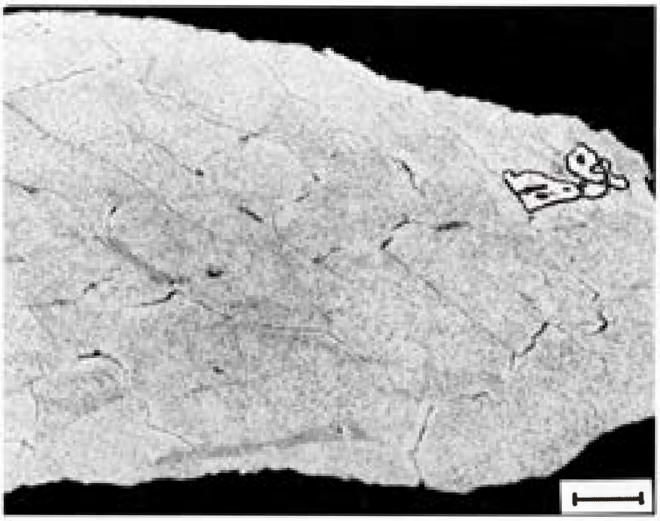

Figure 469. Canyon Diablo (Copenhagen no. 18463). Shock-annealed stage VI. Typical matte structure, with some cohenite crystals to the right. Etched. Scale bar 2 mm.

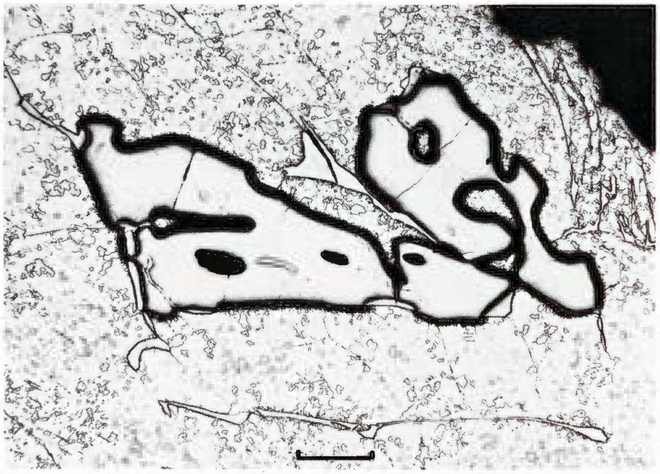

Figure 470. Canyon Diablo. Stage Vi, as Figure 469. The cohenite crystals, Figure 469, show distinct black rims, and the kamacite displays unequilibrated α_2. Scale bar 500 μ.

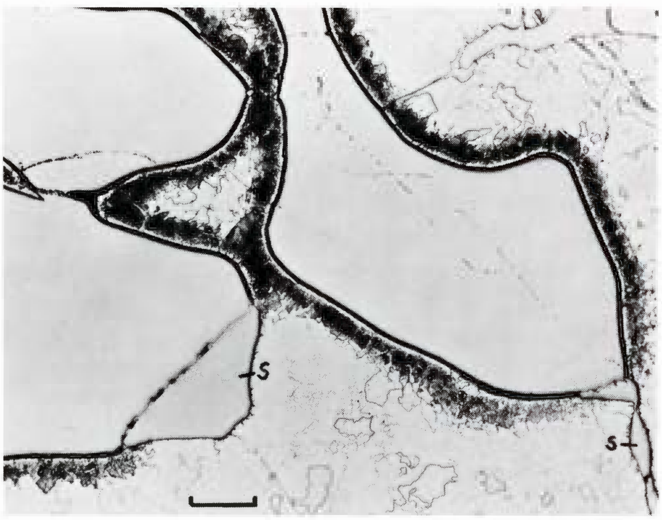

Figure 471. Canyon Diablo. Stage VI, detail of Figure 470. Cohenite with black reaction rims in the granulated kamacite. Schreibersite (S) does not react except by showing fine thorny projections. Etched. Scale bar 100 μ.

The primary structure is as before. However, the kamacite has been briefly reheated above 600° C and has recrystallized throughout the sample. The new grains are unequilibrated, serrated and have hardnesses of 145-210. The previous Neumann bands are still plainly visible, and so are the old subboundaries because the original precipitates delineate their locations.

The schreibersite and cohenite crystals are still monocrystalline, and there are no reaction rims around them. The troilite is micromelted, usually to a somewhat larger extent than is present in I-III.

Severe shear zones, 100-200 μ wide, cross the entire specimens. They are wavy, fan out, coalesce again, and may displace taenite, plessite and minerals several millimeters. The present exterior surfaces of the slugs and wedge-shaped masses have no doubt been produced in a similar fashion by shear-rupture and have later become corroded.

The taenite rims and lamellae are dirty-brownish, with low hardnesses, 160-200, due to annealing. In crossed Nicols the taenite displays an unusual sheen from many small crystals, each 5-10 μ across.

This kind of material is believed to represent shock-annealed fragments of the impacting main body. Since the fragments have not had a very long flight through the atmosphere, well developed fusion crusts and heat-affected rim zones are not expected to be present. The energy responsible for bulk reheating of the small masses to about 600° C is believed to have come from the conversion of kinetic to heat energy during the impact and fragmentation.

V. Shock-annealed to α_2 transformation. Specimens usually smaller than 5 kg. Corresponds to the heavily shocked category of Heymann et al. (1966). Type examples Tempe no. 34.4045 (about 200 g) from the rim (Moore et al. 1967) and U.S.N.M. no. 3189 (about 50 g). Structures as for I-IV, but with additional effects from relaxation reheating to above 750° C. All, or nearly all, specimens of this category come from the rim. Diamonds are known to occur in some samples, e.g., no. 34.4045.

The kamacite has been through the $\alpha \rightarrow \gamma \rightarrow \alpha_2$ transformation, i.e., the temperature has been briefly above 750° C. The resulting α_2 phase consists of 20-100 μ units which may be serrated, unequilibrated in small masses of high cooling rate, or more equiaxial in larger masses of lower cooling rate. The hardness range is 150-165. The Neumann bands have entirely disappeared, and the oriented sheen is almost lost. The taenite lamellae have developed a peculiar mosaic of yellow and gray patches, separated by straight boundaries. This taenite modification is known to occur in the heat-affected rim zones of normal falls; it indicates peak temperatures of 800° C and above.

The schreibersite is monocrystalline and the troilite is, as before, micromelted. The cohenite shows incipient recrystallization to 1-100 μ grains, particularly along shear zones. The cohenite is surrounded by an indistinct 20-30 μ wide reaction rim, caused by carbon diffusion in the surrounding metallic matrix.

There are conspicuous shear zones through the entire specimen and the taenite and plessite have been distorted and annealed (HV 148-190).

VI. Shock-annealed to α_2 transformation and recrystallization of cohenite and schreibersite. Specimens usually smaller than 5 kg. Corresponds to the heavily shocked category of Heymann et al. (1966). Type specimen Copenhagen no. 18463 (part of a 50 g wedge-shaped mass).

The kamacite is transformed to α_2 and annealed to equiaxial structures, 20-100 μ across, with hardnesses of 150-170. The oriented sheen from the Widmanstätten is now entirely lost, and original Neumann bands have been erased.

The schreibersite has recrystallized to 5-25 μ grains, and thorns protrude out into the surrounding kamacite. The cohenite is totally recrystallized to 20-200 μ grains and surrounded by 20-50 μ wide, dark-etching rims of bainitic transformation products. The troilite is micromelted, and the rim minerals and the silicates are violently shattered and dispersed as angular fragments through the melt. Veins of troilite penetrate several millimeter out into the kamacite. Conversion of graphite to diamond and lonsdaleite has taken place.

The peak temperature of the bulk material may be estimated to have been above 900° C; the schreibersite is still unmelted.

VII. Partly remelted specimens. Usually smaller than 5 kg. U.S. National Museum no. 1725 (about 4 kg), no. 76844 (about 1 kg), Copenhagen (no. 121264, 10 g), all collected on the crater rim. Corresponds to the most heavily shocked samples of Heymann et al. (1966), such as numbers 16, 17, 55, 56 and 57.

The kamacite has been through the $\alpha \rightarrow \gamma \rightarrow \alpha_2$ transformation and was somewhat annealed afterwards. It forms 25-100 μ more or less equiaxed grains with hardnesses of 165±10. The oriented sheen and the Neumann bands are entirely lost. The taenite is decomposed to polycrystalline aggregates of 20-100 μ martensitic grains. The exterior contours are preserved, but carbon has diffused some 10-20 μ out into the adjacent kamacite.

The schreibersite is micromelted and, if in contact with troilite melts, dispersed as 20-50 μ globules through the troilite. If in contact with cohenite, complex Fe-Ni-P-C eutectics, resembling ultrafine ledeburite and steadite, have formed. The melts are extremely fine-grained and alternate rapidly between "white cast iron," "gray cast iron with flaky graphite (5 x 0.5 μ flakes)" and "nodular cast iron with spherulitic graphite (3-15 μ in diameter)." Some cohenite remains unmelted but displays severe recrystallization or decomposition to badly defined polycrystalline anisotropic structures. The cohenite is surrounded by 50-100 μ wide black-etching bainitic rims (HV 210±15).

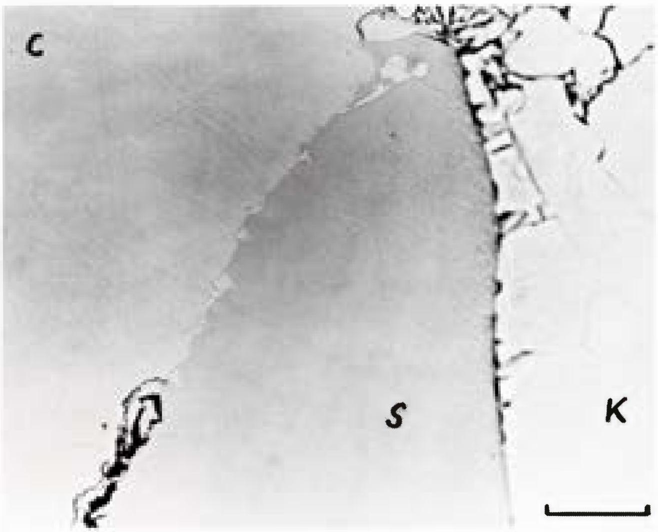

Figure 473. Canyon Diablo. Stage VI, detail of Figure 471, adjacent to Figure 472. The interface cohenite (C)-schreibersite (S) shows whitish unidentified reaction products, which possibly are taenite particles. Etched. Oil immersion. Scale bar 20 μ. See also Figure 154.

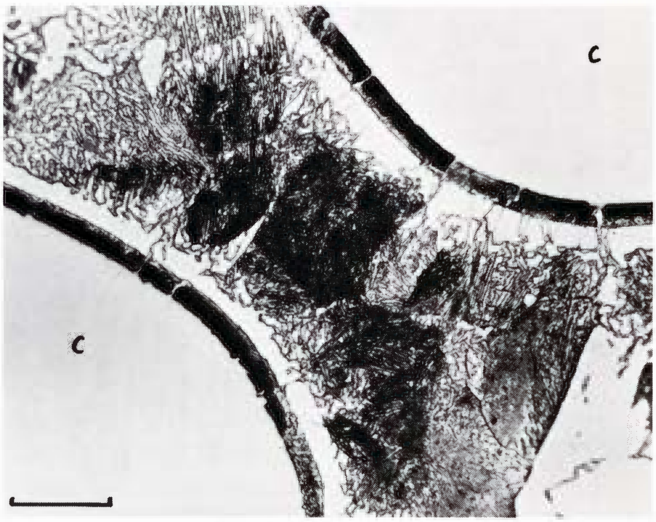

Figure 472. Canyon Diablo. Stage VI, detail of Figure 471. Cohenite (C) with bainite, ferrite and pearlite reaction rims. Etched. Oil immersion. Scale bar 20 μ.

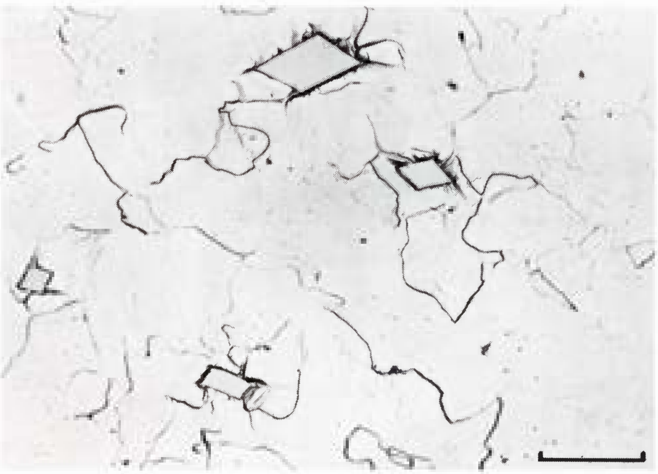

Figure 474. Canyon Diablo. Stage VI, as Figure 469. Detail of unequilibrated α_2 kamacite. Four rhabdites with thorns protruding into the kamacite. Etched. Scale bar 50 μ.

These black rims zones cannot be satisfactorily resolved by optical microscopy. It appears, however, that they formed in the manner described in this paragraph. Upon brief reheating, the cohenite rim decomposed to carbon and nickel-poor (2%) austenite. The carbon diffused outwards into the nickel-rich austenite (6-7%). Upon cooling, three distinct zones developed. In contact with the cohenite, a nickel-poor and carbon-rich, extremely fine-grained pearlite formed. On the former cohenite-kamacite interface and accurately following the original boundary, a 2-4 μ wide "line" of proeutectoid ferrite formed. The outermost and widest zone is a nickel-rich, carbon-poor dark-etching bainite type. From observed structures it is estimated that such specimens reached bulk temperatures of 1000-1100° C, at which temperature both troilite and schreibersite – and, to a minor degree, cohenite – were temporarily melted.

It should perhaps be noted here that specimens of stage VI-VII are apparently unique so far among iron meteorites. Stage V may be present in some specimens from the Morasko crater field.

The stage beyond VII has not been recognized in massive samples from the crater field. It appears that only a little extra energy beyond VII would be required for complete disintegration of the material now so rich in micromelted constituents. Such material would then be dispersed either as minute distorted metallic fragments or as minute melted spherules, oxidized during their formative stage and afterwards weathered during a long exposure to the terrestrial surroundings.

Various analyses indicate that the metallic spherules are enriched in nickel relative to the main body, a fact which may be explained by the selective oxidation of iron during the high temperature formative stage. There are also indications that the spherules immediately became covered with a thin silica coating which precipitated from the shock-vaporized Coconino sandstone. This silica would provide a corrosion resistant coating that would help to explain why the small metallic spherules have resisted weathering for thousands of years. Excellent descriptions of the meteoritic spherules, usually 0.1-1.5 mm across, have been presented by e.g., Nininger (1952a: 241; 1956), Zaslow & Kellogg (1961), Mead et al. (1965) and Hodge & Wright (1970; 1971 and Blau et al. (1973).

The Canyon Diablo masses are weathered to a surprisingly large variety of forms. On the large masses found on the surface, such as Amherst no. 627 (310 kg) and New York no. 2235 (493 kg), the soil line is indicated. Below the soil line there is a caliche incrustation; above it the meteorite is little weathered and displays a desert varnish. Similar caliche incrustations are also present on a great many of the smaller masses. Often only little of the meteorite has actually been lost by weathering.

The large masses display some puzzling cavities. On Yale no. P 400 (375 kg), Amherst no. 627 and some Washington masses, the holes are conspicuous, measuring, e.g., 4 x 7, 4 x 4 and 2 x 2 cm in aperture at the surface, with depths of 3 to 10 cm. The holes are frequently undercut, and adjacent holes may coalesce below the surface. It is believed that the holes are due to the combined action of ablation burning of troilite and subsequent corrosion during long terrestrial exposure.

The wedge-shaped slugs are usually covered with caliche and 0.1-2 mm thick limonitic crusts. The shape of these characteristic masses is apparently mainly due to the impact explosion which produced bombshell like fragments. Subsequent weathering removed many of the fine details and twisted edges.

Around the crater, enormous quantities of magnetic iron shale has been – and may still be – collected. These oxides consist of shapeless, angular fragments, ranging in size from a sand grain to half a kilogram. The majority are either relatively flat or highly angular. The flat samples

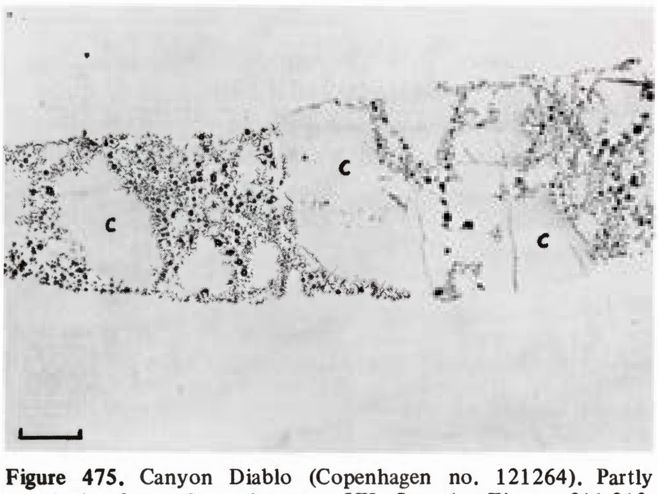

Figure 475. Canyon Diablo (Copenhagen no. 121264). Partly remelted, of transformation stage VII. See also Figures 211-213. The cohenite crystal which extends across the picture field has been partly melted. It is now subdivided in recrystallized fragments (C) and wholly melted material which has solidified to fine-grained "cast-iron" structures with spherulitic graphite. Polished. Scale bar 100 μ.

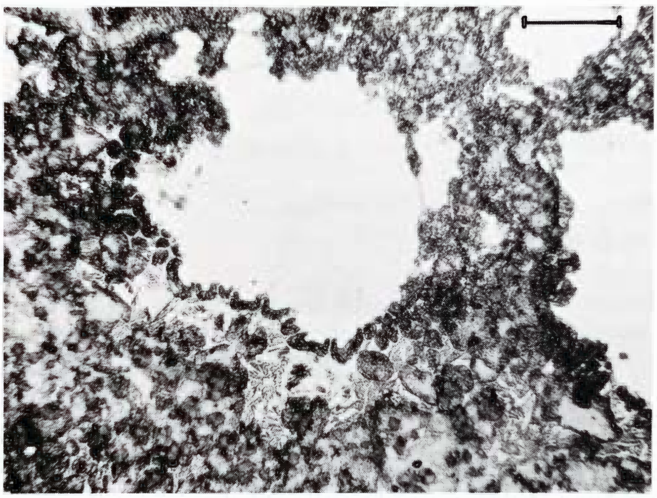

Figure 476. Canyon Diablo. Stage VII. Detail of left part of Figure 475. Cohenite fragments (white) swim in a "cast iron" matrix, which displays both graphite flakes and spherulites, and ledeburitic elements. Etched. Slightly crossed polars. Scale bar 40 μ.

Figure 477. Canyon Diablo. Section through an angular shapeless oxide ball. Small unweathered meteorite particles, mainly of taenite and schreibersite, may be seen as white specks in the limonite. Polished. Scale bar 10 mm. S.I. neg. M-951.

measure typically 3 x 2 x 0.4 cm and may be slightly curved and display desert varnish on one or both sides. It is supposed that they are the surviving fragments of shale balls.

The shale balls are 5-30 cm in diameter and often possess a sizable metallic core. The outer portion is of lamellar oxide with deep, radial, V-shaped cracks so that the exterior of a cleaned shale ball is not unlike a so-called breadcrust lava bomb. Apparently nearly all shale balls have been found beneath the present surface. Barringer found more than a hundred of them in exploratory digging outside the crater, the largest of which weighed about 20 kg. Good descriptions, analyses, photographs and discussions of the various oxides and shale balls are to be found in Farrington (1906), Merrill & Tassin (1907), Barringer (1909), Nininger 1952a: 161) and Buddhue (1957: 103).

The shale balls belong to the more puzzling phenomena associated with Meteor Crater. Barringer had concluded that all metallic specimens represented residual cores left from disintegrated shale balls and that the holes and deep depressions in many irons were the products of weathering of shale-ball iron. As has been shown above, this view is untenable since many masses are clearly so little weathered that the heat-affected α_2 zones are retained.

Farrington (1906), Nininger (1952a: 161) and Krinov (1966a: 113) suggested that the shale balls represented such parts of the main mass that happened to have had the highest content of the cosmic mineral lawrencite, $FeCl_2$. The presence of this mineral would have catalytically accelerated the terrestrial corrosion. This view cannot be supported since, as repeatedly shown in this book, there can be no such cosmic mineral as lawrencite in iron meteorites. The chloride detected in the analytical work has for the major part been introduced along grain boundaries with terrestrial ground water. This view is corroborated by the observation that shale balls are found not on the surface but only upon digging. In other words, it appears that the shale balls represent subsurface weathering on the Colorado Plateau while the well-preserved major masses represent surface weathering.

Much has already been gained from the study of the Canyon Diablo meteorites and, no doubt, much is still to be learned from systematic and accurate studies of Meteor Crater and its associated meteorites. It is hoped that the present summary may aid in the understanding and that it has drawn attention to several problems, as yet, unsolved.

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

50.4 kg (no. 194), 16.2 kg (no. 197), 338 kg (no. 198), 435 kg (no. 210), 9.2 kg (no. 355), 16.9 kg (no. 373), 32.8 kg (no. 394), 95.5 kg (no. 401, subdivided), 27.4 kg (no. 571), 1.8 kg (large graphite inclusion, no. 807), 66 g (from Mount Elden, no. 840), 452 kg (no. 857), 19.9 kg (no. 1529, located by mine detector 6.5 km northwest of crater rim), 15.4 kg (no. 1530, the same, 5 km east-northeast of crater rim), 30.6 kg (no. 1531, the same, 5 km south-southeast of crater rim), 36 g (no. 1723, a knife measuring 12 x 1.5 x 0.2 cm, forged from Canyon Diablo material in the Smithsonian Institution), 3.22 kg (no. 2585, shale ball), 2.18 kg (no. 3214, shale ball), 1.64 kg (no. 3215, shale ball). Also numerous other masses, slugs and sections totaling 136 kg. Finally, 57 kg (no. 3310), originally in the University of Minnesota mislabeled Estherville, but during the present study found to be a beautifully preserved Canyon Diablo mass; compare page 540. Now divided into 37 kg and 16 kg pieces.

Canyon Diablo (Ashfork), Arizona, U.S.A.

34°53'N, 112°37'W

Coarse octahedrite, Og. Bandwidth 2.40±0.40 mm. Neumann bands. HV 160±8.

Group I. 7.00% Ni, 0.25% P, 83 ppm Ga, 330 ppm Ge, 2.5 ppm Ir.

A transported Canyon Diablo specimen.

HISTORY

A mass of about 27 kg was found by Charles Quitzow in 1901, about 25 miles south-southwest of Ashfork

CANYON DIABLO (ASHFORK) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wiik & Mason 1965	7.04	0.54										
Wasson 1968	6.97								83	330	2.5	

While Whitfield's Ni and Co values (Reeds 1937) are erroneously low, his analysis of 0.25% phosphorus is in harmony with the structure.

in an area known as Cedar Glade. In 1930 the main mass was in private possession (Reeds 1937). Inspection and analysis of the 1.5 kg slice in the American Museum of Natural History led Wiik & Mason (1965) to the conclusion that Ashfork is a transported fragment of Canyon Diablo. A similar conclusion was reached by Wasson (1968) and is supported here.

COLLECTIONS

New York (1,470 g), Tempe (224 g), Washington (39 g).

DESCRIPTION

The description is based on the specimen in the U.S. National Museum and may be incomplete because of the small amount of material. The Widmanstätten structure is coarse with a bandwidth of 2.40±0.40 mm, and the lamellae are irregular because of late grain growth. Plessite is scarce, often with a martensitic or pearlitic interior, which is typical of group I irons. Neumann bands are common and well developed. The microhardness is 160±8. Schreibersite is present as 5 x 2 or 3 x 1 mm hooks and hieroglyphs, and as 25 μ wide, irregular ribbons in the grain boundaries. Rhabdites, typically 10 μ in diameter, are ubiquitous. Troilite, daubreelite, cohenite and graphite were not observed, but, locally, a 30 μ chromite crystal has served as nucleus for a growing schreibersite. The subboundaries of the ferrite are conspicuous by their decoration with precipitates, probably phosphides.

The structure of Ashfork is thus typical for the Canyon Diablo specimens of the inclusion-free type. As it is unshocked, it may have come from the plain surrounding the crater. Since it was found about 150 km west of Meteor Crater, it probably was transported by Indians before white men entered the territory, like many other Canyon Diablo specimens of handy size.

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

39 g part slice (no. 1362, 5 x 4 x 0.5 cm wedge, cut from the specimen in New York)

Canyon Diablo (Bloody Basin), Arizona, U.S.A.

34°10′N, 111° 43′W

A mass of 5,174 g was discovered in 1964 and described by Buseck & Moore (1964) as the independent octahedrite Bloody Basin. As such, it was incorporated in Hey's catalog (1966: 59). The find, which was made in an Indian dwelling, must, however, be a transported mass of the mildly shocked variety of Canyon Diablo. This conclusion is based on the general circumstances of the finding, my structural examination, and the chemical analysis by Wasson which is given below. Independently, he reached a similar conclusion (1968).

Canyon Diablo (Camp Verde), Arizona, U.S.A.

34°34′N, 111°51′W; 1050 m

Coarse octahedrite, Og. Bandwidth 2.0±0.4 mm. Neumann bands. HV 164±4.

Group I. 7.16% Ni, 0.44% Co, 0.19% P, 78 ppm Ga, 322 ppm Ge, 2.0 ppm Ir.

Probably a transported Canyon Diablo fragment.

HISTORY

"On the top of a mesa a few miles east of Camp Verde, George E. Dawson came upon a stone cyst in the corner of an ancient Indian dwelling. Instead of finding a child burial as he expected, he found a 61.5 kg metallic meteorite wrapped in a feather-cloth." (Nininger & Nininger 1950: 106). Considerable pottery was found associated with the burial by which its age was determined as about 800 years (Nininger 1952a: 8). The meteorite was found about 1915 33 km south of Sedona and 85 km southwest of Meteor Crater, in Yavapai County. The approximate coordinates are given above. The ancient Indian cliff dwellings, Montezuma Castle, are about 7 km north of the find. While the find was briefly reported by A.D. Nininger (1940) and photographed by Nininger & Nininger (1950: plate 6) and Nininger (1952a: plate 1), it was only analyzed lately by Moore et al. (1969) and by Wasson (1968). Wasson

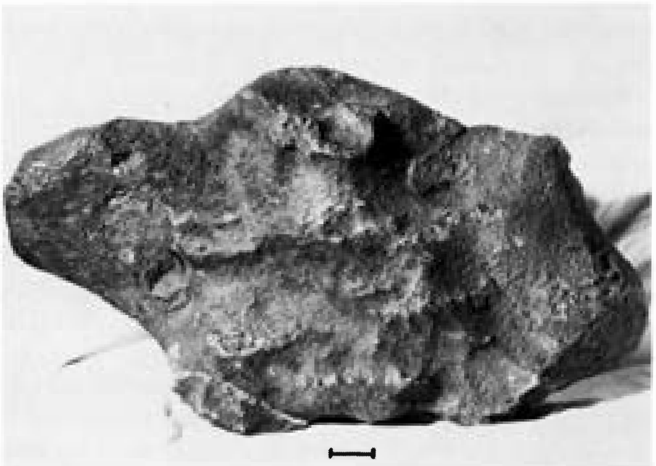

Figure 478. Canyon Diablo. The Camp Verde specimen of 61.5 kg (Tempe no. 440.1). This mass was probably transported by the Indians, and it was buried in a stone cyst, wrapped in a feather-cloth. Scale bar 4 cm. S.I. neg. 42350.

CANYON DIABLO (BLOODY BASIN) – SELECTED CHEMICAL ANALYSES

Reference	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1970a	6.79								81.6	320	2.0	

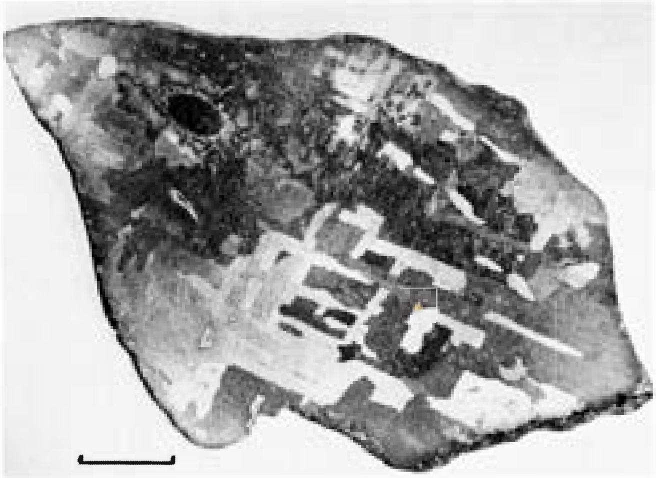

Figure 479. Canyon Diablo. Section through the end of Figure 478. (U.S.N.M. no. 1523, 433 g). Troilite with schreibersite and cohenite rims, and scattered schreibersite and cohenite skeleton crystals. Deep-etched. Scale bar 20 mm. S.I. neg. 42374A.

concluded on the basis of Ga-Ge-Ir contents, which were similar within analytical error to Canyon Diablo, that Camp Verde was a mass transported from the strewnfield of Meteor Crater.

COLLECTIONS

Tempe (58.3 kg, main mass; 400 g); London (671 g), Washington (541 g).

DESCRIPTION

The flat, somewhat oak-leaf shaped mass measures about 60 x 32 x 12 cm. It is smoothly rounded and distinctly different in its exterior appearance from the ragged, sharp-edged Canyon Diablo fragments. A close examination of the apparently well-preserved surface discloses that the meteorite has lost its fusion crust, regmaglypts and heat-affected α_2 zone, and that the troilite inclusions lie flush with the adjacent surface. The iron is, therefore, no doubt, of a considerable terrestrial age, having lost more than 3 mm of the surface on the average.

Etched sections display a coarse Widmanstätten structure of irregular, swollen, short ($\frac{L}{W} \sim 10$) lamellae with a width of 2.0±0.4 mm. As typical for group I irons one section may be almost inclusion free, while another section, one or two centimeters distant, may contain 1-3 cm troilite nodules and 4 x 3 cm^2 patches rich in cohenite crystals. The cohenite-rich lamellae usually have a bandwidth 25% smaller than the average width. On the other hand, a late grain growth has produced, in many inclusion-free places, irregular lobed α-grains up to 10 mm in diameter.

Neumann bands occur in the α-phase, frequently decorated by <1 μ phosphides. Subgrain boundaries, also decorated, are ubiquitous. The microhardness is 164±4, a hardness which is similar to that of many large Canyon Diablo specimens, e.g., Washington no. 210. Plessite is not prominent. One or two 1 mm fields per square centimeter are normal. They are spheroidized, or martensitic, or pearlitic with 0.5-2 μ wide taenite lamellae.

Schreibersite occurs as 30-80 μ grain boundary precipitates and as occasional 1-10 mm skeleton crystals. They are monocrystalline, but brecciated, and sheathed in 0.2-0.5 mm cohenite. Rhabdites of 1-10 μ are ubiquitous.

Troilite occurs as scattered nodules, 1-3 cm across. Irregular graphite patches occupy 0-40% by area of the troilite. As usual in group I, the troilite has nucleated a surrounding shell of 0.5-1 mm schreibersite (HV 925±25) and 0.2-0.5 mm cohenite. Locally, a couple of 100 μ cliftonite crystals were found, one of them developed around a 30 μ silicate crystal. The cohenite was, before the shock event discussed later took place, under decomposition to graphite. Apparently this decomposition started in cohenite fissures at the interface between cohenite and schreibersite and proceeded outward in the cohenite along the fissures, and, to a minor extent, along the cohenite-schreibersite interface. The result is a network of 5-15 μ microcrystalline graphite lamellae, often 500 μ long, in an envelope of 10-25 μ microcrystalline α-iron. The graphite between schreibersite and cohenite is only about 1 μ thick; a microcrystalline α-iron rim 3-5 μ wide separates the graphite from the cohenite.

The large cohenite-rich patches are of the usual group I form. Irregular, rounded, vermicular crystals of cohenite (HV 1080±30), 3 x 1 mm in size, occupy the central parts of slender kamacite lamellae and are often in contact with taenite.

A 10 mm troilite complex was closely examined. The central troilite has been shock melted (HV 225±15) and has sent minute veinlets out through 5-25 μ wide fissures in the surrounding schreibersite. The schreibersite and cohenite did not melt at the event but were partially disengaged and suspended as 5-100 μ angular fragments in the melt. Original daubreelite now occurs as 1-5 μ rounded, suspended grains that occupy about 10% by area of the troilite phase. The troilite itself is an aggregate of various grain sizes, from 1 μ-100 μ, and locally it contains eutectic, iron-rich parts. Since the shock-melted troilite has partially dissolved the microcrystalline α-iron around the graphite lamellae described above, the shock event must be later than the slow, diffusion-controlled process of cohenite decomposition.

CANYON DIABLO (CAMP VERDE) – SELECTED CHEMICAL ANALYSES

References	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1968	7.06								78	322	20	
Moore et al. 1969	7.25	0.44	0.19	60	20		130					

Camp Verde is an inclusion-rich coarse octahedrite which structurally cannot be distinguished from large Canyon Diablo fragments (stage III, page 394). Since Wasson (1968) and Moore et al. (1969) have found chemical identity to Canyon Diablo, it is probably safe to conclude that Camp Verde is a man-transported Canyon Diablo fragment. Camp Verde is, however, distinguished by its shape, being a smoothly rounded slab.

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

433 g slice (no. 1523, 16 x 9 x 0.5 cm)
108 g part slice (no. 1523, 11 x 8 x 0.2 cm)

Canyon Diablo (Ehrenberg), Arizona, U.S.A.

33°31'N, 114°32'W

A mass of 10 pounds was found near the town of La Paz, situated on the Colorado River in Yuma County, by H. Ehrenberg in 1862 (Whiting 1863). The locality was later renamed Ehrenberg, and the mass received the same name; the coordinates are given above. A brief description by Palache (1926a) indicated that it was a coarse octahedrite. It is not known where the main mass is, but 46 g is in Harvard and 11 g in Yale.

Recently, Wasson (1968) has shown that the chemical composition is identical, within analytical error, to Canyon Diablo, so he concluded that Ehrenberg was a transported sample from the area around Meteor Crater. I have reached a similar conclusion on the basis of structural observations. A 10 pound mass could easily be transported a distance of 300-350 km; moreover, the mass was apparently found close to one of the main routes from Arizona to California.
Herman Ehrenberg was a German mining engineer who, in 1854 and later with Charles D. Poston, "Father of Arizona," traveled through Arizona, prospecting and establishing new mines. Ehrenberg's interest in minerals no doubt put him on the trail of the native iron mass. It is interesting to note that the Ehrenberg mass was the first Canyon Diablo sample brought to scientific attention; however, this was not realized until a century later.

Canyon Diablo (Fair Oaks), Arizona, U.S.A.

A mass of 787 g, allegedly found on the surface of the ground by a hunter near Fair Oaks in 1937, was listed in the Meteoritical

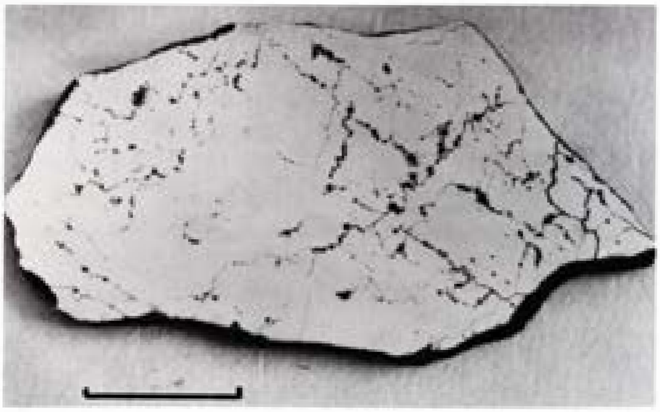

Figure 480. Canyon Diablo (Tempe & Copenhagen no. 34.4011). A lightly shocked sample. Cut in two, polished and then exposed to a normal indoor climate. Within a few weeks stained by rust along Widmanstätten grain boundaries. Chlorine ions are present in almost every stained spot. It appears that the chlorine ions penetrated along microfissures during long exposure to the terrestrial ground water. Scale bar 20 mm.

Bulletin (Number 33, 1965) and in Hey (1966: 158). The locality is reported to have the coordinates 34°44'N, 112°44'W and thus lies about 150 km west of Meteor Crater. However, since the structure is identical to Canyon Diablo, and Wasson (1968) has shown that the detailed chemical composition is also identical, within analytical error, it may be assumed that Fair Oaks is a transported specimen of Canyon Diablo. The entire mass is in Tempe.

Canyon Diablo (Helt Township), U.S.A.

Coarse octahedrite, Og. Bandwidth 2.4±0.5 mm. Partly recrystallized. HV 165±10.

Group I. 6.7% Ni, 0.45% Co, about 0.25% P, 80 ppm Ga, 1.2 ppm Ir.

Under no circumstances an observed fall in 1883. Rather a transported rim specimen of Canyon Diablo.

HISTORY

A mass of 218 g was found about 1920 in a mineral collection which had previously been owned by the state geologist of Indiana, John Collett, who died 1899. It was

CANYON DIABLO (EHRENBERG) – SELECTED CHEMICAL ANALYSES

Reference	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1968	6.98								79.9	314	1.8	

CANYON DIABLO (FAIR OAKS) – SELECTED CHEMICAL ANALYSES

Reference	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1968	7.08								81.8	318	1.9	

CANYON DIABLO (HELT TOWNSHIP) – SELECTED CHEMICAL ANALYSES

Reference	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Cobb 1967	6.69	0.45					158		80		1.2	

acquired by Perry in 1927 and fully described, with 17 photographs, later (1939a). Perry assumed that the meteorite had falled in 1883 or 1884 in Helt Township, Vermillion County, Indiana. The basis for this assumption was an old, incomplete label, with this text, and a letter from a nephew of Collett, who reported that a farmer had recovered this meteorite after having seen and heard it fall in 1883 or 1884. As will be shown below the story may be somewhat different.

Perry (1950) reproduced several of the photomicrographs, interpreting them as showing heat-affected rim zone with melted phosphides and preserved fusion crust. Cobb (1967) presented the only known analysis. Voshage (1967) found too low a concentration of potassium isotopes for an age determination.

COLLECTIONS

Washington (95 g), Chicago (50 g).

DESCRIPTION

Before cutting the mass had the overall dimensions of 7 x 6 x 1.5 cm and weighed 218 g (Perry 1939a). While 50 g of Perry's specimen was donated to Chicago, the remainder came to Washington. The Washington specimen is flat, with one full polished face of 5 x 4 cm, while the opposite side represents the natural surface. No fusion crust and no heat-affected zone are preserved. On the contrary, terrestrial corrosion has attacked the mass considerably and has created 0.1-1 mm thick, laminated oxides in which may be seen embedded rhabdites. The alleged sculpturing with thumbprints from atmospheric entry is rather the result of corrosional pitting, whereby one centimeter or more of the original skin has been lost. The meteorite probably has a considerable terrestrial age, and in any case it appears to be out of the question that it was observed to fall in 1883.

Etched sections display an indistinct coarse octahedrite structure of bulky, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 2.4±0.5 mm. Local grain growth of the kamacite has resulted in more or less equiaxial grains 5-10 mm across. Plessite covers about 2% by area, mostly in the form of acicular wedges. Taenite bands are common between the individual kamacite lamellae.

Schreibersite occurs as 3 x 0.4 and 1 x 0.3 mm skeleton crystals, enveloped in 2-3 mm swathing kamacite, and as 50-100 μ wide grain boundary precipitates. Rhabdites are common in the shape of prisms, 1-25 μ across. Unaltered troilite was not observed.

Thus, so far, Helt Township appears to be a normal coarse octahedrite of group I, closely related to, e.g., inclusion-poor specimens of Canyon Diablo.

Helt Township shows a number of secondary structural alterations which Perry (1939a; 1944), on account of the small size, ascribed to a significant heat penetration of the

Figure 481. Canyon Diablo. The Helt Township sample (U.S.N.M. no. 1323). The microstructure corresponds closely to that of shock-annealed samples of stage IV. Compare Figures 461-465. Etched. Scale bar 100 μ. (Perry 1950: volume 2.)

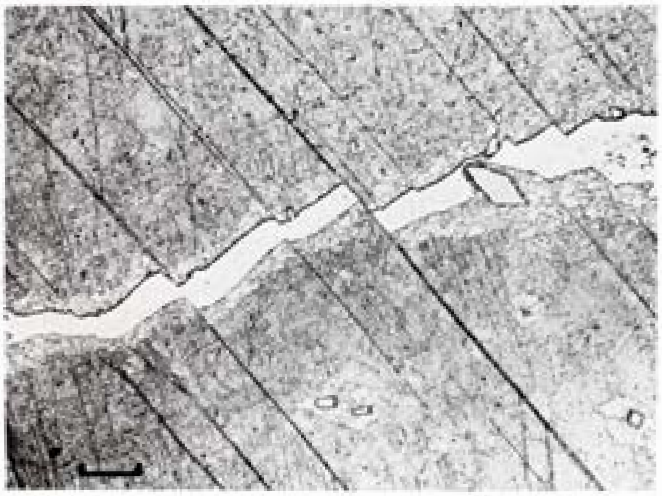

Figure 482. Canyon Diablo. As Figure 481. A taenite lamella which has been shear-displaced in a number of places. The black lines are not Neumann bands, but severely deformed kamacite. Etched. Scale bar 100 μ. (Perry 1944: plate 76.)

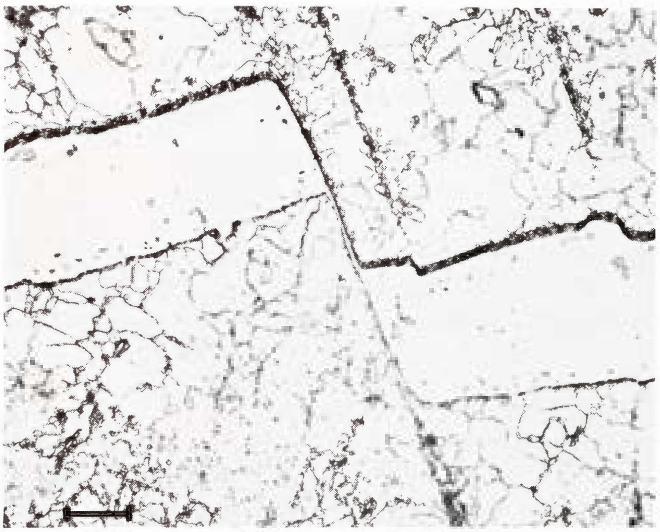

Figure 483. Canyon Diablo. As Figure 481. Detail of a sheared taenite lamella which was ductile enough to be drawn into a thin connecting bridge. Recrystallized kamacite. Etched. Scale bar 20 μ. (Perry 1944: plate 76.)

meteorite when it entered the atmosphere. If this was true, we would expect some kind of temperature gradient, as in Föllinge, with the outer parts heated to 1500° C and the inner parts to some lower temperature. No such temperature gradient can be found; all the matrix is rather uniformly converted to a mixture of recrystallized alpha grains and indistinctly preserved Neumann bands. The recrystallization is particularly well developed along grain and subgrain boundaries and around phosphide inclusions, leading to 10-100 μ units, often of columnar shape perpendicular to the nucleating boundary. Furthermore, the mass is beset with heavy plastic deformation. From a near-surface inclusion, now severely corroded, several sets of deformation bands visible to the naked eye spread over the etched surface. Heavy displacement of inclusions and plessite (Perry 1944: 76) has taken place here. Locally the heat generation had just been sufficient to micromelt the phosphides and sulfides which happened to lie in the shear planes. Since these micromelts may be found deep under the surface and only in connection with heavy shear zones, they cannot be from normal atmospheric ablation. The phosphides away from the shear zones show incipient resolution, with 1-2 μ diffusion haloes and with thorny edges protruding into the surrounding matrix. The microhardness of the metal is 165±10, increasing to about 210 in cold-worked shear zones. The taenite has a low hardness of 195±10, suggesting thorough annealing.

To sum up, we may state that Helt Township cannot have been observed to fall in 1883 but constitutes a corroded fragment of considerable terrestrial age. The observations on the structure lead to the conclusion that it is a severely shocked, coarse octahedrite which partly recrystallized as a result of the relaxation heat. In shear zones the heat input was sufficient to melt troilite and phosphides. The above described structure is relatively rare. It occurs in a minor number of the Canyon Diablo specimens, particularly in fragments found upon the crater rim (stage IV, page 394). Helt Township does, in fact, in its exterior morphology and size, in its macro- and microstructure and in its chemical composition, closely resemble these rim specimens of Canyon Diablo. Since we know so little of its early history we may, I think, assume that it is such a specimen which was acquired by Dr. Collett shortly before his death in 1899, and, therefore, was only insufficiently labeled.

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

85 g part slice (no. 1323, 6 x 4 x 1 cm)
10 g smaller sections (no. 1323)

Canyon Diablo (Houck), Arizona, U.S.A.
35°16′N, 109°16′W

A mass of 66.7 kg was found in 1927 in Section 30, Township 32 north, Range 30 east, of Apache County, and was acquired for the Chicago collection (Annual Report of the Field Museum of Natural History for 1928, Volume 7: 471). It was not examined before Wasson (1968) analyzed a small sample and suggested that Houck was a transported specimen from the Canyon Diablo crater field.

DESCRIPTION

I have examined the main mass and slices cut from it and can fully support the conclusion that Houck is another Canyon Diablo specimen.

The mass measures 33 x 30 x 20 cm and is slightly hat- or shield-shaped. At one end a 14 x 12 cm cut and etched surface indicates where an endpiece of about 1.7 kg measuring 14 x 12 x 2.5 cm, has been removed by the Field Museum. In another place a 6 x 4 cm surface indicates that a small sample has been removed at an earlier date, probably by the discoverer. Part of the surface, 25 x 12 cm in size, is only slightly corroded, displaying 2-4 cm regmaglypts and indistinct remnants of fusion crusts. On the average, less than 1 mm is lost here by weathering. In other places corrosion is severe and has, for example, excavated holes up to 4 x 2 cm in aperture and 5 cm deep.

Figure 484. Canyon Diablo. The so-called "Basket" specimen, weight 22 kg. Displays a convenient handle which has apparently invited theft. Up to about 1968 in Meteor Crater Museum but, according to a note by R.W. Barringer, it has since been stolen.

CANYON DIABLO (HOUCK) – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1968	7.1								80.5	330	1.8	

The fact that these holes are normally undercut strongly suggests that they are due to corrosion and were not previously present or ablated during the atmospheric flight.

Etched sections display a coarse Widmanstätten structure of straight, somewhat bulky ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.0±0.4 mm. Neumann bands are common. Taenite and plessite cover about 5% by area. Troilite occurs with 1 mm rims of schreibersite upon which 0.5 mm cohenite is precipitated. All other details of the structure comply with Canyon Diablo plain specimens.

It is unknown whether the mass was moved by Indians or by pioneers in more recent times. Houck is situated 160 km east of Meteor Crater, but the transport of a 67 kg mass over that distance should not present major difficulties.

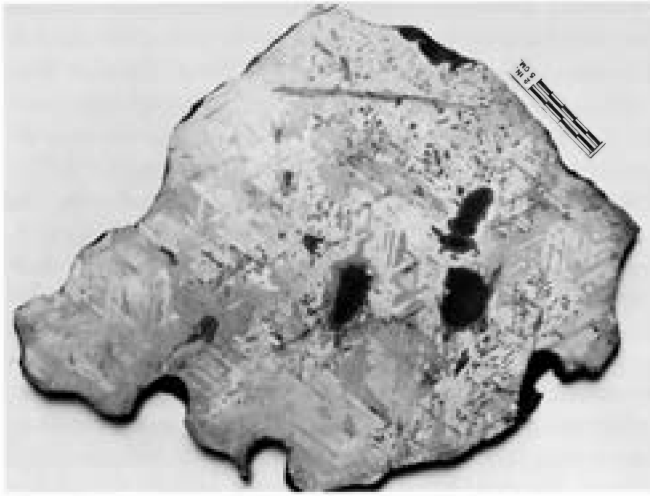

Figure 485. Canyon Diablo (U.S.N.M. no. 676). The Moab specimen (not shown) resembles this typical Canyon Diablo specimen, which is a 4.2 kg slice through a mass that originally weighed over 25 kg. Deep-etched. Scale bar 5 cm. S.I. neg. 38792.

Canyon Diablo (Moab), Utah, U.S.A.

38°3′N, 110°19′W; 1500 m

Coarse octahedrite, Og. Bandwidth 2.3±0.5 mm. Neumann bands. HV 180±15.

Group I judging from the structure. About 7.0% Ni, 0.2% P, 0.1% C.

The finding place is highly disputable; probably a transported Canyon Diablo mass.

HISTORY

A mass of 19.5 kg was found by C.M. Simms in 1954 between South Hatch Canyon and Fiddler Butte near the Colorado River in Garfield County. A Jeep trail was allegedly cut to the rather inaccessible place in order to retrieve the meteorite. It was purchased by Monnig, who, in a letter to the Smithsonian Institution on September 22, 1961, provided the above information and the coordinates which place the find about 90 km southwest of Moab. Mason (1962a) mentioned Moab in his list of meteorites.

COLLECTIONS

O.E. Monnig, Fort Worth (19 kg main mass), Washington (240 g).

ANALYSES

None. From structural observations the author would expect 7.0% Ni, 0.2% P and significant amounts of carbon, comparable to Canyon Diablo specimens.

DESCRIPTION

The slices in the U.S. National Museum show Moab to be a corroded meteorite. It is covered by 0.5-1 mm thick oxide crusts, and the fusion crust and the heat-affected zones are lost. Selective corrosion attacks the Neumann bands and the immediate surroundings of rhabdites and phosphides.

Etched sections display a coarse Widmanstätten structure of straight, bulky ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.3±0.5 mm. Grain growth has locally destroyed the regular pattern and has created 5-10 mm equiaxial grains. The kamacite has subgrain boundaries, decorated with 1-2 μ phosphides, and numerous, often very broad, Neumann bands. The microhardness of the interior is 180±15. Taenite and plessite cover 2-3% by area and are particularly common as residual 1 x 0.2 mm fields which are crisscrossed by pointed, 3-10 μ wide kamacite needles. Comb plessite and taenite with tarnished rims are also common.

Schreibersite occurs as 2-7 mm skeleton crystals which are enveloped by 300 μ wide cohenite rims. Schreibersite is further ubiquitous as 10-50 μ wide grain boundary veinlets. Rhabdites occur in two, or perhaps three, generations 50 μ, 5 μ and less than 1 μ in cross section. All the phosphides are monocrystalline but are sometimes displaced 1-2 μ by shear.

The cohenite is under decomposition to graphite and granulated ferrite. The graphite plumes extend as 2-5 μ wide lamellae in several directions through the cohenite. It resembles the decomposition stage reached in, for example, Wichita County and Camp Verde.

Moab is a coarse octahedrite, that, no doubt, belongs to group I. It closely resembles – so far as the few sections permit one to conclude – the inclusion-poor varieties of Canyon Diablo, and its general state of corrosion is also the same. The finder insists, however, that it was found on the floor of a canyon 340 km north of Meteor Crater (Monnig, personal communication).

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

168 g slice, close to one end (no. 2067, 17 x 6 x 0.4 cm)
72 g slice (no. 2067, 9 x 5 x 0.3 cm)

Canyon Diablo (Otasawian)

See Otasawian in the Supplement.

Canyon Diablo (Pulaski County fragment), Georgia, U.S.A.

Coarse octahedrite, Og. Bandwidth 1.8±0.5 mm. Partly α_2 structure. HV 170±10.

Group I. About 7.0% Ni, 0.2% P.

HISTORY

A small mass of 116 g was said to have been found in a pasture in Pulaski County, Georgia, in 1955. It was brought to the Department of Mines, Mining and Geology in Atlanta, Georgia, by John Peterson of Hapeville and was identified as a meteorite by Henderson & Furcron (1957) who briefly described it. The specimen, which had been returned to its owner, was later obtained by Hugh H. Howard, a collector, and was finally, in 1959, purchased by the U.S. National Museum. A letter from Howard, dated July 14, 1958, to Dr. A.S. Furcron reports the locality as near Hawkinsville with the coordinates 32°20'N, 83°32'W.

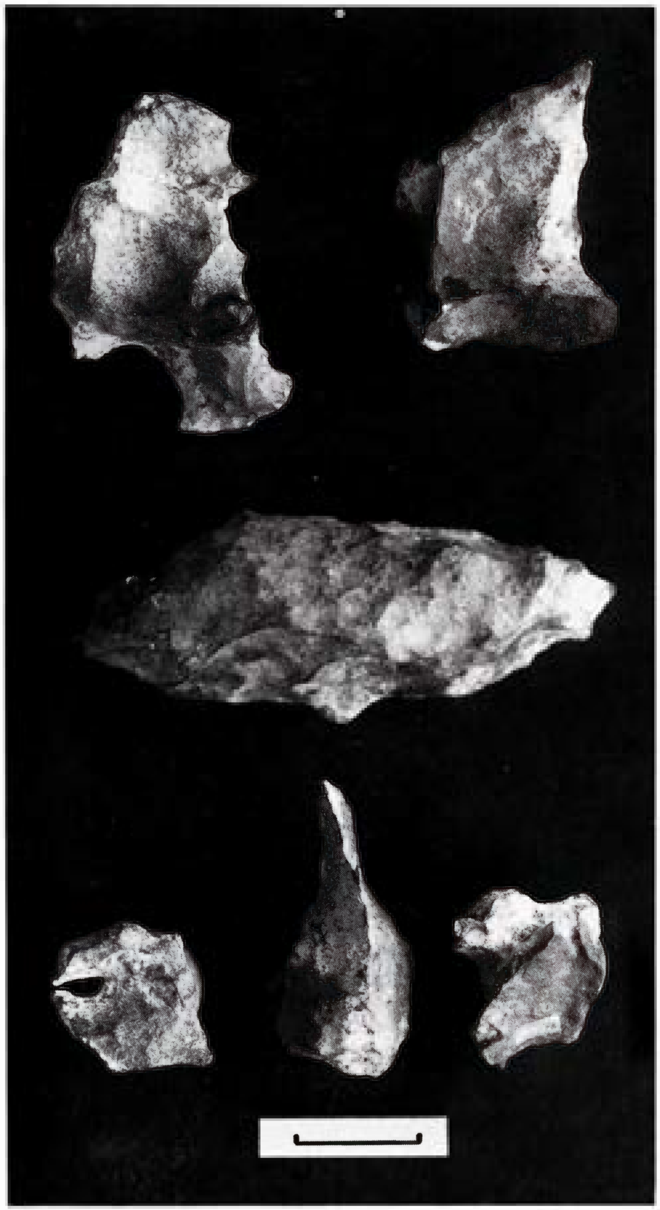

Figure 486. Canyon Diablo. Six characteristic slugs, or explosive fragments, collected around Meteor Crater. Sharp edges and reentrant angles are common. Scale bar 40 mm. (Merrill & Tassin 1907: plate 21.) S.I. neg. 20035.

COLLECTION

The whole specimen is in Washington.

ANALYSIS

No analysis has been performed. From the structure, I would estimate the meteorite to contain 7.0% Ni, 0.2% P and significant amounts of carbon, with trace element quantities placing it in the chemical group I close to Canyon Diablo.

DESCRIPTION

The mass is a flat, sharp-edged fragment with the average dimensions of 5.5 x 4.5 x 1.5 cm. It is weathered and covered with a crust of terrestrial oxides 0.1-1 mm thick. No fusion crust and no heat-affected α_2 rim zone are present. In its exterior shape and state of corrosion it closely resembles the typical specimens found around Meteor Crater in Arizona.

Etched sections reveal a coarse Widmanstätten structure of bulky, short ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.8±0.5 mm. The bands are narrowest in the cohenite-rich parts. The kamacite exhibits a confusing mixture of Neumann bands, cold-worked shear zones and α_2 structure, with the latter component constituting more than half of the small sections. The microhardness is 170±10, increasing in the cold-worked areas to 220±10.

Taenite and plessite cover 5-10% by area, mostly as comb plessite or as narrow taenite ribbons closely associated with cohenite crystals. The taenite is remarkably soft (HV 195±15), probably because it is annealed, but it frequently contains high-carbon, high-nickel, acicular martensite interiors with a hardness of 425±25. Some pearlitic areas, with 0.5-1 μ wide taenite lamellae, are also present. In several places the taenite and plessite fields are sheared.

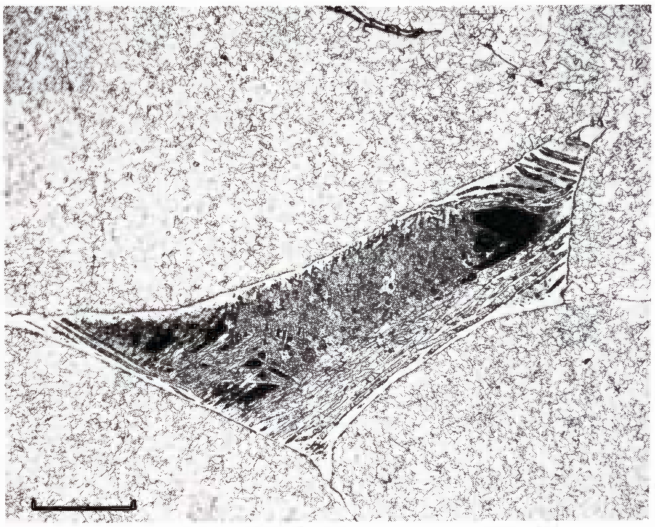

Figure 487. Canyon Diablo. Comb plessite with dark, unresolvable plessite wedges. Recrystallized kamacite. Structure of a small, but unspecified slug, like any of those in Figure 486, or Pulaski County. Etched. Scale bar 400 μ. (Perry 1950: volume 1.)

Schreibersite occurs as 20-50 μ wide grain boundary precipitates and as tiny blebs included in cohenite. Cohenite is a dominating mineral, covering about 5% by area as small, rounded crystals aligned after the Widmanstätten structure. The crystals are typically 2 x 0.5 mm in cross section and have a hardness of 1150±50. Tiny windows of kamacite, taenite and schreibersite are common. The crystals are somewhat sheared, and heavy plastic deformation is present in the adjacent kamacite.

The structure suggests that Pulaski County was violently detached from its parent mass, probably by a crater-forming event. It was irregularly reheated to about 800° C for a brief period, whereby the cold-worked matrix was partially transformed to polycrystalline austenite which, upon renewed cooling, formed serrated α_2 units. Such structures are only known from fragments of large meteorites, particularly from Canyon Diablo. Since Pulaski County in all other respects also closely corresponds to this fall and since the original report of the discovery, at best, appears little trustworthy, I conclude that Pulaski County is a man-transported rim specimen of Canyon Diablo.

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

88 g main mass (no. 1766, 4 x 4.5 x 1.5 cm)
20 g polished endpiece (no. 1766, 4 x 1.5 x 0.8 cm)

Canyon Diablo (Rifle), Colorado, U.S.A.

39°31'N, 107°50'W

A mass of 102.7 kg was allegedly found in 1948 near Rifle, Garfield County, and was described as the independent coarse octahedrite, Rifle (Nininger & Nininger 1950: 127; plate 18). According to a note in the Smithsonian Institution, the finder, Harry M. Morre of Rifle, maintained that the specimen had been found about six miles from Rifle. However, Dr. E.P. Henderson suspected it to be just another Canyon Diablo specimen. Maringer & Manning (1962) noted in passing the softly bent Neumann bands and rhabdites and gave a photomicrograph. Bollman & Maringer (1964) examined the graphite nodules and found indications of a particle bombardment by cosmic neutrons. Wasson (1970a) assumed that Rifle was an independent meteorite and gave a photograph of the large etched section in U.S. National Museum.

COLLECTIONS

Tempe (25.8 kg), London (21.77 kg), Washington (2.7 kg), D.M. Gillespie's private collection (51.1 kg).

DESCRIPTION

An examination of the specimens in Tempe, London and Washington, shows that the Rifle material is a typical Canyon Diablo specimen of the plains type. There is no point in giving a full description, since the structure corresponds in all details to what has already been described under Canyon Diablo, Stage I. I will, however, particularly draw attention to the large complex graphite-iron nodule of 4 cm which is a hallmark of Canyon Diablo and has never been reported for any other iron meteorite. The analytical data are, within experimental error, identical to those of Canyon Diablo.

It must be concluded that Rifle is another of those transported fragments from the Meteor Crater field. However, it is not known when this occurred. The distance between Meteor Crater and Rifle is 600 km as the crow flies, but Rifle is situated on Highway 70, and the automobile was invented long before the 100 kg mass was "discovered."

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

2.7 kg full slice (no. 1705, 39 x 18 x 1 cm)
1.6 kg slice (no. 1705)

CANYON DIABLO (RIFLE) – SELECTED CHEMICAL ANALYSES

References	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	7.30	0.47	0.16	1775	25		140					
Wasson 1970a	7.20								77.2	281	1.7	

Canyon Diablo (Schertz), Arizona, U.S.A.

A mass of 308 g was listed in the "Catalogue of Texas Meteorites" (Barnes 1939a: 601) as coming from Schertz, Guadalupe County. After quite a lot of detective work, Monnig (1941) succeeded in proving that it was a transported Canyon Diablo fragment. Not only did he establish this fact, but he also divulged that a large shipment of iron meteorites from Canyon Diablo was sent to Schertz about 1893, and that all of these irons were subsequently abandoned or

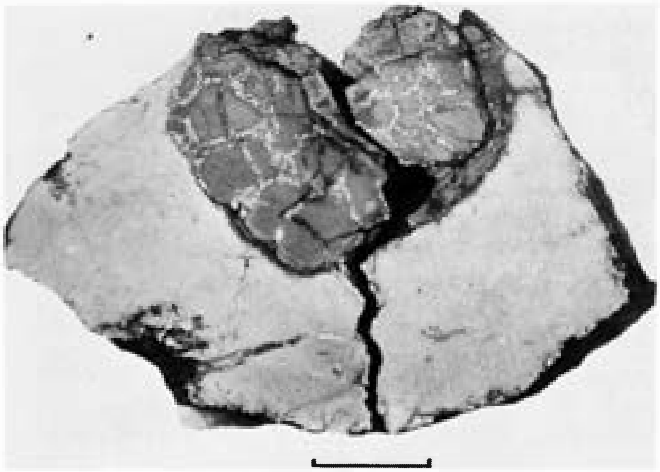

Figure 488. Canyon Diablo (U.S.N.M. no. 807). In the Rifle specimen, Figure 197, and in some other Canyon Diablo samples, very peculiar graphite nodules occur. They contain a network of granulated kamacite, and their origin is obscure. The specimen shown here is unfortunately broken and now partly lost. Polished. Scale bar 30 mm. S.I. neg. 28947.

lost except one piece of some 80 kg (175 pounds), which was relocated in Yorktown, Texas.

The collector responsible for the shipment was a Mr. Haberle who was employed by a railroad company and assisted in the construction of water tanks on the line to California. He had evidently acquired the numerous samples, estimated to consist of five or six large masses and a large number of smaller ones, shortly after Foote (1891) had announced the discovery and initiated the systematic search for samples around Meteor Crater. Mr. Haberle was, however, less successful than Foote in transforming the meteorites into money since he was unable to sell them, and they were finally abandoned in a storage building which was later demolished.

Canyon Diablo (Wickenburg), Arizona, U.S.A.

33°58'N, 112°44'W

A mass of 250 g was preliminarily listed as Wickenburg by A.D. Nininger (1940) and Nininger & Nininger (1950). The size, shape and structure suggested, however, that the Wickenburg mass was a transported sample from the vicinity of Meteor Crater. This was confirmed by Wasson (1968) who reported 7.07% Ni, 82.6 ppm Ga, 321 ppm Ge and 1.8 ppm Ir, values which are identical to Canyon Diablo, within analytical and sampling error.

COLLECTIONS

London (50 g), Tempe (47 g). The 1.5 kg sample listed by Hey (1966: 519) as being in Chicago is a specimen of the *chondrite* Wickenburg (stone).

Cape of Good Hope, Cape Province, South Africa

Approximately 33½°S, 26°E

Nickel-rich ataxite, D. Duplex $\alpha + \gamma$ with broad twins and a few 30 μ wide α-spindles. HV 244±8.

Group IVB. 16.32% Ni, 0.84% Co, 0.12% P, 0.20 ppm Ga, 0.06 ppm Ge, 36 ppm Ir.

HISTORY

A mass of about 300 pounds (135 kg) was found in the Dutch Cape Colony on a plain east of the Great Fish River close enough to the coast so that it was assumed to be part of a ship's anchor carried away by the Kaffers (Barrow 1801: 225-26). According to Dankelmann (1805) the mass had been transported to Capetown by the soldier-adventurer Carl Sternberg, from whom Dankelmann acquired a fragment of 84 kg on behalf of the Dutch government. Sternberg told that he had found the mass himself in 1793 about five miles from the coast between two small rivers, Karega and Gasoga. Although Dankelmann assumed these to be nonexistent, they may be located on Barrow's map (1801: volume 1) as Kareeka and Kasowka, about 750 km straight east of Cape of Good Hope, near the present-day Port Alfred. Dankelmann did not believe Sternberg's story and discovered later by actual travel and inquiry in the region that the mass had been found by a farmer, Royen, long before 1793, farther west, but still about 700 km east of Cape of Good Hope. The locality was on a plain northeast of Swartkops River between Sondags and Boesmans Rivers. Since this version of the find appears to be the most plausible, the corresponding coordinates are given above. Royen's father had from time to time dislodged fragments from the mass and forged hoes and plowshares, and the family regretted very much that they had disposed of their iron lump, since iron was difficult to acquire.

While 84 kg arrived in Haarlem in 1803 and was described as meteoritic by Marum (1804), another large fragment came to London where Tennant (1806) confirmed its meteoritic nature by finding 10% Ni in an analysis. The mass proved to be malleable and very ductile so that James Sowerby in 1814 was able to forge a slightly curved sword, 60 cm long and 3.5 cm wide, from it. The sword was presented to Czar Alexander in gratitude for Russia's stand against Napoleon. "The blade has been hammered at a red heat, without admixture, out of a single piece of this iron, an inch thick, ground and polished. Its spring was given it by hammering when cold. The haft was lengthened by welding on a small piece of steel. It was found to work very pleasantly, the whole operation taking about ten hours." (Sowerby 1820). An attempt in 1937 to trace the whereabouts of this sword resulted in a negative reply from Dr. J. Astapowitsch, of the Sternberg Astronomical Institute of Moscow (Khan: 1944). In the British Museum, however, a few specimens (no. 15143; no. 1935, 47) of forged material from Sowerby's experiments are still preserved.

Stromeyer (1817) found cobalt in the iron, and Chladni (1819: 317; 331-33) reviewed the older literature. In the nineteenth century, Cape of Good Hope was

CAPE OF GOOD HOPE – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wöhler in Rose 1864a	16.22	0.73	0.15									
Fahrenhorst in Cohen 1900a; 1905	15.67	0.95	0.09	300		400	300					
Goldberg et al. 1951	16.48								0.43			
Nichiporuk & Brown 1965											8.5	11.8
Schaudy et al. 1972	16.92								0.198	0.059	36	