops to 190 near the corroded surface, from which we may infer that only a few millimeters of the exterior has been lost by corrosion (hardness curve type I, where the heat-affected zone is corroded away). Triangular and trapezoidal plessite fields are faintly visible between the kamacite lamellae. They are almost resorbed plessite with less than 10 μ wide taenite ribbons. Locally, a wider, wedge-shaped taenite bleb may be found; its interior is then invariably martensitic-bainitic, locally merging into duplex $\alpha + \gamma$ structures.

Schreibersite is macroscopically invisible. At higher magnification it will be found locally, particularly as 5-30 μ irregular blebs associated with the few plessite fields. Plastic deformation after the ϵ-forming shock event has bent and distorted the linear elements of all phases. Rhabdites, 0.5-1 μ thick, occur in limited numbers.

Troilite was observed once as a 3 x 2 mm diffuse nodule with a 200 μ wide daubreelite bar and a 75 μ angular chromite crystal. The troilite is shock melted and has dissolved the enveloping kamacite. Upon the rapid solidification, only part of the metal was redeposited on the wall; the remainder was trapped as 1-2 μ particles dispersed in the troilite. The daubreelite is shattered and partially

DAVIS MOUNTAINS – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Butler in Farrington 1914	7.54											
Nichols in Farrington 1914	7.40	0.32	0.11									
Scott et al. 1973	7.29								17.4	33.7	14	

The cobalt value is, no doubt, about 30% too low.

dissolved. Subangular daubreelite fragments of 5-10 μ are dispersed in the troilite. The troilite itself is a fine-grained, polycrystalline aggregate of 1-3 μ grains.

Daubreelite occurs further as scattered 10-30 μ blebs in the kamacite phase. The tiny hard platelets of carlsbergite observed in, e.g., Costilla Peak, are also present here, mainly as oriented 20 x 3 x 0.5 μ precipitates in the kamacite phase.

Davis Mountains is a shocked, and somewhat annealed, medium octahedrite of unusually low contrast in the Widmanstätten structure. This is due partly to the ϵ-structure, partly to the almost resorbed taenite and plessite and partly to the lack of macroscopic inclusions. It is closely related to such well known irons as Costilla Peak and Henbury.

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

28 g surface knob (no. 441, 4 x 2 x 1 cm)
89 g slice (no. 1443, 10 x 4.5 x 0.4 cm)

Dayton, Ohio, U.S.A.

Approximately 39°45'N, 84°10'W

Finest octahedrite, Off. Bandwidth 45±15 μ. Neumann bands. HV 170±15.

Group IIID. 17.62 Ni, 0.70% Co, 0.4% P, 5.2 ppm Ga, 3.5 ppm Ge, 0.028 ppm Ir.

Not a fall as claimed. Probably transported to Dayton from an unknown place of find.

HISTORY

A mass of 26.3 kg was allegedly seen and heard to fall in the summer of 1892 by Albert Seifert of Dayton, Ohio. The meteorite was said to have landed on the Montgomery County Fairgrounds in Dayton, a summer evening, and dug a 4- to 5-foot deep hole, from which it was immediately excavated. It was reported to be too hot to handle for several hours. The meteorite was kept in the attic of the family's home, but was eventually, in 1951, reported to Cincinnati University by L.R. Keyser, a grandson of the finder. Through a generous grant from Stuart H. Perry, the U.S. National Museum was able to acquire the whole mass, which was undivided and undamaged (source: letter of May 16, 1951 from Professor M.G. Frey, Department of Geology, University of Cincinnati, Ohio). Since the meteorite already, at a visual inspection, looked too corroded to be a witnessed fall, E.P. Henderson interviewed the family and discovered that there was a solid tradition as to the fall, but important details other than those already mentioned could not be obtained. However, it turned out that Seifert, the original owner, was for many years traveling in Ohio, Indiana and Illinois, running concession stands for fairs and exhibits. Isn't it plausible that, in this business, he came upon an opportunity to acquire the meteorite from some unknown finder (a farmer ?), and afterwards displayed it as a curiosity at different fairs? There are no local records of a meteorite fall in Dayton, and the meteorite tradition appears to be strictly limited to the Seifert-Keyser family. As the following examination shows, there is no doubt whatsoever that the fall took place hundreds or thousands of years ago and not in 1892 as claimed. The story, as related by the finders, is nevertheless given above in order to show how vivid man's imagination is and how careful one must be – even when a solid tradition exists. Compare, also, the story of the Deep Springs "fall."

The meteorite was briefly mentioned by Henderson & Perry (1954) with chemical analysis and density determinations. Feller-Kniepmeier & Uhlig (1961: figure 18) examined the composition of the kamacite and the taenite and presented a photomicrograph of acicular kamacite in a light taenite matrix. Goldstein (1965) and Goldstein & Ogilvie (1965b) discussed the mechanics of nucleation and growth of the Widmanstätten structure and used Dayton as one example. Mason (1962a: figure 56) presented a photomacrograph. Fuchs (1969) reported albite and three phosphate minerals from Dayton: whitlockite, $Ca_3(PO_4)_2$; brianite, $Na_2CaMg(PO_4)_2$; and panethite, $(Na, Ca)_2(Mg Fe)_2(PO_4)_2$, the latter two being new minerals, unusually rich in sodium for meteoritic environments.

Herr et al. (1961) determined the extremely low amounts of osmium and rhenium present. Voshage (1967) found the cosmic ray exposure age to be 215±85 million years. Vilcsek & Wänke (1963) found 140±10, and Chang & Wänke (1969) found 140±20 million years. The last authors found the terrestrial age to be too low for their technique, that is, lower than 10^5 years.

COLLECTIONS

Washington (24.4 kg), Chicago (487 g), Tempe (324 g), Sydney (237 g), Mainz (about 200 g).

DESCRIPTION

The irregular, deeply indented mass had, before cutting, the overall dimensions of 24 x 24 x 13 cm and a volume of 3,750 cm^3. It is covered by 0.1-1 mm thick,

DAYTON – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Henderson & Perry 1954	18.10	0.81	0.001									
Moore et al. 1969	17.74	0.58	0.08	510			515					
Wasson & Schaudy 1971	17.02								5.16	3.52	0.028	

limonitic products, and incrustations of soil and limonite are found firmly attached to the meteorite in several places. The regmaglypts from the atmospheric entry are boldly sculptured as 2-5 cm large, deep depressions. About 1/3 of the surface is flat or has only very shallow depressions. Warts or ridges could not be identified and are probably corroded away. In some depressions, however, the indistinct, corroded remnants of the original magnetite fusion crust are preserved. It is also clear that several of the "chisel-mark" indentations on the surface are holes from ablation-melting of schreibersite and not damage from man. The largest is a wedge-shaped cavity, 50 mm long, 8 mm wide and 15 mm deep. Summing up, it may be concluded that the state of corrosion shows Dayton to be a relatively recent fall, geologically speaking, but it is unlikely that it was observed to fall in 1892 as claimed.

Etched sections confirm that the fall is neither very old, nor an observed fall in 1892. The 50μ wide kamacite lamellae are selectively corroded in the same way as described from Tazewell and Föllinge (Buchwald 1967b), both of which are finds. Also, the α-phase of the pearlite is selectively attacked to an extent which would be impossible had the meteorite been recovered immediately. On the other hand, heat-affected α_2 zones, 0.3 mm wide, are preserved in many places. Micromelts of schreibersite are also present in the extreme surface zones. There is, thus, no doubt that the complex exterior morphology is due to atmospheric sculpturing and not to subsequent corrosion. The hardness of the α_2 in the lamellae is 170±10.

The structure is unusual and surprisingly variable, displaying both the finest octahedral structure and pearlitic patches. It does not fit into our structural classification schemes. Macroscopically, the dominant features are the large, angular skeleton crystals of schreibersite. They are usually about 6 x 1 mm, but frequently reach 10 x 3 mm, and one individual is at least 15 x 12 x 10 mm in size. Point counting of the phosphides upon 200 cm^2 sections leads to an estimate of about 0.4% phosphorus in the mass. Many of the schreibersite crystals are built around 0.2-5 mm wide nuclei of white to greenish phosphate crystals.

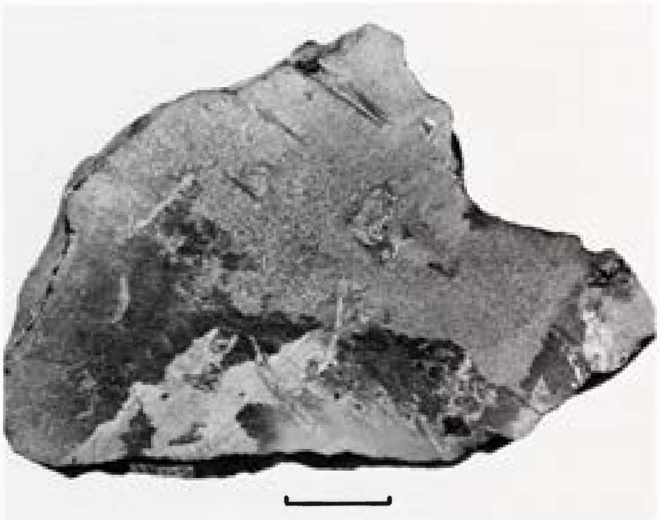

Figure 687. Dayton (U.S.N.M. no. 1506). A full slice which shows the surprising structural variation. The lower left half is dominated by pearlitic structures, while the upper right half shows a finest octahedral structure similar to that known from Föllinge and Tazewell. Deep-etched. Scale bar 20 mm.

The metallic matrix was originally a homogeneous austenite individual, but it is now developed differently near the inclusions and away from the inclusions. Far from the inclusions the original austenite is decomposed to a fairly normal, but extremely fine, Widmanstätten structure with long ($\frac{L}{W} \sim 50$) kamacite lamellae 45±10 μ wide. The lamellae display numerous subgrain boundaries and the widest lamellae contain a few Neumann bands. The hardness is 165±20. The interstices between the lamellae are developed as acicular or martensitic-bainitic plessite fields with repetition of the overall Widmanstätten directions. These parts closely resemble the structures of Tazewell and Föllinge.

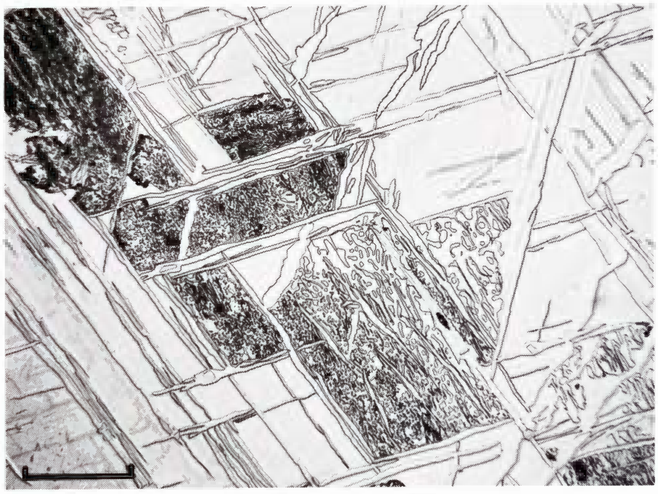

Figure 688. Dayton (Tempe no. 653.1). Mixed structure. Pearlitic and spheroidized plessite fields alternate with martensitic fields. Due to the light etching the fields are almost unattacked and appear structureless. Scale bar 400 μ.

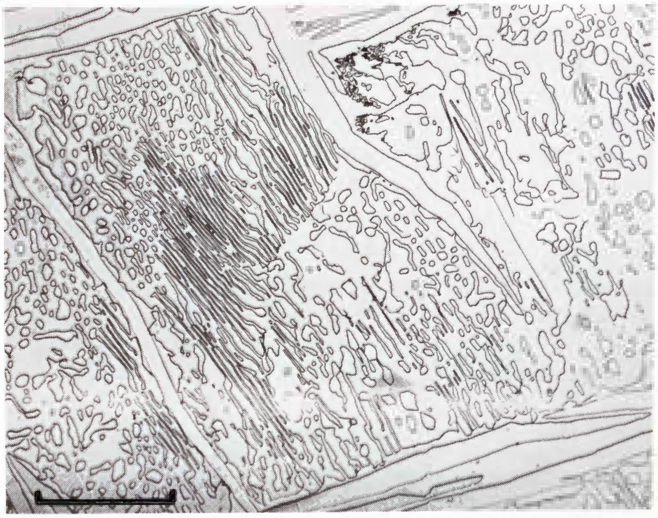

Figure 689. Dayton (Tempe no. 653.1). Detail of a pearlitic and spheroidized plessite field. Etched. Scale bar 100 μ.

Near the inclusions the matrix is pearlitic in the best sense of the word: the slightly undulating, 1 μ wide on the average, subparallel γ-lamellae cover large areas and give the etched surface a macroscopically visible mother-of-pearl sheen. The pearlitic packets closely resemble pearlite in steel, except that they are coarser and, of course, consist of ferrite and austenite and not of ferrite and cementite. In addition, vermicular 5-20 μ wide bodies of schreibersite substitute regularly for taenite. The bulk hardness of the pearlite is 200±7; the individual taenite lamellae are 265±20, while the individual kamacite lamellae are 170±10. The lamellar packets occupy several square centimeters of rather uniform orientation, different from the Widmanstätten orientation. In places the lamella width of the pearlite changes abruptly, such as from 2.5 μ to 0.7 μ in one place for a full period of which the taenite constitutes about 33%. Such changes in steel are known to reflect a drastic difference in growth temperatures. Dayton provides a good chance to study the pearlite formation and morphology in meteorites as compared to that in steel and other alloys.

It is hardly a coincidence that the pearlitic structures are associated with the schreibersite inclusions. The analysis by Moore et al. (1969) shows an unusually high C-value, and it may well be that the carbon in some way is responsible for the pearlitic development, for example, by becoming concentrated in the immediate surroundings of the schreibersite, which upon growing would have rejected the carbon. The mechanism is not at all clear, and it is not known whether an intermediate phase of cohenite was present. In any case, the normal Widmanstätten structure and the pearlitic patches developed competitively at about the same temperatures, judging from the intriguing interlocking and sequence of structures, probably with the pearlite formation being a horsehead in advance. The carbon is now mostly in solid solution in the taenite lamellae which develop a tarnished, spotty appearance upon etching.

Schreibersite occurs as millimeter- to centimeter-sized skeleton crystals, enveloped in 0.1-1 mm swathing kamacite which displays a few Neumann bands. Schreibersite is further common as 20-50 μ angular crystals centrally in the Widmanstätten lamellae and as 5-20 μ vermicular bodies substituting for taenite in the pearlitic areas.

Troilite is not abundant but was observed as 1-5 mm nodules associated with the large schreibersite-phosphate aggregates. The troilite is monocrystalline with a few lenticular deformation twins.

When the meteorite was first cut in 1952, the saw hit a large cavity, 50 x 45 x 40 mm, of a kind which probably never has been reported in a meteorite. The cavity, which is more than 20 mm below the surface, is lined with 0.4 mm schreibersite and with a hard, black, unidentified mineral. The cavity was filled by a loose grain aggregate which, upon cutting, got mixed with water and carborundum and was only partially saved by being scraped out with a wooden spatula (E.P. Henderson, personal communication). An examination of the mixture is still pending, but it appears that crystalline graphite makes up a significant portion.

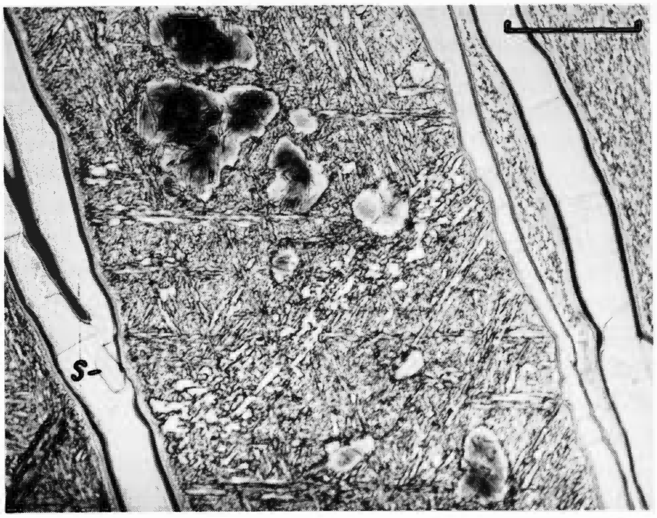

Figure 690. Dayton (Tempe no. 653.1). Detail of a martensitic field with platelets parallel to the bulk Widmanstätten structure. A schreibersite crystal (S). Etched. Scale bar 100 μ.

Dayton is structurally and chemically an unusual meteorite. In many respects it is identical to Tazewell, Wedderburn and Föllinge. In particular, the resemblance to Tazewell is remarkable except that Tazewell shows no pearlitic patches and no phosphates in the examined sections.

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

22 kg main mass (no. 1506, 24 x 20 x 13 cm)
1.8 kg slices (no. 1506, typically 13 x 8 x 0.5 cm)
660 g slices (no. 1592; 379 g and 281 g endpiece: 9 x 9 x 1 cm)

Deelfontein, Cape Province, South Africa
30°59'S, 23°47'E

Coarse octahedrite, Og. Bandwidth 1.75±0.25 mm. Neumann bands. HV 205±12.

Group I. 7.01% Ni, 0.41% Co, 0.16% P, 83 ppm Ga, 306 ppm Ge, 1.4 ppm Ir.

DEELFONTEIN – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Comerford et al. 1968	6.90	0.40										
M.I.T. in above	7.01	0.42	0.16									
Wasson, 1970a	7.11								83.1	306	1.4	