solution after the formation of the structure. No rhabdites proper were observed.

Troilite occurs as scattered, small nodules which all show the effect of shock melting. A typical 100 μ bleb has fringed borders against the kamacite and is solidified to a 1-2 μ grain aggregate in which small amounts of schreibersite and metal are dispersed. Troilite also occurs as rounded pockets enclosed in the larger schreibersite crystals. Such pockets have sharp edges, do not contain metal and are solidified to somewhat coarser aggregates. The adjacent schreibersite is penetrated by 2-10 μ wide cracks which usually are completely filled with injected, microcrystalline troilite. Unfortunately, terrestrial corrosion obscures the situation somewhat.

Graphite is an important accessory mineral, occurring as angular and spherulitic aggregates, associated with schreibersite and a little troilite. The best crystallized units are 50-100 μ across and may be termed cliftonite, but most of the graphite blebs are spear-shaped or spheroidized and easily break out during polishing.

Due to the few and small specimens preserved it has not been possible to obtain a clear structural picture of Livingston (Tennessee), but it is certainly anomalous by its small bandwidth on the 7.4% Ni level, by its high-carbon content as manifested by the graphite crystals, and by the partial recrystallization that has modified the kamacite and the taenite significantly. The troilite indicates that some shock melting took place, so it is possible that the mass recrystallized assisted by the relaxation heat. After full recrystallization and phosphide precipitation in the boundaries another shock – a milder one – created the Neumann bands, and in due time even these became annealed and decorated. Evidently Livingston must have had a complex history. No direct relationship to other meteorites can be observed, but some of its features do occur in, e.g., Morrill, Kendall County, Murnpeowie, Santa Rosa, Willamette and Mundrabilla.

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

98 g endpiece (no. 1420, 4.5 x 3 x 0.5 cm)
10 g slice (no. 1420, 3 x 2.5 x 0.2 cm)

## **Locust Grove**, Georgia, U.S.A.

33°20′N, 84°6′W.

Hexahedrite, H. $\alpha_2$ matrix and micromelted phosphides and sulfides. HV 152±15.

Group IIA, judging from what remains of the original structure. 5.63% Ni, 0.54% Co, 0.25% P, 60.6 ppm Ga, 180 ppm Ge, 7.5 ppm Ir.

The whole mass has been reheated artificially to about 1000° C.

### HISTORY

A mass of 10.3 kg was found in 1857 near Locust Grove, in Henry County. It was in private possession until 1895 when B. Stürtz, in Bonn, acquired and cut it. A full description was given by Cohen (1897e; 1905: 44) who found it structurally similar to Siratik and Campo del Cielo but had difficulties in identifying the structural elements. Klein (1906: 106) noted the similarity to Chesterville, and so did Perry (1944) who presented seven photomicrographs. Perry discussed the unique inclusions, apparently caused by rapid solidification of phosphorus and carbon-bearing melts, but it did not occur to him that the structures could be artificial. Henderson & Furcron (1957) reproduced some of Perry's photographs but did not reach a conclusion as to the peculiar structures. Buchwald (in Hey 1966: 275) noted that the specimens he had examined in Prague and Vienna suggested an artificial heat treatment. This is now confirmed after examination of specimens in

**Figure 1079.** Locust Grove (Vienna no. G8418). An 8 mm thick slice, somewhat flattened by forging. The structure is entirely altered from that of a normal hexahedrite, due to artificial reheating above 1000° C. Deep-etched. Scale bar 20 mm.

LOCUST GROVE – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Sjöström in Cohen 1897e | 5.57 | 0.64 | 0.18 | 325 | 500 | | tr. | | | | | |
| Lewis & Moore 1971 | 5.77 | 0.43 | 0.31 | 20 | | | | | | | | |
| Wasson 1971, pers. comm. | 5.55 | | | | | | | | 60.6 | 180 | 7.5 | |

Berlin, Tempe and Washington. All specimens indicate that the mass was reheated as a whole, before it was acquired by Stürtz and cut. Reed (1969) examined the composition of the kamacite with the electron microprobe.

## COLLECTIONS

Washington (2,166 g), Bonn (958 g), London (557 g), Vienna (381 g), Chicago (370 g), Leningrad (333 g), New York (325 g), Tübingen (250 g), Tempe (212 g), Berlin (174 g), Prague (171 g), Ann Arbor (148 g), Greifswald (120 g), Harvard (94 g), Strasbourg (72 g), Amherst (46 g).

## DESCRIPTION

The club-shaped mass was 24 cm long, 10 x 9 cm thick at one end and at the other end approximately 9 x 6 cm thick. It was cut in more or less parallel slices and widely distributed after 1897. The endpiece in the U.S. National Museum shows a weathered crust, but the original regmaglypts, 15-30 mm in diameter, are still preserved as shallow depressions. There are a few hammer and chisel marks. The small endpiece in Tübingen (no. 9112216, 250 g) shows significantly more artificial damage, and areas as large as 6 x 4 $cm^2$ are flat-hammered and chisel-marked. Cohen (1897e) reported that Locust Grove was a witnessed fall in 1857, but he doubted the fact; and the amount of corrosion present would also indicate that the fall is of much greater age.

On sections no heat-affected rim zone is found. It appears as if the whole mass is rim zone. The metallic matrix is composed of serrated and lobed $\alpha_2$ units, which are quite large, 0.2-0.7 mm in diameter. In these are situated numerous phosphide-rich melts, vaguely indicating the location of preexisting rhabdites. The structure is closely related to the artificial structures obtained by air cooling of iron alloys with 6% Ni and 0.2% P, which have been heated at 1100° C (Buchwald 1966). A further indication that the mass has been artificially reheated is the general and rather uniform reheating to the center of the mass. If the structure had been caused by ablational reheating in the atmosphere, some kind of gradient from the surface inwards would be expected, with the 1000° C isotherm located only a few millimeters under the surface. Here it appears that the whole mass was above 1000° C. The hardness is 152±15 with somewhat erratic jumps because the artificial heat treatment was too brief for homogenization to occur.

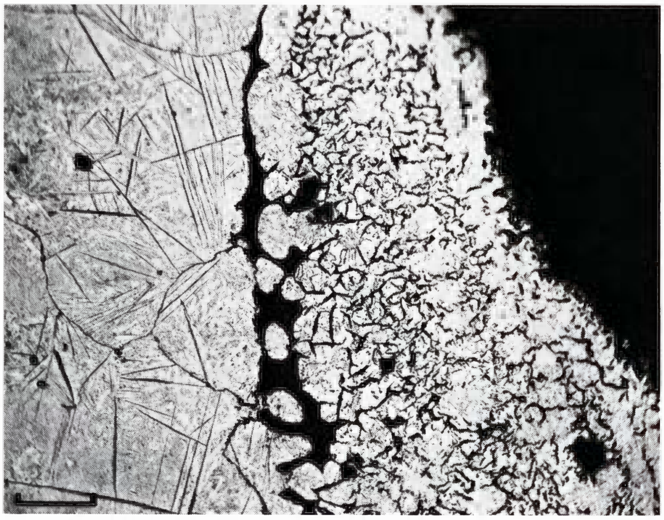

**Figure 1080.** Locust Grove (U.S.N.M. no. 538). Artificially reheated to above 1000° C. Edge of a former troilite-schreibersite-cohenite inclusion, now entirely melted and resolidified to a structure which resembles cast iron with flake graphite. To the left altered kamacite. Etched. Scale bar 50 $\mu$. (Perry 1950: volume 8.)

Since there was the remote possibility that the structure was the result of cosmic shock followed by reheating, the corroded surface was examined. This displays a high temperature intercrystalline attack, where iron-sulfur-oxygen eutectics penetrate some millimeters along the grain boundaries. There are also complicated reaction products, presumably from high temperature reactions between terrestrial corrosion products and meteoritic minerals. Finally, there are numerous gasholes, perhaps caused by the degassing of limonitic minerals at high temperature. While the exact mineralogy is less important, we are able to conclude definitively that the mass corroded before it was reheated. Since no report from the original owners of the mass indicate anything else than Locust Grove was a well-preserved specimen, observed to fall in 1857, the reheating comes as something of a surprise; therefore, the proofs have been elaborated upon somewhat, and many different specimens have been checked, all leading to the same result.

As far as can be judged from the preserved structure Locust Grove was originally a hexahedrite, probably a single crystal like Walker County or Coahuila. It contained angular schreibersite crystals, in sizes up to 5 x 1 mm, and a profusion of rhabdites, 5-15 $\mu$ in cross section. Many rhabdites were 4-6 mm long and only 10 $\mu$ thick. The rhabdites were rather evenly dispersed and not arranged in parallel rows. Scattered troilite nodules, 1-4 mm in diameter, were common, and these had served as nuclei for

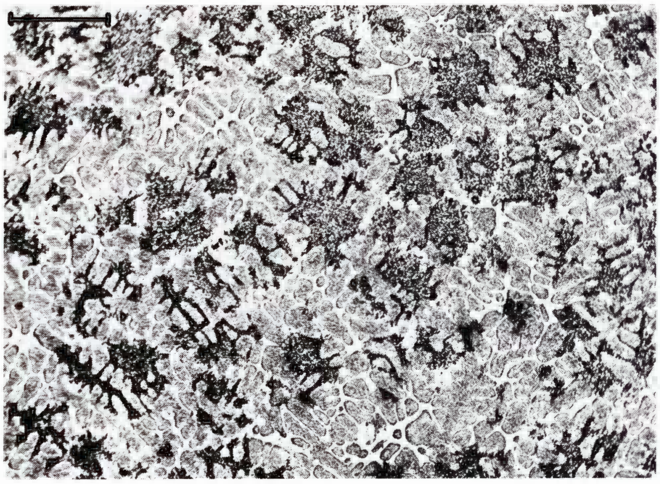

**Figure 1081.** Locust Grove (U.S.N.M. no. 538). Interior of a former troilite-schreibersite cohenite inclusion. Graphite nests, martensitic iron dendrites and eutectic iron phosphides (white). Etched. Scale bar 200 $\mu$. (Perry 1944: plate 65.)

precipitating schreibersite, often forming star or rosette shapes. A little cohenite was probably also present, since some inclusions now display structures which contain martensite, ledeburite, and even free graphite, in the form of flakes otherwise only seen in gray cast irons (ASTM type D). The presence of graphite or cohenite in hexahedrites is, as shown herein, quite widespread (Bingera, Coahuila, Forsyth County, Walker County and many others), although the minerals occur only as accessory constituents. Locust Grove may structurally and chemically have been related to Gressk, Coahuila and the North Chilean group of hexahedrites.

Unfortunately, all details of the structure were destroyed, when a heat treatment estimated to last about half an hour at 1000° C, micromelted all inclusions, partly dissolved the phosphides and created $\alpha_2$ transformation structures upon cooling. The crucial proof lies in the heat-affected corrosion products and the high temperature, intercrystalline surface attack. It is understandable that Cohen (1897e), Klein (1906) and Perry (1944) compared Locust Grove to Siratik, Campo del Cielo, Cincinnati, San Francisco del Mezquital and Chesterville, since all of these are artificially reheated meteorites, which fact, however, was not known at that time.

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

163 g slice (no. 538, 9 x 6 x 0.5 cm)
187 g wedge-shaped part slice (no. 2884, 4.5 x 3 x 2 cm)
1,816 g endpiece (no. 2885, 10 x 8 x 4 cm)

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## **Lombard**, Montana, U.S.A.

46°6'N, 111°24'W

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Hexahedrite, H. Rhabdites in parallel planes. Neumann bands. HV 185±10.

Group IIA. 5.65% Ni, 0.42% Co, 0.28% P, 58 ppm Ga, 174 ppm Ge, 2.3 ppm Ir.

### HISTORY

No details of this find have been published. It appears that a mass of about 7 kg was found near Lombard, in Broadwater County, and was recognized as a meteorite in 1953 by Nininger who acquired it. A significant portion is in the possession of the American Meteorite Laboratory, Denver, but a certain part has been cut in 5 mm thick slices and sold since about 1956. Herr et al. (1961) determined the osmium and rhenium concentrations, and Hintenberger et al. (1967) determined the occluded, noble gases. The cosmic ray exposure age was found to be 290±30 million years by the $^{36}$Ar/$^{36}$Cl method (Vilcsek & Wänke 1963); but later it was found to be 160±40 million years by the $^{36}$Ar/$^{10}$Be method, and the first value was discarded as being affected by a high terrestrial age (Chang & Wänke 1969). Voshage (1967) estimated the exposure age as 295±200 million years from the $^{40}$K/$^{41}$K method. The terrestrial age was estimated as $230{,}000^{+150{,}000}_{-110{,}000}$ years (Chang & Wänke 1969).

### COLLECTIONS

London (292 g), Mainz (about 250 g), Perth (83 g), Chicago (79 g), Tempe (76 g), Tübingen (about 75 g), Washington (62 g).

### DESCRIPTION

The slice in the U.S. National Museum measures 6 x 3 x 0.5 cm and represents a full section through the mass. It shows a corroded surface with 0.1-1 mm thick, terrestrial oxides; and no fusion crust or heat-affected $\alpha_2$ zone are preserved. Corrosion has particularly attacked the phosphorus-depleted regions around the rhabdites, but the attack does not penetrate more than a few millimeters from the external surface, except where long, brecciated rhabdites provide an easy access for the terrestrial ground water.

Lombard is a single kamacite crystal which, however, displays numerous subboundaries, decorated with 0.5-1 $\mu$ thick rhabdites. Neumann bands cross the entire sections with few interruptions. Schreibersite occurs as scattered skeleton crystals, 0.5-2 mm across. Rhabdites are conspicuous, both as prisms and thin lamellae. A large portion of them are arranged ~~in~~ parallel planes, spaced with irregular intervals of 6-20 mm. The individual rhabdite plates in the planes are 25-100 $\mu$ wide and about ten times as long. From some of the rhabdites other rhabdites of comparable sizes branch off. The texture and morphology closely resemble what is found in, e.g., Hex River and Uwet. Between the rows is a large population of finer rhabdites, ranging from 5-40 $\mu$ in thickness. The phosphides are monocrystalline, but most of the larger ones are brecciated and show step-wise shear displacements, with individual steps of about 10 $\mu$. The cold-worked kamacite has a hardness of 185±10.

While the U.S. National Museum specimen does not contain larger inclusions, the author has upon other specimens found troilite-daubreelite inclusions, 2-10 mm in size.

**LOMBARD – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Moss in Hey 1966 | 5.6 | | | | | | | | | | | |
| Wasson 1969 | 5.59 | | | | | | | | 58.0 | 174 | 2.3 | |
| Lewis & Moore 1971 | 5.75 | 0.42 | 0.28 | 50 | | | | | | | | |

Scattered through the alpha phase there occur, with a high frequency, tiny, hard plates, approximately 20 x 0.5 μ in size. They are uniformly oriented precipitates and identical to the chromium nitride, carlsbergite, seen in Costilla Peak, Cape York and Schwetz.

Lombard is a weathered, monocrystalline hexahedrite. Its prominent characteristic are the numerous rhabdites which are arranged in parallel planes. It is structurally and chemically closely related to Hex River and Uwet. Its relatively high hardness probably reflects a slight cosmic cold-deformation.

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

62 g slice (no. 1684, 6 x 3 x 0.5 cm)

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## **Lonaconing**, Maryland, U.S.A.

Approximately 39°40′N, 79°0′W

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Anomalous, coarse octahedrite, Og. Bandwidth 2.0±0.3 mm. Neumann bands. HV 160±5.

Anomalous. 9.7% Ni, 23.5 ppm Ga, 62.1 ppm Ge, 0.9 ppm Ir.

### HISTORY

A mass of 1.3 kg (45 oz.) was plowed up in 1888 by a boy in Garrett County, Maryland. It was acquired by Foote and briefly described by him with a photomacrograph and a photograph of the exterior (1892). The locality is only given very inaccurately as "12 miles from the Post Office of Lonaconing, not far from the boundary." "The boundary" could be the Maryland-West Virginia boundary, which is within this distance, south of Lonaconing, and this interpretation is used by Ward (1904a: 16), Reeds (1937: 590) and Hey (1966: 276). It might, however, also be the Maryland-Pennsylvania boundary, the Mason-Dixon line, which lies about 12 miles north of Lonaconing. Since Foote in the preceding paragraph talks of the Maryland-Pennsylvania boundary, and since the Mason-Dixon line is more apt to be called "the boundary," it is here concluded that the finding place was about 12 miles north of Lonaconing, in Garrett County, corresponding to the coordinates given above. Brezina (1896: 287) gave a short description of the Vienna slices. According to Wülfing (1897: 213) the main mass of 819 g was purchased by the École des Mines in Paris.

### COLLECTIONS

École des Mines, Paris (about 600 g), Vienna (133 g), Paris (127 g), New York (99 g), London (74 g), Chicago (39 g), Washington (24 g).

### ANALYSES

A preliminary analysis by Koenig showed over 11% of nickel and cobalt (Foote 1892). A new analysis is needed, since the nickel content appears to be significantly overestimated. Wasson (1974, personal communication) found 9.7% Ni, 23.5 ppm Ga, 62.1 ppm Ge and 0.9 ppm Ir.

### DESCRIPTION

The mass is in the shape of a smoothly curved, somewhat flattened cylinder with the approximate length of 10 cm and a cross section of 6 x 5 cm. The fusion crust has been removed by corrosion, but the heat-affected rim is preserved as a conspicuous zone, 4-6 mm wide. Micromelted phosphides are present to a depth of 2-3 mm. Corrosion has attacked the mass superficially, especially converting the α-phase of the plessite to "limonite," but it has also penetrated to the center of the mass along certain grain boundaries and phosphide inclusions, presumably aided by the gradients in the nickel-depleted zones and by the brecciated character of the phosphides.

Etched sections display an anomalous Widmanstätten structure with rather few, but very broad, kamacite lamellae. The lamella width is 2.0±0.3 mm, and the length-width ratio is about 15. Neumann bands are common, and so are subboundaries, which are decorated with 1-2 μ rhabdite precipitates. The hardness is 160±5; it increases in the heat-affected $\alpha_2$ zone to 195±8 (hardness curve type III). The hardness of 160 was found at all depths below 8 mm; the low hardness appears in part to be due to annealing or recovery of the small mass during the atmospheric penetration.

The taenite and plessite fields, which cover 40-50% by area, are large and display a secondary Widmanstätten structure where the individual alpha lamellae of the comb plessite are 0.1-0.2 mm wide. Other coarse octahedrites with a bandwidth about 2 mm show a quite different development and amount of the intervening fields; compare, e.g., Hope, Bischtübe or Canyon Diablo. The taenite rims (HV 260±20) around the plessite are often very broad in Lonaconing, 40-80 μ, and frequently contain 1-2 μ wide kamacite needles. Following the rim zone is a martensitic zone with individual platelets lined up along the octahedral directions (HV 320±20); and following this are various grades of duplex $\alpha + \gamma$, often rather coarse-grained. They range in hardness from 275 for the fine-grained to 175 for the coarse-grained varieties.

Schreibersite occurs as 100-200 μ skeleton crystals, enveloped in kamacite, and, further, as 20-100 μ wide grain boundary precipitates, and as 5-30 μ irregular, concave bodies inside the plessite fields. Locally a few 1-2 μ rhabdites occur. The schreibersite is monocrystalline but brecciated. The bulk phosphorus content is estimated to be about 0.25%.

Troilite was only observed as 10-100 μ blebs, associated with or enveloped by the larger schreibersite crystals. The troilite is a polycrystalline aggregate of 10 μ units and contains about 10% daubreelite, in the form of short, parallel bars. A single 100 μ chromite crystal was observed.

Cohenite has been reported by Brezina (1896), but this seems to be an error. The carbon content of Lonaconing is probably low, lower than in group I. and comparable to group III. Lonaconing is structurally and chemically anomalous.

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

24 g slice (no. 1360, 5 x 4 x 0.15 cm; the type specimen of Foote 1892: figure 1)

## **Loongana Station.** See Mundrabilla

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## **Loreto**, Baja California, Mexico
### 26°0'N, 111°20'W

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Medium octahedrite, Om. Bandwidth 1.15±0.15 mm. ε-structure. HV 210±15.

Group IIIA. 7.78% Ni, 0.49% Co, 0.12% P, 19.3 ppm Ga, 38.3 ppm Ge, 3.8 ppm Ir.

It appears that the main mass of this fall is still waiting to be recovered.

### HISTORY

A mass of 95 kg (209 pounds) was found about 1898 in the arid mountains, about 6 hours by burro southwest of the village of Loreto, in Lower California. It was hauled to the patio of the finder, Mr. Davis, in Loreto, where it remained until Nininger heard of it from various sources. He visited Loreto in 1950 and secured the mass for the U.S. National Museum, aided by a donation from S. H. Perry. The son of Mr. Davis and the neighbors all testified that the mass had been discovered only a few feet from another, larger, iron mass that extended down into the ground deeper than Davis was able to dig. This mass, estimated to weigh over a ton, has never been relocated, although attempts by Dr. Nininger in 1964 and 1965 were undertaken (personal communication).

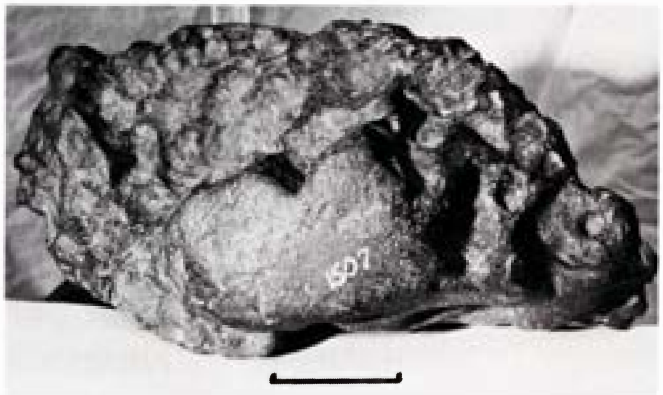

**Figure 1082.** Loreto (U.S.N.M. no. 1507). The 88 kg main mass has a small hemispherical cap and a large bowl-shaped depression, the inside of which is subdivided in smaller regmaglypts. Scale bar approximately 10 cm.

The 95 kg mass was received in Washington in 1951, and a full description with photographs of the exterior and of etched slices appeared a few years later (Henderson & Perry 1956). The authors noted the close similarity to Morito and proposed that Loreto and Morito were paired falls, although they were found about 600 km apart. Herr et al. (1961) determined the osmium and rhenium abundances.

### COLLECTIONS

Washington (88.6 kg main mass and 3 kg slices), Oscar E. Monnig (625 g), Tempe (417 g), Mainz (200 g), Sydney (166 g).

### DESCRIPTION

The irregular, angular mass is 50 cm long, 26 cm wide and 21 cm high, when it rests upon its flattest surface. It is boldly carved by the atmospheric frictional ablation and possesses numerous, marked regmaglypts, 25-40 mm across. In one place is a bowl-shaped depression, 14 cm across and 6 cm deep, the inside of which is subdivided into smaller regmaglypts. At the very bottom of the bowl is a 15 mm wide and 10 mm deep spherical pit, evidently the cavity from a troilite nodule that burned out. Two or three similar pits may be observed in other places on the ablated surface. The overturned edges mentioned by Henderson & Perry (1956) are few and insignificant; since they are only found on exposed, high ridges and look battered, the present author believes that they are due to transport of the heavy mass and were not formed during flight. The fusion crust is

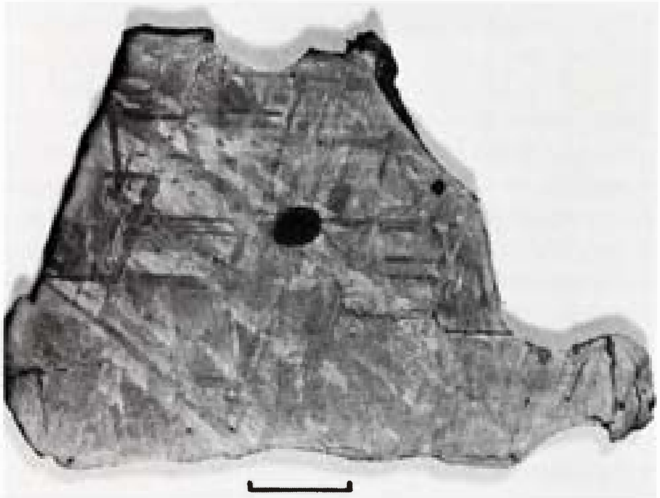

**Figure 1083.** Loreto (U.S.N.M. no. 1507). Medium octahedrite of group IIIA. Two shock-melted troilite nodules (black). Deep-etched. Scale bar 20 mm. S.I. neg. 41839.

**LORETO – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Moore et al. 1969 | 7.89 | 0.49 | 0.12 | 175 | 85 | | 160 | | | | | |
| Scott et al. 1973 | 7.67 | | | | | | | | 19.3 | 38.3 | 3.8 | |

preserved over many square centimeters as 0.1-1 mm thick, warty skins. It is corroded and spalling off, but nevertheless occurs sufficiently evenly distributed to indicate that practically no metal has been removed by corrosion. This is corroborated by examination of etched sections, which all display 1-3 mm wide, heat-affected $\alpha_2$ zones. Where the fusion crust is spalled off corrosion has started to pockmark the surface: numerous small, shallow pits, 2-3 mm in diameter, occur close together and probably form the initial phase of the characteristic, coarse pockmarking as present on, e.g., Filomena and Maria Elena. The attack does not appear to be controlled by the structure or precise chemical composition of the meteorite, since it develops similarly on hexahedrites, and medium and fine octahedrites. It is, however, conditioned by the climate, since it is only found on iron meteorites from arid zones, like the North American Southwest, Mexico and Chile's Atacama desert.

One side of Loreto is rather flat, about 45 x 25 cm in size and without fusion crust or regmaglypts. It appears to represent a late fracture along octahedral planes, forming a somewhat hackly, rough surface. Sections through this surface show that no $\alpha_2$ zone is present and that the Widmanstätten lamellae are bent and distorted locally, probably caused by the violent break away from another mass very late in the flight or upon impact with the ground. The presence of the hackly, flat surface and the distorted lamellae strongly supports the local stories that Loreto was found close to a larger mass. It should, in fact, not be too difficult to relocate it today.

Etched sections display a medium Widmanstätten structure of little contrast. The kamacite lamellae are straight, long ($\frac{L}{W} \sim 25$) and 1.15±0.15 mm wide. Due to a high intensity shock the kamacite is converted to the hatched $\epsilon$-structure. The microhardness is 210±15, suggesting significant annealing after the shock. It increases to about 250 locally where the slipline concentration is high. It drops to a minimum of 170±10 (recovery) at the transition to the reheated rim zone, which itself has a hardness of 210±20 (hardness curve type II). Taenite and plessite cover about 40% by area, mostly as rather open-meshed comb and net plessite, with discontinuous taenite borders, but also in minor amounts as dark-etching duplex structures which are almost unresolvable with a 40x objective and oil immersion. In the dense duplex matrix numerous, 1-2 μ wide, pointed kamacite spindles occur.

Schreibersite is present as evenly dispersed, 20-50 μ wide, grain boundary precipitates and as 5-50 μ irregular, concave blebs inside the coarser plessite fields, substituting for taenite of comparable form and size, and easily confused with the taenite. In some kamacite lamellae are numerous rhabdites, 2-5 μ across. All the phosphides are monocrystalline, but brecciated, and often displaced 5-10 μ by shear.

Troilite is common as 5-10 mm rounded nodules and as 0.5-5 mm rhombic and lenticular bodies. Some have and some do not have 1 mm wide rims of swathing kamacite. The troilite is shock melted and solidified to very fine-grained aggregates, about 1 μ size. The troilite was melted

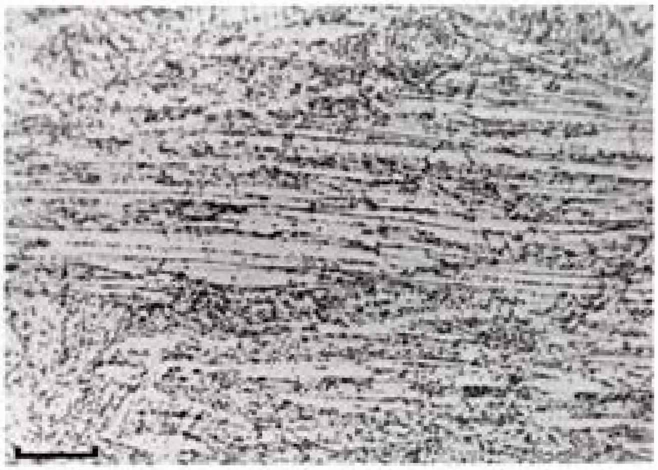

**Figure 1085.** Loreto (Tempe no. 600.2). Annealed shock-hatched kamacite. Numerous almost submicroscopic precipitates of taenite line previous shear planes of the kamacite. Etched. Scale bar 20 μ.

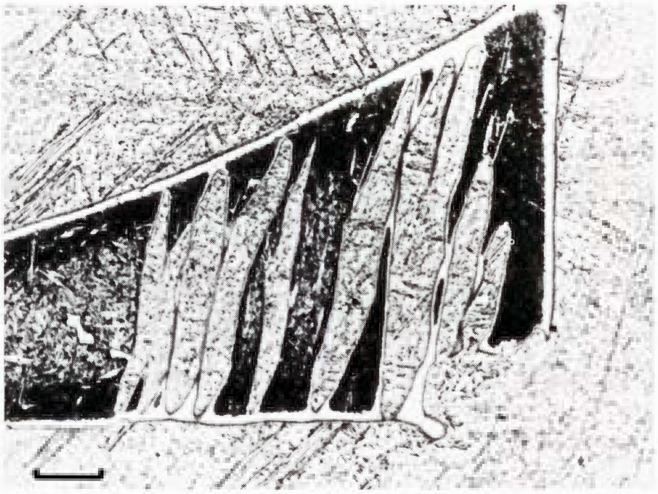

**Figure 1084.** Loreto (Tempe no. 600.2). Plessite field with cloudy taenite rims and annealed martensitic interiors. Annealed shock-hatched kamacite. Etched. Scale bar 50 μ.

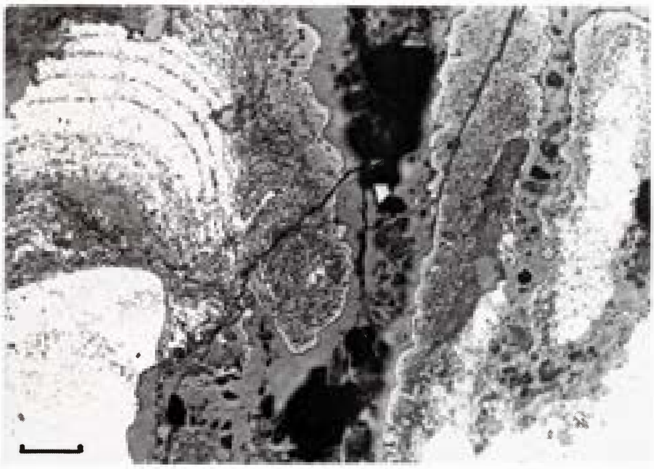

**Figure 1086.** Loreto (Tempe no. 600.2). Corroded whirlpool fusion crust. The left and right parts of the crust are only little corroded and show the complex, dendritic metallic layers. Lightly etched. Scale bar 50 μ.

just long enough to dissolve some of the surrounding metal; when solidifying it created a characteristic fringed border against the matrix which displays ε-structure to the very edge of the troilite. The original 10-100 μ wide daubreelite bars are shattered in various degrees and the angular, 2-10 μ fragments are now dispersed in the troilite. Also, small amounts of 5-25 μ schreibersite fragments have become detached from their original position around the troilite and are now dispersed in the melt. From the troilite melts radiate zigzagging dark fissures; mainly following the octahedral boundaries and the schreibersite grains. The nearest 1-5 mm are filled with injected, 10-25 μ wide troilite veinlets, but the more remote fissures were probably empty for a long time until the meteorite landed and started to corrode. The fissure zones were readily available for terrestrial ground water, so various "limonite" minerals were produced.

In the kamacite are numerous, hard oriented platelets, about 20 x 2 x 1 μ in size, of the chromium nitride, carlsbergite.

The fusion crust is 0.1-1 mm thick and consists of magnetite and wüstite, intergrown with terrestrial corrosion products. Under this is a laminated, metallic fusion crust, 250-500 μ thick in places, and composed of four to eight individual, more or less discordant sheets. The microhardness is 320±25. The metal hosts numerous 0.5-2 μ spheres of oxides, formed in the late ablation stages. Locally, there are 0.5-1 mm whirlpools of intricate shapes, with melted metal and oxides deposited in concentric zones, probably caused by local eddies in the hot, streaming gases. Under the fusion crusts is a normal $\alpha_2$ zone, ranging from 1-3 mm in thickness. In the outer 50% of the $\alpha_2$ zone the phosphides are micromelted and clearly solidified by heat conduction from the cool interior of the meteorite.

Loreto is a well-preserved fall, of which more, no doubt, is waiting to be recovered. It is structurally closely related to Merceditas, Norfolk, La Porte, Canyon City, Frankfort and Morito. There is no specific reason to believe that Loreto and Morito should be a paired fall, particularly not when the distance seems prohibitive, and both belong to a common category of group IIIA meteorites. They do, on the other hand, resemble each other closely.

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

88.6 kg main mass, cut at one end (no. 1507, 45 x 26 x 21 cm)
1,065 g slice (no. 1507, 14 x 11 x 1 cm)
953 g slice (no. 1507, 16 x 11 x 0.8 cm)
About 1,000 g slices and part slices (no. 1507)

## **Los Reyes**, Federal District, Mexico

19°21'N, 98°58'W; 2,000 m

Medium octahedrite, Om. Bandwidth 0.90±0.15 mm. Partly recrystallized. HV 155-205.

Group IIIB. 8.71% Ni, about 0.35% P, 20.9 ppm Ga, 40.7 ppm Ge, 0.12 ppm Ir.

The mass has been artificially reheated to 500°-600° C.

### HISTORY

A mass of 19.5 kg (43 pounds) was plowed up in 1897 near Los Reyes, about 20 km east-southeast of Mexico City. It was obtained for the Field Museum from E. O. Mathews of Mexico City and was described by Farrington (1902: 305) with photographs of the exterior and of an etched slice. He considered it a part of the Toluca shower then but later changed his mind and listed it as an independent fall (Farrington 1915: 284) without new evidence being presented, however. In 1917 a few slices were cut from the mass, but apparently no reexamination was ever published. Farrington gave the locality as Los Reyes, a railway junction at the southern end of Lake Texcoco, but other villages of the same name exist in the vicinity of Mexico City. The coordinates for the railway junction at the boundary between the Federal District and the State of Mexico are given above. The coordinates listed in Hey (1966) are erroneous.

### COLLECTIONS

Chicago (14.6 kg main mass and 3.70 kg slices), Washington (377 g).

### DESCRIPTION

The mass is shaped as an oversized, somewhat flattened pear with the maximum dimensions 24 x 16 x 15 cm. It appears to have lost a little by terrestrial weathering, probably on the average 1 mm. Fusion crust and heat-alteration zones were not identified in the examined sections but seem to be present in others.

Etched sections display a medium Widmanstätten structure of straight, swollen ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 0.90±0.15 mm. The kamacite appears to have been originally of the acicular ε-variety, indicative of shock pressures above 130 k bar but a late heat source has partially recrystallized the matrix to ferrite grains, 20-150 μ across. The recrystallized grains occupy about 50% by area of the kamacite, and are particularly pronounced around the schreibersite inclusions. The hardness varies in an irregular way from 155 to 205, reinforcing the impression of an imperfectly annealed structure. Taenite and plessite

LOS REYES – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Scott et al. 1973 | 8.71 | | | | | | | | 20.9 | 40.7 | 0.12 | |

cover about 40% by area, mostly in the form of acicular areas where concave taenite blebs, 10-50 μ in size, are situated in a network of kamacite islands. This plessite variety is particularly well developed in Apoala, Cuernavaca, Narraburra and other group IIIA-IIIB irons.

Schreibersite is very common as platy and irregular skeleton crystals, typically 7 x 1, 10 x 2 or 9 x 0.5 mm in size, and always enveloped in 0.6-1.5 mm swathing kamacite. In the swathing kamacite are numerous rhabdites, 5-15 μ in thickness; and rhabdites are also common elsewhere. Schreibersite further occurs as characteristic "island arcs" in front of the taenite and plessite fields. Individual islands are 5-15 μ wide and situated a similar distance in front of the taenite. The bulk phosphorus content of the mass is estimated to be 0.35±0.05%.

Troilite was only observed in the middle of a deep-etched section as 1-3 mm nodules, surrounded by discontinuous, 0.3 mm thick rims of swathing kamacite.

All phosphides are brecciated and apparently monocrystalline, but they show 1-2 μ wide reaction rims against the terrestrial oxides. The rhabdites have fine, thorny projections, and in the grain boundaries are various high temperature, lace-like reaction products. It appears that the mass has been reheated somewhat by the finders, perhaps to 500° or 600° C for a short time, and that this is the reason for the partly recrystallized structure and the irregular hardness values.

Before the artificial reheating Los Reyes was a typical medium octahedrite with ϵ-structure, and closely related to, e.g., El Capitan, Apoala and Oroville. From the structural and chemical observations it is concluded that it belongs to the irons transitional from group IIIA to IIIB. It is in no way related to Toluca.

**Specimen in the U.S. National Museum in Washington:**
377 g slice (no. 578, 16 x 10 x 0.5 cm)

## **Losttown**, Georgia, U.S.A.

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm. Recrystallized. HV 150±10.

Group IIIA, judging from the structure. About 8.5% Ni, 0.5% Co, 0.25% P.

The mass appears to have been artificially reheated to about 650° C.

### HISTORY

A mass of 3.0 kg (6 lbs 10 oz) was plowed up in 1867 on the farm of Michael Sullivan, 2.5 miles southwest of Losttown, in Cherokee County. It was purchased by Shepard, who briefly described it (1868) and analyzed it (1869). When the Canton iron was found in Cherokee County a generation later, it was preliminarily combined with Losttown by Brezina (1896) and Wülfing (1897), but Ward (1900; 1904a) correctly identified the masses as separate falls. Berwerth (1905: 353) noted the serrated (*"fetzige"*) alpha grains of the matrix and concluded that Losttown had been artificially reheated. However, since he included far too many irons in his metabolite group, – such as irons which were not artificially reheated but rather were reheated in cosmos or superficially reheated in the atmosphere, – his observations were of minor value and were apparently forgotten and rarely quoted. Henderson & Furcron (1957) briefly reviewed the literature and noted that the specimen in the U.S. National Museum, of which they presented a photomacrograph, had double the bandwidth given by Brezina (1896). Wiik & Mason (1965) showed that 877 g specimens in the American Museum of Natural History, labeled Losttown (Mason 1964), were in fact slices of Canton. Some of the material listed below appear also to be mislabeled Canton material, but a check of the microstructure will rapidly identify any particular specimen. The Chicago specimen listed by Horback & Olsen (1965: 252, No. 1058 of 75 g) was thus examined by me and found to be a slice of a coarse Canyon Diablo-like meteorite, very different from authentic Losttown material. The locality is not known today with any degree of precision; Losttown is not listed in Colton's General Atlas (1866) or Rand McNally's Indexed Atlas of the World (1882), and it is not marked on available quadrangle maps.

### COLLECTIONS

Amherst (2,513 g main mass), Vatican (87 g?), Washington (71 g), Tempe (49 g), London (45 g), Vienna (34 g), Budapest (22 g), Paris (20 g), Berlin (16 g), Harvard (13 g), Yale (3 g), Strasbourg (2 g).

### ANALYSES

Shepard (1869) found 3.66% Ni, and no later analyses have been reported. From an examination of the structure the present author would expect 8.5-9% Ni, 0.5% Co and about 0.25% P.

**Figure 1087.** Losttown (Amherst). The 2.5 kg main mass resembles a small foot. Only a few slices have been cut from one end. Etched. Ruler is 10 cm.

**DESCRIPTION**

The mass, in Amherst, resembles a small foot and has the approximate overall dimensions 16 x 9 x 5.5 cm. From one end a few slices have been cut, leaving a polished and etched, cut surface of 6 x 4.5 cm. Another small cut has left a polished surface of 4.5 x 2 cm. The exterior is corroded, and, locally, the surface is disintegrating into octahedral fragments. On sections no trace of the fusion crust or of the heat-affected $\alpha_2$ zone can be found. On the contrary, it is seen that corrosion has selectively attacked the α-phase of the plessite fields and penetrated to several centimeters depth along the schreibersite inclusions.

Etched sections display a medium octahedrite structure of straight, swollen ($\frac{L}{W} \sim 15$) kamacite lamellae with a width of 1.00±0.15 mm. The width of the lamellae is apparently difficult to measure, since Brezina (1896) said 0.4-0.6 mm, Henderson & Furcron (1957) 1.1 mm, and Hey (1966) 1.65 mm. Part of the explanation lies in the small amounts of material available, part in the unfortunate cutting angle with respect to the (111) pattern, that make two sets of lamellae stand out with almost double their actual width on most polished sections.

The kamacite is recrystallized to a ferritic grain aggregate, with grain sizes ranging from 25-100 μ, the largest grains generally being found around the schreibersite inclusions. No Neumann bands are present. The hardness is 150±10 in accordance with the recrystallized structure. The former subboundaries in the kamacite are feebly visible, due to a limited decoration with 1-2 μ phosphides. Taenite and plessite cover about one-third by area, mostly in form of comb and net plessite. The duplex $\alpha + \gamma$ fields are easily resolvable, probably because they are annealed at the same heat treatment that was responsible for the recrystallized kamacitte.

**Figure 1088.** Losttown (U.S.N.M. no. 1071). A medium octahedrite which may be transitional between group IIIA and IIIB. Deep-etched. Scale bar 10 mm. S.I. neg. M-31.

Schreibersite is common as 0.2-0.5 mm wide skeleton crystals, that may be 1-3 mm long, and are wholly embedded in the kamacite lamellae. It is further common as 20-80 μ wide grain boundary precipitates and as 5-30 μ thick, irregular blebs inside the various plessite fields. The schreibersite is monocrystalline, but it has a fringed reaction rim where it abuts against the terrestrial corrosion products. Also the terrestrial oxides in the grain boundaries show signs of high temperature decomposition, probably from artificial reheating to about 650° C.

Troilite is only present as 50-500 μ nodules, more or less enveloped by the schreibersite. In one place an 800 x 100 μ chromite crystal has served as nucleus for the growth of a 500 x 200 μ troilite, which later has precipitated a 500 x 30 μ daubreelite lamellae parallel to and in direct contact with the chromite. The troilite is recrystallized to 5-100 μ units, apparently as a result of the artificial reheating. The growth of the individual recrystallization units has been visibly impeded by the presence of terrestrial oxidation products. Some pentlandite veining also occurs.

Losttown is completely different from Canton, perhaps most easily seen by the unlike amount and distribution of phosphides. Losttown is a medium octahedrite which may be related to Aggie Creek and Campbellsville. Since the structure is somewhat altered due to artificial reheating to about 650° C it is, however, difficult to arrive at a final conclusion until a modern analysis has been performed.

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

71 g part slice (no. 1071, 3.5 x 3 x 1 cm)
28 g rusted fragments and oxide-shales (nos. 33, 411, 1071)

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## **Lucky Hill**, Jamaica

17°54'N, 77°38'W

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**Medium octahedrite, Om. Structural details unknown.**
**Group unknown. Analysis unknown.**

**HISTORY**

Little is known of this heavily weathered meteorite. According to Fletcher (Introduction to the Study of Meteorites, editions 1886, 1888 and 1894) the mass was found in 1885 at Lucky Hill, St. Elizabeth and was presented by the Governors of the Jamaica Institute, in Kingston, to the British Museum. The following is an excerpt from a handwritten entry in the acquisition record book of the Institute of Jamaica, Kingston, containing a preliminary report of the Island Chemist: "Found in digging yams in garden in front of house, about two feet deep, April 17th, 1885. Presented by (the finder) Philip Sterling, Lucky Hill, Bellevue, St. Elizabeth. – Reveived in three pieces which fitted together showing they were the three fragments of one stone. They weighed respectively 25 lbs, 11 lbs, and 8 lbs., totalling 44 lbs. The small fragments weighed 9 ozs. so that the whole stone before it was broken must have weighed over 45 lbs. (20.5 kg). The outside of the stone appeared to be hematite, the portion within the outer skin – proved to be magnetic oxide of iron. – The mass was made up of either tetra- or octahedral crystals, some nearly 3/4 inch in length of edge. These crystals when not tarnished were of almost silver whiteness, they easily cleaned yielding thin plates, and proved to be iron with a little nickel."

The coordinates of the place have been given differently by Brezina (1896), Ward (1904a) and Hey (1966). Those above are as reported by the last mentioned.

### COLLECTIONS

London, British Museum (4,640 g, probably the 11 lb fragment), London, Museum of Practical Geology (3.2 kg, probably the 8 lb fragment), Berlin (64 g), Chicago (51 g), Washington (40 g), Vienna (21 g). Smaller fragments are present in many collections, but all specimens appear to be extremely weathered.

### ANALYSIS

No analytical work has been reported because of the bad state of the material.

### DESCRIPTION

The three fragments in the U.S. National Museum are oxidized fragments with indistinct octahedral outlines. They contain a few specks of unaltered metal, insufficient, however, for any description. The specific gravity is about $4.2\ \mathrm{g/cm^3}$. The 4.6 kg in the British Museum consist of similar weathered fragments, ranging from powder size to 4 x 2 x 2 cm in size. Unweathered metal is apparently inside some fragments and should be examined.

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

Three, weathered fragments of, respectively, 15, 21 and 3.8 g (nos. 2888 and 2889)

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## **Luis Lopez**, New Mexico, U.S.A.

Approximately 34°0'N, 106°58'W; 1,500 m

Medium octahedrite, Om. Bandwidth 1.15±0.20 mm. Deformed Neumann bands. HV 178±10.

Group IIIB. 8.64% Ni, about 0.33% P, 20.1 ppm Ga, 41.9 ppm Ge, 0.15 ppm Ir.

### HISTORY

A mass of 6.9 kg was found in 1896 by Mr. Gonzalez, a Mexican who was very reluctant to provide exact information of the locality since he believed he had found a valuable ore indication. The locality appears to have been about 8 km southwest of Socorro, near the hamlet of Luis Lopez, in Socorro County. The approximate coordinates are given above. The mass went through several hands before it was purchased by Ward in 1899 and briefly described by Preston (1900a). Half of the mass was sliced by Ward's Establishment, and the sections were marketed, first as "Magdalena," later as "Luis Lopez." Ward (1904a: plate 1) gave a photomacrograph of a slice with the name "Magdalena" etched in; such mislabeled material may still be around in some sleeping collections. Mauroy (1913: plate 1) gave a brief description and a photomacrograph.

### COLLECTIONS

Chicago (3,107 g half mass), Harvard (580 g), London (426 g), New York (362 g), Washington (172 g), Bonn (121 g), Prague (105 g), Paris (94 g), Tübingen (79 g), Vienna (76 g), Yale (57 g), Calcutta (46 g), Berlin (32 g), Ottawa (21 g), Vatican (20 g), Budapest (12 g).

### DESCRIPTION

The rectangular mass measured, according to Preston (1900a), 19.5 x 13 x 8 cm and weighed 6.9 kg. It is corroded and covered by terrestrial oxides, which are laminated and up to 1 mm in thickness. On sections it is seen that the fusion crust and the heat-affected zone are lost due to corrosion. The alpha phase of the plessite fields and the Neumann bands are selectively attacked, particularly near the surface. Luis Lopez is clearly of a considerable terrestrial age. One end is seriously hammered and displays a 7 x 3 cm flattened area, but no artificial reheating has taken place.

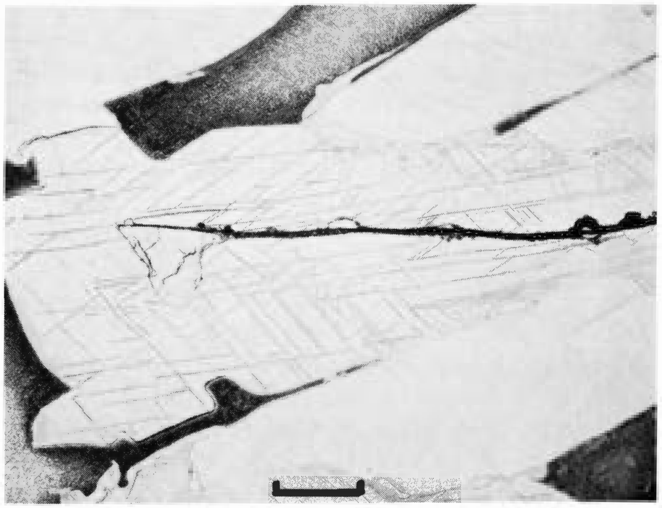

**Figure 1089.** Luis Lopez (Harvard no. 541). A horizontal Reichenbach lamella of chromite with blebs of phosphide and shock-melted troilite. Deformed Neuman bands in the swathing kamacite. Annealed plessite fields. Etched. Scale bar 500 μ.

**LUIS LOPEZ – SELECTED CHEMICAL ANALYSES**

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Scott et al. 1973 | 8.64 | | | | | | | | 20.1 | 41.9 | 0.15 | |

Mariner & Hoskins (in Preston 1900a), in an otherwise unsatisfactory analysis, reported 0.33% P.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.15±0.20 mm. The kamacite has indistinct Neumann bands which in numerous places are heavily faulted and distorted. They are decorated along both sides with fine phosphides, generally less than 1 μ in diameter; and, locally, recrystallization has started, creating irregular ferrite grains, 10-50 μ across. The recrystallized units are particularly common around the sheared schreibersite crystals, where the metallic matrix evidently was severely deformed. Lenticular deformation bands are found in many kamacite areas. The hardness of the kamacite is low, 178±10, corresponding to the recrystallized state.

Taenite and plessite cover about 30% by area, mostly in form of duplex, dark-etching fields, which are unresolvable with a 40x objective (HV 225±10). Several wedge-shaped fields display high-nickel martensite with acicular platelets occurring in numerous directions. Other, larger fields, at a lower nickel level, display martensite platelets arranged parallel to the octahedral directions only. The martensitic structures are annealed, resembling those of Anoka and Livingston (Tennessee) and having low hardnesses of 265±15. Also the taenite ribbons are relatively soft, 210±10.

Schreibersite is common centrally in the kamacite lamellae as 0.2-0.6 mm wide and often several millimeters long, angular bodies. They are monocrystalline, but often violently sheared. Schreibersite also occurs as 20-100 μ wide grain boundary precipitates, but rhabdites are not present. The 0.33% P, as reported by Preston, appears to be a good bulk phosphorus value.

Troilite occurs as 5-25 mm nodules, which are partially surrounded by narrow rims of schreibersite. At least the smaller nodules have been shock melted and afterwards solidified to unequilibrated, fringed troilite, subdivided into 2-5 μ small grains.

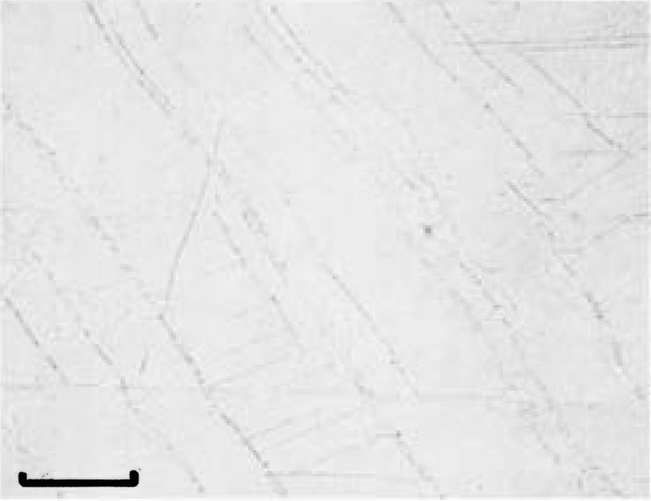

**Figure 1090.** Luis Lopez (Harvard no. 541). Deformed Neumann bands and incipient recrystallization. Lightly etched. Scale bar 100 μ.

Chromite is relatively common as thin platelets, e.g., 20 x 8 x 0.1 mm or 15 x 4 x 0.02 mm in their greatest dimensions. The plates have served as a substrate for solidifying troilite and precipitating schreibersite, in that order, and various combinations occur as to size and relative amounts. The precipitates may well be termed Reichenbach lamellae; and they occur with a frequency of about one per 10 cm$^2$, possibly only parallel to the $\{100\}\gamma$ planes. The lamellae are enveloped in asymmetrically developed, 0.1-1 mm wide rims of swathing kamacite. The aggregates are often severely damaged by the same shock event which melted the troilite. The chromite plates may then be compressed zigzag structures, into the fissures of which micromelted troilite has been injected. Unfortunately, the detailed structures are often blurred by terrestrial oxidation products, since circulating ground water has had rather easy access to these microcracked areas.

Graphite was reported by Preston (1900a), but probably erroneously. No graphite or cohenite were present in the sections examined by the author, and they would certainly not be expected in the mineral association of Luis Lopez.

Luis Lopez is a shock-deformed and annealed, medium octahedrite which shows incipient recrystallization locally. It is related to El Capitan, Aggie Creek, Tamarugal and other octahedrites of group IIIA, transitional to group IIIB.

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

| | |
|---|---|
| 21 g | part slice (no. 217, 3.5 x 2 x 0.5 cm, labeled "Magdalena") |
| 117 g | part slice (no. 451, 7 x 3 x 0.8 cm) |
| 34 g | corner (no. 2890, 3 x 2 x 1 cm) |

## **Lujan**, Buenos Aires, Argentina

Approximately 34°40′S, 59°22′W

A piece of about 50 grams was found six meters deep in Quaternary formations below remains of a megatherium (Kantor 1921; Radice 1959). It has been listed as a mesosiderite (?) by Hey (1966), but his classification is doubtful.

The 33 g specimen in the La Plata Museum measures 4.5 x 3 x 2.5 cm and is an iron thoroughly oxidized to limonite. The specific gravity is approximately 4.5, and the specimen is almost nonmagnetic. In the author's opinion the Lujan material is an entirely corroded octahedrite rather than a mesosiderite. A close study of a modern polished section might help to solve the question, since it might be possible to identify remnants of any octahedral structure and perhaps even find some untransformed schreibersite or troilite.

## **Lusk**, Wyoming, U.S.A.

42°46′N, 104°21′W; 1500 m

A sliver of iron oxide shale weighing 46 g was found in 1940 near Lusk, Niobrara County, by Earl Quigley while he was searching for Indian arrow heads. (A. D. Nininger 1940: 556; Nininger & Nininger 1950: 70, 113). Buddhue (1957: 141) briefly discussed the material. There is, however, no proof that Lusk should be an independent iron meteorite. It may well be a transported, weathered fragment of some better known mass. The material, which apparently was an octahedrite, was divided in 1959: 22 g in Tempe, 23 g in London.

## Madoc, Ontario, Canada

44°30'N, 77°28'W; 200 m

Medium octahedrite, Om. Bandwidth 0.95±0.15 mm. Deformed $\epsilon$-structure. HV 240–340.

Group IIIA. 7.76% Ni, about 0.11% P, 19.4 ppm Ga, 36.4 ppm Ge, 6.8 ppm Ir.

### HISTORY

A mass of 168 kg (370 pounds) was found in 1854 lying on the surface of the ground near Madoc, in Hastings County. Madoc has the coordinates given above. The mass was acquired by the Geological Survey of Canada, Ottawa, and was briefly mentioned by Hunt (1855). A few kilograms were cut and distributed about this time. It was examined by Reichenbach (e.g., 1862a: 622; 1862b: 589), by Brezina (1885: 210) and by Cohen (1905: 354), all of whom were evidently puzzled by the fine structure and classified it as a fine octahedrite, a classification which still is maintained, erroneously, by Dawson (1963: 41), Hey (1966: 285) and Douglas (1971: 23). Meunier (1893a: 255) even established a separate group with Madoc as the only member. Brezina & Cohen (Atlas 1886-1906: plate 22) presented four photomicrographs, together with a short description. They reported cohenite (?), but what they saw was probably only schreibersite. Jain & Lipschutz (1969) reported shock structures associated with peak pressures of 400-750 k bar.

### COLLECTIONS

Ottawa (160 kg main mass, 5 kg slices), London, British Museum (396 g), London, Museum of Practical Geology (301 g), Paris (236 g), Vienna (210 g), Tübingen (170 g), Amherst (169 g), Harvard (81 g), Strasbourg (68 g), Dresden (43 g), Philadelphia (30 g), Berlin (29 g), Dorpat (28 g), New York (27 g), Yale (26 g), Chicago (24 g), Leningrad (19 g), Göttingen (19 g), Calcutta (18 g), Washington (11 g).

### DESCRIPTION

According to Hunt (1855), the mass is "rudely rectangular and flattened, but very irregular in shape; its surface is deeply marked by rounded depressions which are lined with a film of oxide." No further description of the 168 kg mass has appeared, but a little can be added on the basis of the small specimens I have examined. Several sections show fusion crusts and heat-affected $\alpha_2$ zones which indicate that Madoc's present shape is only little altered by weathering. The fusion crust consists of 50-150 $\mu$ thick layers of dendritically solidified metal, which exhibits a wide hardness range (218-306), probably due to microporosities. The exterior part of the fusion crust (magnetite etc.) has corroded away. The $\alpha_2$ zone is 1.5-2 mm thick and composed of serrated, 5-30 $\mu$ $\alpha_2$ units that are small, since they formed from deformed $\epsilon$-structures. The hardness is 185±8 (hardness curve type IV).

Etched sections display a medium Widmanstätten structure of straight or somewhat deformed, long ($\frac{L}{W} \sim 20$) kamacite bands with a width of 0.95±0.15 mm. The kamacite has subboundaries, decorated with 1 $\mu$ rhabdites and there are also numerous rhabdite prisms, 1-2 $\mu$ across, in the interior of the kamacite. These details are, however, largely obscured by a severe deformation which appears to be due to shock pressures above 130 k bar. The kamacite displays a mixture of lenticular deformation bands, martensitic appearing $\epsilon$-matrix and of shear zones with relative displacements of 10-100 $\mu$. In accordance with these features, the microhardness ranges from 240 to 340 within the same primary kamacite lamella. The highest values are associated with visibly distorted and sheared $\epsilon$-structures.

Taenite and plessite cover 25-35% by area. The plessite fields are mostly of the degenerated comb and net plessite types with discontinuous taenite frames. The larger wedges, which are nickel-rich, display a poorly resolvable, duplex $\alpha + \gamma$ interior (black taenite, HV 300±20), or they may show acicular precipitates of fine kamacite needles, 1-3 $\mu$ thick (HV 375±20).

Schreibersite is present as 10-50 $\mu$ wide grain boundary veinlets, and as 2-10 $\mu$ thick blebs in the plessite interior, where it substitutes for taenite of the same general size. The schreibersite is monocrystalline but often heavily brecciated and sheared due to plastic flow of the surrounding, metallic matrix. The bulk phosphorus content is estimated to be 0.11±0.02%.

Troilite is present as scattered 1-2 mm lenticular nodules. Larger bodies are no doubt present in the uncut main mass. A typical lens, 0.6 x 0.3 mm in size, had parallel 5-80 $\mu$ wide daubreelite lamellae, occupying about 20% by volume. The troilite was deformed and showed multiple twinning and undulatory extinction. Such troilite nodules, which happen to be situated in the heat-affected $\alpha_2$ zone above the 850° C isotherm, have partly recrystallized to 5-50 $\mu$ equiaxial grains. Daubreelite occurs dispersed through the kamacite as rounded, 10-50 $\mu$ wide grains.

The hard carlsbergite platelets, typically 20 x 1 $\mu$, reported from Cape York and other irons, are also present in Madoc.

The U.S. National Museum specimen is heavily deformed at the surface, probably from hammering. It is,

MADOC – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Sen Gupta 1968 | 8.00 | | | | | | | | | | 3.1 | 6.1 |
| Scott et al. 1973 | 7.52 | | | | | | | | 19.4 | 36.4 | 6.8 | |

therefore, not possible to distinguish a fusion crust or a heat-affected zone on this sample.

Madoc is a shock-hardened medium octahedrite related to Boxhole, Canton and Chilkoot. It is a normal member of group IIIA. Its classification as a fine octahedrite should be discontinued.

**Specimen in the U.S. National Museum in Washington:**
11 g part slice (no. 1074, 20 x 15 x 4 mm)

## **Magdalena**. See Luis Lopez

## **Magnesia**, Izmir, Turkey
### 37°52′N, 27°31′E

"The fall of this iron (about 5 kg) was witnessed in 1899 by a Turkish peasant in a village near Magnesia (Magnissa), since destroyed; the mass remained in his family until 1918 when it was purchased by a Turkish army officer and ultimately by Col. L. Vésignié" (Hey 1966: 285).

When, about 1950, Vésignié's large collection of minerals and meteorites was acquired by the Muséum National d'Histoire Naturelle, in Paris, Magnesia again changed hands, but it was not analyzed or described.

A cursory examination shows rather surprisingly that Magnesia is only a 5 kg fragment of a larger mass. It is a flat "cone," measuring 18 x 15 x 7 cm, and is on the tapering side covered with regmaglypts 10-20 mm in diameter. The fusion crusts are well-preserved in spite of the obvious handling by the many owners. The flat rear side presents a 15 x 14 cm octahedral (?) fracture plane which is not apparently smoothed by atmospheric ablation during flight. It remains an open question when the fragmentation took place. It appears that no one, at present, has any knowledge of the missing fragment, which may have the same size as the preserved one. Presumably the early owners, now entirely unknown, are the only ones who could elucidate the problem. Magnesia appears to be a medium octahedrite. See the Supplement.

### COLLECTIONS

Paris (5,002 g), London (1 g).

## **Magura**, Zilina Region, Czechoslovakia
### 49°20′N, 19°29′E

Coarse octahedrite, Og. Bandwidth 2.4±0.6 mm. ε-structure. HV 200-350.

Group I. 6.67% Ni, 0.46% Co, 0.24% P, 94 ppm Ga, 483 ppm Ge, 3.2 ppm Ir.

### HISTORY

Numerous weathered masses appear to have been found about 1840 by miners associated with ironworks around the river Arva, now called Orava, in the High Tatra region of the Carpathians. The locality was kept secret for a while, so when Haidinger (1844) was able to report the find for the first time it seems that about "32 centner" (about 1,600 kg) had already been melted in the ironworks, under the supervision of "Bergingenieur" Weiss (Buchner 1863: 168). The total weight of preserved specimens must be between 150 and 200 kg, estimating from what is reported in various collections.

The locality appears to have been the forest-covered slopes at the foot of the Magura Mountains, near the village

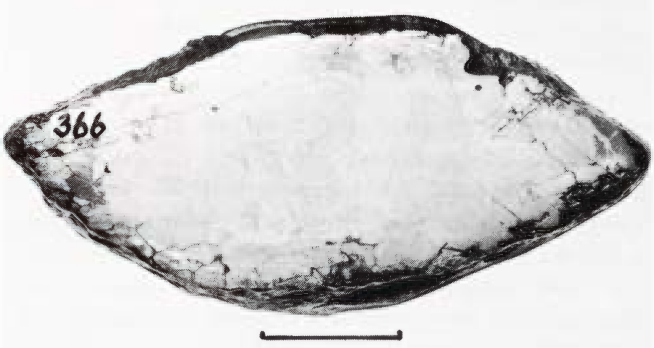

**Figure 1091.** Magura (Prague no. 366). A 279 g full slice 14 mm thick. Typical sample of the cohenite-poor Magura variety. The structure is that of a coarse octahedrite, exhibiting some grain growth. Etched. Scale bar 20 mm.

**Figure 1092.** Magura (Copenhagen no. 21). A 120 g part slice, 15 mm thick. Typical sample of the cohenite-rich Magura variety. The cohenite crystals appear black on the photograph. Deep-etched. Scale bar 10 mm.

of Szlanicza, east of Namestovo, for which Brezina (1896) and Tuček (1966) gave the coordinates quoted above. The coordinates quoted by Hey (1966) place the locality 70 km too far east.

It is often stated, for example by Tuček (1966) and Hey (1966), that "one mass of about 1500 kg was found," but a close inspection of the preserved specimens and a comparison with the very little information concerning the source clearly shows that Magura was a shower of numerous individuals ranging from less than 1 kilogram through 2.5-5 kg specimens (in Budapest), 10.5 kg (in Vienna) to at least 42 kg (in Tübingen). In other words, the occurrence bears a strong resemblance to Toluca.

Magura was for the nineteenth century scientists of Europe what Canyon Diablo has been for the twentieth century scientists of the United States. Haidinger and Patera (quoted in American Journal of Science 1849: Volume 8: 439) proposed the name schreibersite for the platy mineral so common in Magura and consisting of 87.20% Fe, 4.24% Ni, 7.62% P and some carbon. Although the name was disputed by Reichenbach who was always in opposition to Haidinger, and although Shepard had simultaneously proposed the name schreibersite for a different mineral in the Bishopville stone, it was from now on associated with the hard, yellowish, platy skeleton crystals so easily observed with the naked eye on polished surfaces. It appears that Reichenbach had observed that the platy minerals of Magura, Sarepta, Cosby's Creek and similar irons were different from schreibersite in other occurrences and deserved their own name. He proposed the name lamprite (Reichenbach 1861: 485), but this was not accepted by Rose (1864a: 54), Haidinger and other authorities. It remained for Weinschenck (1889) to verify Reichenbach's observations. He showed that two optically similar, but chemically different minerals were, in fact, hidden under the name schreibersite. He proved that most of Magura's hard minerals (the type occurrence of schreibersite!) were iron carbides with a few percent nickel, which he named cohenite after Emil Cohen (1842-1905); and he also observed that cohenite generally included blebs of schreibersite, which made the separation and chemical analysis of the two minerals rather difficult.

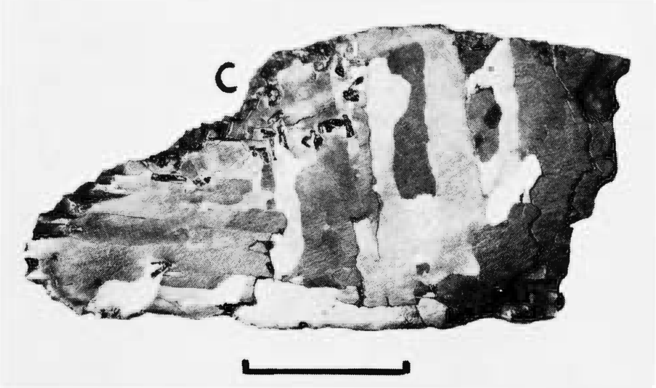

**Figure 1093.** Magura (U.S.N.M.). A sample which shows an intermediate variety of coarse Widmanstätten structure, with a cluster of cohenite crystals at C. Deep-etched. Scale bar 20 mm.

Haidinger (1846) observed cubic graphite crystals with truncated edges and suggested that they were terrestrial pseudomorphs after pyrite, while Rose (1864a: 40) was more inclined to interpret them as pseudomorphs after diamond, albeit diamond had never been found in meteorites. Brezina (1889) discussed Fletcher's description (1887c) of graphite crystals in Youndegin and added his own observations on Magura in support of the diamond pseudomorph theory. Fletcher had previously called the graphite mineral cliftonite and maintained that it could hardly be a pseudomorph after pyrite or diamond but was a separate species, a skeleton growth independent of previous minerals. Only in recent years, corroborated by the observations of, e.g., Lipschutz & Anders (1961), Brett & Higgins (1967) and Buchwald & Wasson (1968) does Fletcher's view again appear to win support: cliftonitic graphite is not a pseudomorph but probably a solid-state precipitation of carbon taking place at long time annealing above 500° C.

Haidinger (1844) observed small vivianite crystals in the corroded crust. The oberservation has never been elaborated upon, and vivianite has not been observed in other meteorites except on some Cape York specimens recovered from Eskimo *"kökkenmöddings."* Haidinger (1862) compared Magura to Sarepta and presented three excellent stereotypes of an etched section.

Weinschenk (1889) identified a few tiny, colorless diamond grains in the mixed residue of cohenite, enstatite and monoclinic pyroxenes which remained after dissolving 70 g of Magura in hydrochloric acid. The only other iron meteorite which contains diamonds is Canyon Diablo. The troilite-graphite nodules and the shocked structure are common to the diamond-bearing specimens. This supports the view that the diamonds were produced by a high intensity shock event from preexisting graphite, embedded in the troilite. While the shock event may have been the cratering impact in the case of Canyon Diablo, it may have been some preterrestrial event in the case of Magura where no associated crater is reported.

Cohen and his co-workers (1891; 1892; 1899, 1900b) analyzed separated fractions of cohenite, schreibersite, kamacite and taenite. Cohenite-rich specimens were very low in phosphorus (< 0.01% P), while cohenite-poor specimens were rich in phosphorus (0.24-0.32% P) and, therefore, schreibersite. It also appeared that there was a real variation in the nickel content, being relatively high (7.0-7.5%) in cohenite-rich specimens but low (6.5-7%) in cohenite-poor specimens. Westgren & Phragmén (1924) examined the cohenite by X-rays, and Heide (1966) reported cohenite to belong to space group $D_{2h}^{16}$ – Pnma, identical to that of technical cementite. Heide also observed and explained the so-called Bitter-pattern which may be seen on polished cohenite crystals when coated with a $Fe_3O_4$ suspension. The pattern is diagnostic for cohenite among meteoritic minerals and reflects the presence of minute, magnetic Weiss' domains. Olsen (1964) included Magura in his discussion of the thermodynamic stability of cohenite.

Reed (1965a, b) examined the composition range of the kamacite (homogeneous with 6.77% Ni) and the schreibersite (33-39% Ni). Buchwald & Munck (1965) and Buchwald (1966: 36) noted that the kamacite was heavily shocked, and Jaeger & Lipschutz (1967a, b) found that the shock intensity had been about 130-400 k bar.

## COLLECTIONS

Tübingen (45.5 kg), Vienna (30.2 kg), Budapest (18.5 kg), Berlin (10.1 kg), London (9.0 kg), Prague (2,266 g), Chicago (1,668 g), Budapest, Eötvös Loránd University (1,384 g), Dresden (1,309 g), Göttingen (1,140 g), New York (1,066 g), Moscow (923 g), Bonn (872 g), Harvard (772 g), Breslau (704 g), Washington (672 g), Stockholm (578 g), Munich (507 g), Uppsala (498 g), Paris (491 g), Copenhagen (346 g), Rome (312 g), Hamburg (300 g), Kazan State University (263 g), Belgrade (214 g), Vatican (200 g), Strasbourg (200 g). Leningrad (182 g), Tempe (163 g), Bally (143 g), Dorpat (140 g), Canberra (133 g), Oslo (120 g), Ann Arbor (98 g).

## DESCRIPTION

As mentioned above, the Magura shower consists of numerous individuals ranging from a few hundred grams to

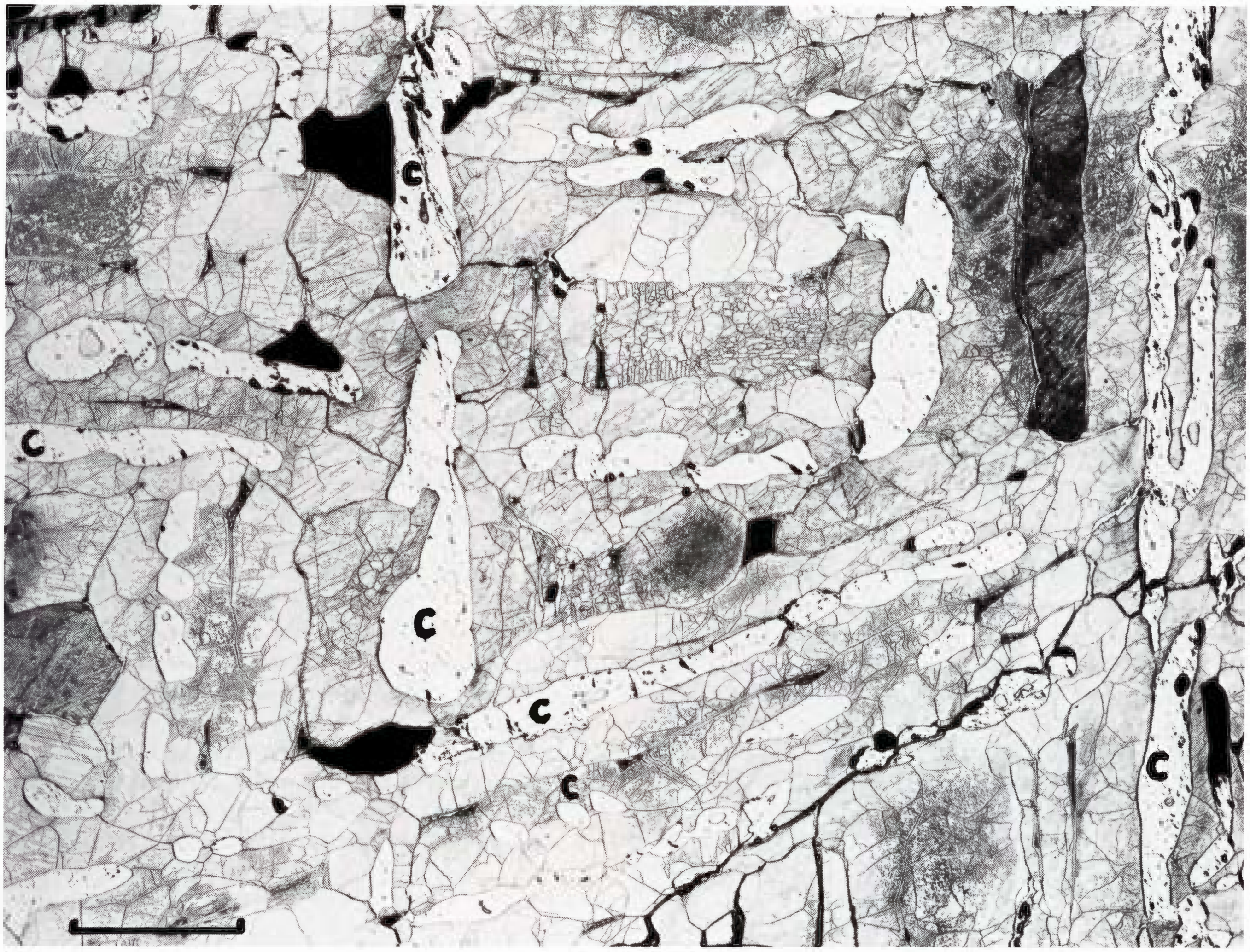

**Figure 1094.** Magura (Copenhagen no. 21). Elongated cohenite crystals (C) in the Widmanstätten kamacite lamellae. Subboundaries are very prominent in the shock-hardened kamacite. Etched. Scale bar 3 mm.

MAGURA – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| References | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Fahrenhorst in Cohen 1900b | 7.08 | 0.51 | 0.24 | 300 | 200 | | 200 | | | | | |
| Lovering et al. 1957 | | 0.46 | | | | 5.2 | 123 | | 82 | 345 | | |
| Wasson 1970a | 6.67 | | | | | | | | 94.6 | 483 | 3.2 | |

Fahrenhorst's and Wasson's analyses were performed on cohenite-poor specimens.

at least 42 kg. Most specimens are lenticular, heavily weathered masses, with no fusion crust and no heat-affected $\alpha_2$ zones preserved. Some specimens, e.g., Washington No. 3250, are strongly magnetic oxide shale balls of some hundred grams weight. The larger specimens are covered by a 1-2 mm thick oxide crust; and a disintegration of the surface along octahedral planes is visible in many places. In the interior, corrosion has selectively attacked the kamacite around the schreibersite and rhabdite and has also dissolved the kamacite before the taenite in the fine-grained plessite. The kamacite is more strongly oxidized around schreibersite than around cohenite, presumably because the nickel gradient near the schreibersite crystals is steeper.

Etched sections reveal that the individual masses are of two types, cohenite-poor and cohenite-rich, in very much the same way as Canyon Diablo, Cranbourne and most other group I irons.

The cohenite-poor variety displays an irregular Widmanstätten structure of bulky, short ($\frac{L}{W} \sim 4$) kamacite lamellae with a width of 3.0±0.9 mm. Local grain growth has annihilated many lamellae and created irregular, almost equiaxial grains, typically 2-4 cm in diameter. Remnants of slender taenite and plessite bodies still indicate the former lamella boundaries. Schreibersite occurs as 10 x 1 or 4 x 0.5 mm skeleton crystals and as 20-200 $\mu$ wide grain boundary precipitates. Rhabdites are very common in the form of 5-50 $\mu$ thick prisms. Troilite with graphite may or may not be present as flat cylinders, 5-15 mm in cross section. This Magura type resembles Seeläsgen and Campo del Cielo to some extent.

The cohenite-rich variety displays a regular Widmanstätten structure of straight ($\frac{L}{W} \sim 10$) kamacite lamellae with a width of 1.8±0.3 mm. Only little, if any, grain growth has occurred; and the taenite and plessite are more abundant, however, rarely occuping more than a few percent by area. The plessite is developed as comb plessite or acicular plessite, and it displays pearlitic areas with about 1 $\mu$ wide taenite ribbons. The subgrain boundaries of the kamacite are decorated with numerous rods of 1-2 $\mu$ thick phosphides.

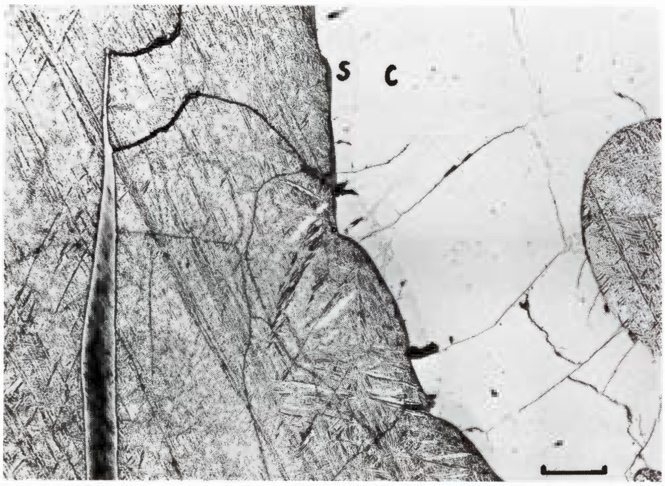

**Figure 1095.** Magura (Copenhagen no. 21). Cohenite (C) with a narrow rim of schreibersite (S). Shock-hatched kamacite and cloudy taenite lamella. Etched. Scale bar 100 $\mu$.

No large schreibersite crystals are present, but 10-100 $\mu$ wide grain boundary precipitates do occur, and a few rhabdites, generally 1-3 $\mu$ in cross section, are present in the kamacite. Troilite-graphite nodules may or may not be present. The cohenite occurs as 3 x 0.6, 6 x 1 or 10 x 1.2 mm irregular, rounded skeleton crystals in the midst of the kamacite lamellae. They are mainly monocrystalline but frequently heavily faulted and brecciated. The microhardness is 1100±50. They have scattered, small inclusions of kamacite, taenite and schreibersite, generally 50-400 $\mu$ in size. The cohenite appears nowhere to be under decomposition to graphite. The cohenite-rich variety resembles the typical cohenite bearing varieties of Canyon Diablo, Smithville, Odessa and others.

Common to both varieties, and their intermediates, is the shocked structure. The kamacite is heavily hatched, with occasional Neumann bands, giving an appearance resembling Grant, Treysa and other shocked irons. Very heavy deformation has distorted all components and, locally, along shear zones has displaced opposite parts 0.5-4 mm, without introducing fissures in the metal. While the ductile phases, such as taenite, are bent and dragged along the shear zones, the brittle phases, like cohenite and schreibersite, are abruptly cut and displaced along a flight of steps. In the most intensely deformed kamacite incipient recrystallization has formed 5-10 $\mu$ wide, irregular ferrite grains arranged in linear rows inside dense bundles of sliplines. Few other iron meteorites display such a wealth of distorted and faulted structures. The microhardness ranges, in accordance with the structure, from about 350 in the intensely deformed $\epsilon$-zones to about 200 in the recrystallized parts. Values of 280±30 are most common.

**Figure 1096.** Magura (Copenhagen no. 21). Cohenite (C) and schreibersite (S) in shock-hatched kamacite. Invading terrestrial limonite along interfaces. It is characteristic that the corrosion has been most active along schreibersite where the kamacite is depleted in nickel. Etched. Scale bar 100 $\mu$.

In sections with shock-altered kamacite, up to 50% by area of the cohenite may have recrystallized to 5-50 μ grains that are often clustered in narrow bands, apparently along shear zones. If a large number of Magura samples were systematically examined, it is likely that a range of microstructures and hardnesses, similar to what is shown for Canyon Diablo in the table on page 391, could be established.

Graphite was reported as up to "hazel-nut size" cubic pseudomorphs after pyrite or diamond (Haidinger 1846; Rose 1864a), but they appear to be far from common, since they were not seen in nine different sections from various museums. Only once, in No. 3336, was a 0.5 x 0.6 mm cliftonite-like crystal observed. It was somewhat deformed, but clearly of cubic outline. It was located in kamacite and 20-50 μ schreibersite had precipitated on it.

Diamond in the form of tiny crystals was identified by Weinschenk (1889). His identification is no doubt correct; however, the number of occurrences must be small since no later examination has reported diamonds. It would be interesting to have a modern investigation study the diamonds in situ; Weinschenk only saw them in the residue from dissolved specimens.

Rhombic and monoclinic pyroxenes were identified by Weinschenk (1889) and Cohen (1891). Corundum (Weinschenk 1889) and quartz (Brezina 1890) and various unidentified silicate minerals in small amounts have also been reported but never verified by modern methods. It would be interesting to determine whether the quartz and some of the other minerals are cosmic or are terrestrial grains that were embedded in the oxidized crust.

The troilite is monocrystalline but heavily shocked and brecciated. Bundles of lenticular deformation twins are very common, particularly along the shear zones. Daubreelite covers less than 5% by area, as 5-25 μ parallel, short lamellae. The troilite has a rim of 0.5 mm schreibersite and 0.5 mm cohenite, and both minerals are heavily sheared. Locally, along the phase boundaries the troilite is shock-melted and injected as 2-25 μ wide veinlets into the brecciated surroundings. The troilite is solidified to fine-grained aggregates of 2-5 μ equiaxial grains. Late corrosion has converted troilite to pentlandite along the grain boundaries and fissures.

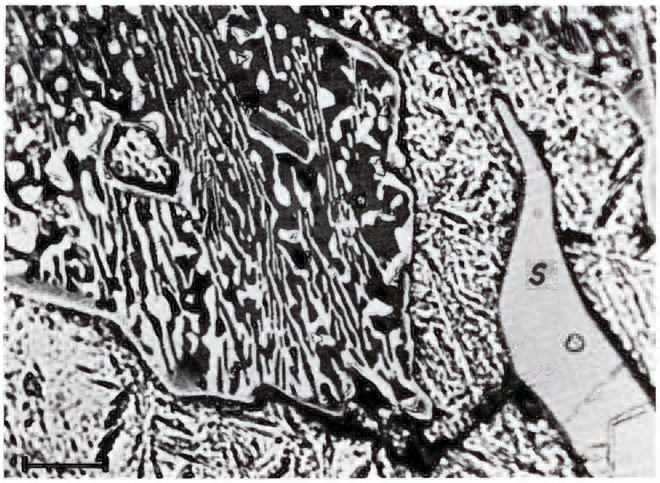

**Figure 1097.** Magura (Copenhagen no. 21). Corroded pearlitic plessite field. Schreibersite (S). The taenite lamellae and spherules survive in a limonitized kamacite. Etched. Scale bar 20 μ.

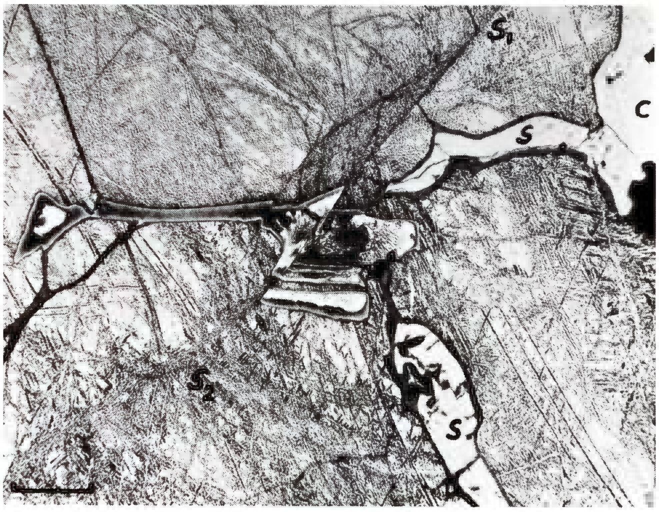

**Figure 1098.** Magura (Copenhagen no. 21). A violent shear $S_1$-$S_2$ has displaced a plessite field about 50 μ. Shock-hatched kamacite, cohenite (C) and schreibersite (S). Etched. Scale bar 200 μ.

Magura is a heavily shocked, coarse octahedrite which is closely related to Canyon Diablo, Smithville, Campo del Cielo, Sarepta and Seeläsgen. The various reported analyses indicate, as does the structural variation, that nickel, phosphorus and carbon vary significantly, from about 6.7% Ni, 0.3% P, < 0.05% C for cohenite-free varieties to about 7.2% Ni, 0.1% P, 0.25% C for cohenite-rich varieties. Sections through individual specimens indicate that at least 10 x 10 x 10 cm volumes may be "homogeneously" of one variety or the other. While Ni, P and C appear to vary significantly it may be expected that Co, Ga, (Ge) and Ir vary considerably less from variety to variety.

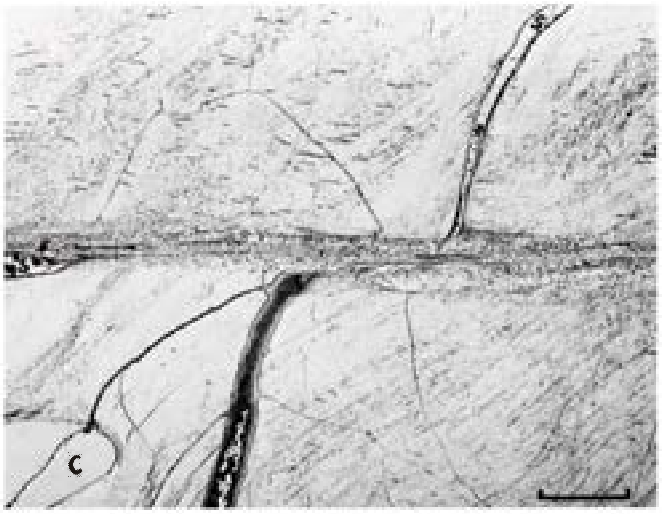

**Figure 1099.** Magura (Copenhagen no. 1877, 3020). Another explosion fragment with extensive shear-deformation. The partly recrystallized shear zone is 150 μ wide. Within it the kneaded remnants of schreibersite and taenite may be identified. Total displacement is about 1.3 mm. Etched. Scale bar 300 μ.

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

| | |
|---|---|
| cohenite-rich | 85 g slice, (no. 310, 7 x 2.5 x 0.5 cm) |
| cohenite-rich | 90 g slice (no. 672, 7 x 5 x 0.3 cm) |
| cohenite-rich | 117 g half mass (no. 672, 6 x 3 x 2 cm) |
| intermediate | 107 g fragment (no. 800, 5 x 3 x 2 cm) |
| | 59 g weathered fragments (no. 1075, Shepard Collection no. 35) |
| | 45 g various fragments (nos. 1662, 2894, 3337) |
| cohenite-poor | 79 g endpiece (no. 2893, 4 x 4 x 0.8 cm) |
| cohenite-poor | 101 g endpiece and fragments (no. 2895, 5 x 5 x 1 cm) |
| | 56 g half shale ball (no. 3250, 5 x 5 x 1.5 cm) |
| troilite-bearing | 22 g part slice (no. 3336, 3 x 2 x 0.6 cm) |

## **Majorca**, Spain

Probably a pseudometeorite.

### HISTORY

A small mass of 809 g is said to have fallen on July 17th, 1935, at 11:37 a.m. The hunter who allegedly observed the fall recovered the mass from a 90 cm deep hole. He gave the location as the junction of the highway from Palma to Manacor, 8 km from Palma. The material was described by Morales (1936) but unfortunately in a very insufficient way, without substantiation of the circumstances of fall, without a chemical analysis and with an inappropriate discussion of the structure.

It is unknown where the material is at present, but it is most likely in the National Museum in Madrid. Hey (1966: 287) only records the summarical data given by Morales, without further comments.

When reading Morales' paper, one is left with the impression that Majorca is a pseudometeorite, probably a piece of cast iron. The pseudometeoritic nature is suspected because (i) an 800 g mass would not penetrate to a depth of 90 cm, exept perhaps in a very loamy soil; (ii) the spectrographically detected nickel appears to be on a low level; (iii) no fusion crust and heat-affected $\alpha_2$ zones are reported; and finally (iv) the photomacrograph of an etched section (Morales 1936: figure 2) is not that of any recorded meteoritic structure, but rather that of an artificial, rapidly solidified material, such as dendritic cast iron.

It is strongly recommended that the small mass be reexamined. If it is not an artificial product it must be a highly anomalous meteorite, perhaps as unusual as Nedagolla and Ysleta.

## **Maldyak**, Khabarovsk Region, RSFSR

63°20'N, 148°10'E

A mass of 992 g was found in 1939 and acquired by the Academy of Sciences in Moscow. The locality and the coordinates above are from Zavaritskij & Kvasha (1952: 53) and Hey (1966: 287), but there seems to be some discrepancy, since the coordinates correspond to a point near Susuman in the Magadan Region. According to Vronskij (1960) it was found under 4.6 m of alluvium, only 4.5 km west of Frunze's Mine, the place where Susuman was discovered.

Maldyak was thoroughly described by Krinov (1949), Zavaritskij & Kvasha (1952: 53), Zavaritskij (1954) and Vronskij (1960), and several photographs of the exterior and of etched sections may be found in these papers. The meteorite was classified as a medium octahedrite and on various occasions assumed to be another fragment of the Susuman mass (Vronskij 1960; Hey 1966: 288). This appears, however, to be an erroneous assumption (Kirova 1962), since the analyses for Maldyak and Susuman are entirely different.

From a brief examination of the two main pieces in Moscow, I must support the observations by Kirova (1962). Maldyak is an independent fall, constituting a shock-hardened medium octahedrite, with imperfect Brezina lamellae of schreibersite. It appears to be closely related to Bartlett, Orange River, Wonyulgunna and Ilinskaya Stanitza, and is probably transitional between the resolved chemical groups IIIA and IIIB. Susuman, on the other hand, is a low-nickel, low-phosphorus member of group IIIA.

MALDYAK – SELECTED CHEMICAL ANALYSES

| | percentage | | | ppm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reference | Ni | Co | P | C | S | Cr | Cu | Zn | Ga | Ge | Ir | Pt |
| Dyakonova & Charitonova 1963 | 8.95 | 0.63 | 0.21 | | | | 300 | | | | | |

## **Manitouwabing**, Ontario, Canada

45°26'24"N, 79°52'32"W

Medium octahedrite, Om. Bandwidth about 1 mm. ε-structure. HV 260±10.

Perhaps group IIIA. About 7.8% Ni, 0.1% P.

### HISTORY

A mass of about 39 kg (85 pounds) was discovered in 1962 by Philip Johnson on his property south of Lake Manitouwabing, between the villages of Hurdville and Broadbent in the Parry Sound District (Meteoritical Bulletin, No. 26, 1963). According to Knox (1964), who described a fragment and gave some excellent photomicrographs of the shock-hatched kamacite, Johnson had done some blasting in 1950 and had placed the loosened blocks in a pile. Reexamining this pile in 1962, he discovered the black meteorite and felt that it was not part of the original pile. Considerable evidence – not yet conclusive – has been amassed by interested parties that the meteorite fell early one winter morning in 1954. Heard (1964) also discussed the problems associated with the alleged fall.

### COLLECTIONS

University of Toronto (main mass), Ottawa (19 g).