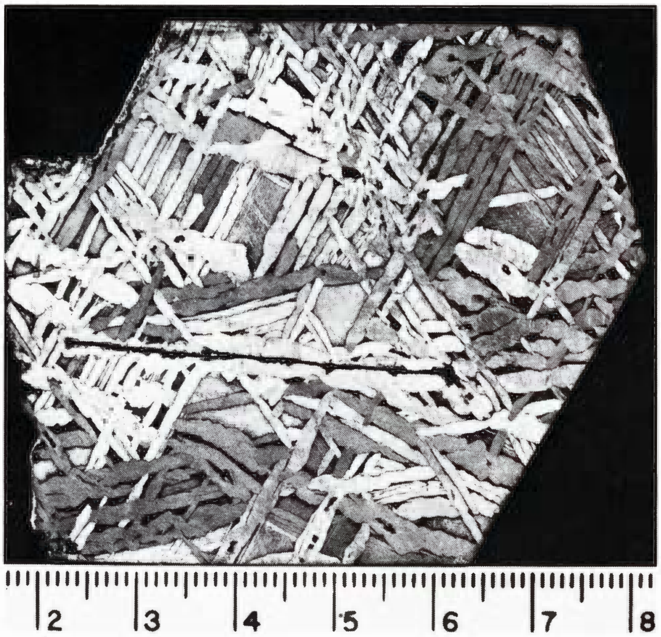

Figure 1049. Lenarto (Tempe no. 70a). A medium octahedrite which is transitional between group IIIA and IIIB. A horizontal Reichenbach lamella of troilite which is now shock-melted and corroded. Deep-etched. Scale in centimeters. (Courtesy C.B. Moore.)

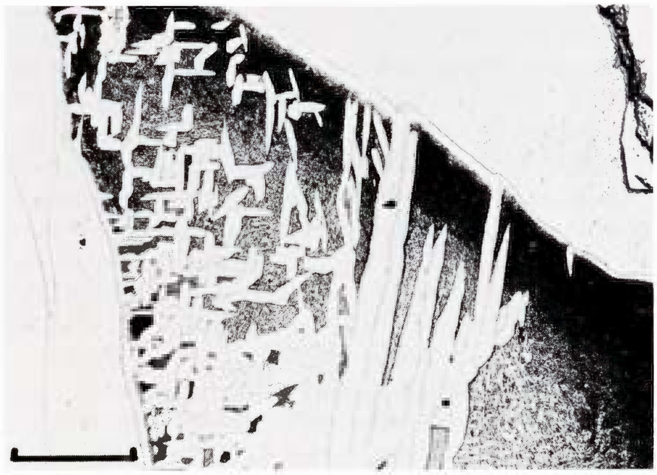

Figure 1050. Lenarto (U.S.N.M. no. 450). Acicular plessite field and the corroded end of a troilite-schreibersite Reichenbach lamella (above, right). Lightly etched. Scale bar 200 μ. (Perry 1950: volume 7.) See also Figure 23.

some α-lamellae, but most of the smaller bodies are present as 40-80 μ wide veinlets in the grain boundaries. Some schreibersite occurs as 1-20 μ vermicular bodies inside the plessite fields where they substitute for taenite. Point counting indicated a bulk content for the meteorite of 0.3% P.

Troilite occurs sparsely as 5-25 mm irregular nodules with 0.6 mm rims of schreibersite. The troilite is more common in the form of Reichenbach lamellae that, typically, are 30 x 20 x 0.2 mm in size and occur with a frequency of one per 25 cm^2. The plates originally consisted of troilite upon which irregular "flags" and "sacks" of schreibersite later precipitated. Zones of swathing kamacite, 1 mm wide, developed around the plates before the Widmanstätten structure formed. The troilite of the plates later micromelted and solidified to 2-5 μ fine-grained eutectics of sulfide and iron in which angular fragments of the enclosing schreibersite became dispersed. Sulfide-eutectics, 2-10 μ wide, were injected into fissures in the remaining schreibersite. The morphology indicates that a shock event caused the troilite to melt, evidently because the troilite, due to its compressibility, was heated far above the surrounding metallic matrix. Unfortunately, it appears that the resulting fine-grained structures with finely dispersed iron are very prone to terrestrial oxidation, so in many specimens the Reichenbach lamellae are converted to limonitic pockets. Another reason for the corrosion along the Reichenbach lamellae are the numerous microfissures that follow them, providing easy access for terrestrial water.

Some few specimens have been cold hammered or even reheated artificially. Vienna No. J4919 is a small slab which, about 1840, was forged by Partsch to a 0.5 mm thick plate and then deep-etched to show the characteristic damask produced by the undulating taenite ribbons and the α_2 structure.

Graphite nodules have been reported by Reichenbach (1862b), but this could not be confirmed and is probably a misinterpretation of some corroded troilite nodules.

Lenarto is a shock-annealed medium octahedrite with ϵ-structure and several Reichenbach lamellae. It closely resembles El Capitan and, in a wider context, also Cleveland, Sierra Sandon, Drum Mountains and others. It is a transitional member of group IIIA - IIIB with about 0.3 ppm Ir, as shown by Wasson.

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

132 g part slice (no. 450, 6.5 x 5 x 0.5 cm)
17 g part slice (no. 1064, 5.5 x 2 x 0.2 cm)
40 g part slice (no. 2878, 4 x 2.5 x 0.5 cm)

Lexington County, South Carolina, U.S.A.

Approximately 33°57′N, 81°14′W

Coarse octahedrite, Og. Bandwidth 2.1±0.4 mm. Neumann bands. HV 176±9.

Group I. 6.69% Ni, about 0.2% P, 85 ppm Ga, 307 ppm Ge, 2.3 ppm Ir.

HISTORY

A mass of 4.8 kg (10.5 pounds) was found in 1880 upon farm land in Lexington County. Since the exact locality is unknown, the coordinates above are those of Lexington town. The mass was acquired by Professor C.U. Shepard who described it with an analysis (1881a) and correctly noted that it was related to Bohumilitz. Brezina (1896: 269) gave a brief description of the 58 g specimen in Vienna. Berwerth (1902: 15) mentioned an additional 369 g specimen in the Vienna Collection, but apparently we are here confronted with one of the frequent mislabelings of Lexington County.

COLLECTIONS

Washington* (2.6 kg), Chicago (1.079 g), London (271 g), Ann Arbor* (216 g), New York (211 g), Berlin* (194 g), Amherst* (85 g), Vienna* (58 g), Vatican (50 g), Yale (49 g), Göttingen (19 g), Budapest (17 g). Since these specimens add up to more than originally found, it is likely that some of them, in fact, are specimens of another meteorite. The specimens marked by an asterisk have been checked by the author and found authentic. The Chicago material was examined by the author and found to consist of three specimens, two small ones totaling 110 g (nos. 111 and 1113) being authentic Lexington County, while the third, a 960 g endpiece (no. 1114) was a typical medium octahedrite with a bandwidth of 1.1 mm. This was confirmed by Wasson, who found 7.85% Ni, 21.7 ppm Ga, 42.6 ppm Ge and 1.1 ppm Ir and classified it as a group IIIA iron (Scott et al. 1973). Specimen No. 1114 has a well-preserved heat alteration zone and cosmically deformed kamacite lamellae. It appears to be a new, hitherto undescribed, meteorite.

DESCRIPTION

The mass had the form of a small loaf with the overall dimensions of 16 x 9 x 6 cm. The half mass in the U.S. National Museum shows that it was severely corroded when found, with 1-2 mm thick terrestrial oxide shales and with a preferential attack along the grain boundaries, whereby small, octahedral fragments became detached. A few hammer marks of little significance have flattened some rough knobs. No fusion crust is preserved, and no heat-affected rim zone was found in the sections, so the mass must have been exposed to terrestrial weathering for a long time.

Etched sections display a coarse Widmanstätten structure of bulky, short ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.1±0.4 mm. Local grain growth has resulted in the development of several, scalloped, almost equiaxial, kamacite grains 5-15 mm in diameter. Inside these a little, still unresorbed taenite may often be seen arranged in the octahedral directions. Neumann bands are common, sometimes, however, appearing in broken units possibly because of an incipient recrystallization. The hardness is 176±9.

Taenite and plessite occupy 2-4% by area. In the cohenite-poor areas the plessite is predominantly of the almost resorbed comb plessite type, while in the cohenite-rich areas the plessite occurs as wedges or dumbbells with acicular, martensitic, pearlitic or spheroidized interiors. A typical field will have a tarnished taenite rim (HV 315±10) and indistinct martensitic transition zones (HV 350±15). The pearlitic areas, with about 0.5 μ wide taenite lamellae, have a hardness of 300±10, while the spheroidized areas, with 1-2 μ thick taenite globules, have a hardness of 210±10.

Schreibersite occurs as 1-5 mm skeleton crystals, frequently enveloped in a continuous, 100 μ wide rim of cohenite. The aggregates are set in a frame of 2-4 mm wide swathing kamacite. The cohenite has a hardness of 1090±20, the schreibersite of 925±20. Both cohenite and schreibersite are monocrystalline but brecciated and sometimes faulted, and the cohenite is under decomposition to ferrite and graphite along internal fissures. The graphite lamellae are about 100 x 3 μ in size and enveloped in a somewhat wider zone of microcrystalline ferrite, which, unfortunately, often is selectively corroded. Schreibersite is further common as 20-100 μ wide grain boundary precipitates. Rhabdites, 5-25 μ in cross section, are very common, especially in the cohenite-poor areas.

Ovoid troilite-graphite nodules, 1-2 cm in diameter, occur in several places but are corroded. The corona of schreibersite and cohenite is normally better preserved. In the adjacent, swathing kamacite there are numerous cliftonite crystals, 50-200 μ in diameter. They are composed of radiating sheaves of graphite with good extinction. Crystalline graphite aggregates with poor crystal facets are present in the cohenite. According to Shepard (1881a) who originally cut the mass, the troilite nodules were particularly common at one end where they were believed to constitute nearly one third of the volume.

Figure 1051. Lexington County (U.S.N.M. no. 1066). A coarse octahedrite of group I. Neumann bands are distinctly seen, and swathing kamacite around schreibersite and troilite-graphite nodules is well developed. Deep-etched. Scale bar 10 mm. S.I. neg. 1511.

LEXINGTON COUNTY – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Wasson 1971, pers. comm.	6.69								85.4	307	2.34	

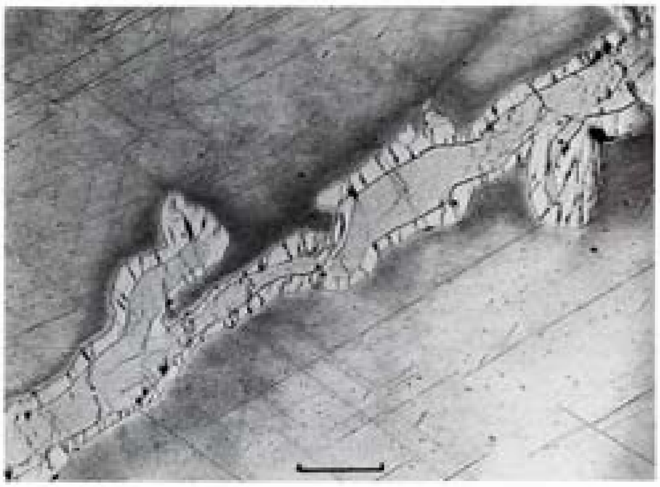

Figure 1052. Lexington County. Detail of the inclusion S in Figure 1051. The center is schreibersite, and it is entirely enveloped in a rim of cohenite. The cohenite is under decomposition to graphite and ferrite along internal fissures. Etched. Scale bar 500 μ. S.I. neg. 1497B.

Lexington County is a coarse, inclusion-rich octahedrite related to Bohumilitz, Dungannon, Yenberrie and Canyon Diablo. It is a normal group I iron.

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

2,511 g main mass (no. 1066, 9 x 9 x 6 cm, Shepard Collection no. 93; recently divided into 2,124 g endpiece and 289 g slice)
100 g slices and fragments (nos. 10, 1066, 3334)

Lick Creek, North Carolina, U.S.A.

Approximately 35°36′N, 80°10′W; 150 m

Hexahedrite, H. Single kamacite crystal larger than 11 cm. Neumann bands. HV 165±6.

Group IIA, judging from the structure. About 5.7% Ni, 0.3% P.

HISTORY

A mass of 1.24 kg was found in 1879 by G.W. Harris while he was prospecting for gold on his land near Lick Creek, Davidson County (Hidden 1880b). Lick Creek is a 15 km long tributary to Yadkin River and runs 2 km northwest of Denton. Hidden reported that he visited the exact spot, but unfortunately he forgot to tell his reader where it was. The approximate coordinates are given above.

For a while the mass was believed to be a "silver nugget," but it was recognized as a meteorite by Hidden who acquired and described it and also gave a few woodcuts of the exterior appearance, emphasizing the thick laminated, terrestrial oxide-shales. Brezina (1881: 280, 291) purchased the entire mass and gave brief descriptions. Cohen (1905: 220) reviewed the literature and added his observations. Wülfing (1897: 204) and Farrington (1915) gave numerous references to the early work.

COLLECTIONS

Vienna (887 g main mass and 63 g slices), Budapest (38 g), Paris (34 g), Greifswald (26 g), London (18 g), Chicago (15 g), Berlin (11 g), Washington (9 g), Harvard (6 g). An additional specimen of 18 g (no. 413) acquired from E.E. Howell about 1905 is in the U.S. National Museum. It was identified by the author as a fragment of Deep Springs. Whether other mislabeled specimens are around is not known.

ANALYSES

Hidden (1880b) quoted the average of four determinations by J.L. Smith and J.B. Mackintosh: 5.74% Ni, 0.52% Co, 0.36% P, and traces of sulfur, chlorine and copper. A fine analysis for those days.

DESCRIPTION

The pear-shaped mass was about 11 cm long and 6 cm thick; it weighed, after substantial amounts of weathered

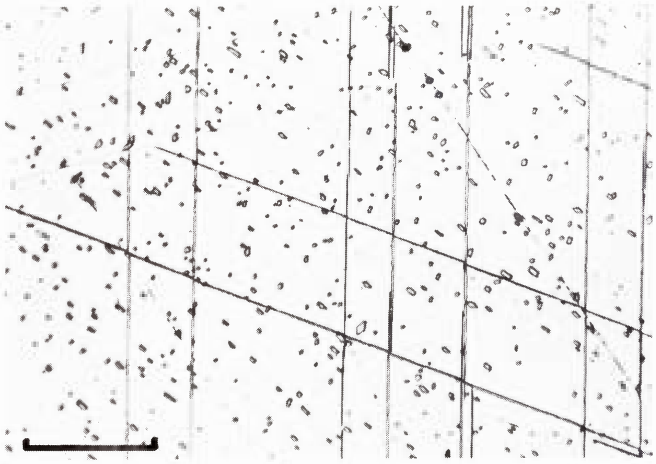

Figure 1053. Lick Creek (Chicago no. 1074). A normal hexahedrite with Neumann bands and prismatic rhabdite needles. Etched. Scale bar 300 μ.

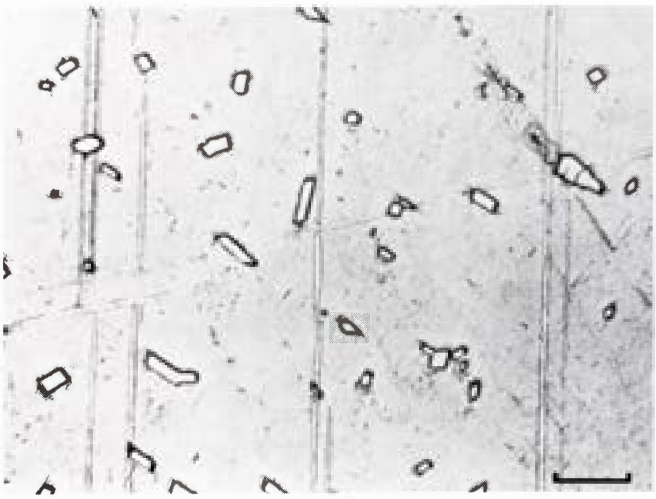

Figure 1054. Lick Creek. Detail of Figure 1053. The rhabdites are sheared and often displaced by the deformation that cold worked the metallic matrix. Subboundaries and a few carlsbergite platelets are indistinctly visible. Etched. Scale bar 50 μ.

crust had been removed, 1.24 kg. The crust was laminated, porous and in places 10 mm thick; on the spot where the meteorite was found at least 170 g of this oxide shale was collected. The original owner had noticed exudations of a yellowish fluid on the cut surfaces, which, when wiped away, would form again during the next 24 hours and had been aptly termed "night sweats" (Hidden 1880b).

Etched sections display a hexahedral structure, broken only by a few small troilite inclusions. Neumann bands cross the entire sections in numerous directions. They are undecorated. Subboundaries are present in the kamacite but usually only distinctly visible adjacent to the larger phosphide and sulfide inclusions. The microhardness is 165±6.

Schreibersite occurs as platelets in several directions; they are typically 0.5-4 mm in two directions and have thicknesses of 5-30 μ. They are slightly sheared and broken by the deformation that created the Neumann bands. Prismatic rhabdites occur in profusion. They are rather uniformly distributed and of uniform sizes, 6-12 μ thick and 100-300 μ long. A few giant hook-like prisms, 200 x 300 μ in cross section, can also be detected.

Troilite occurs as a few 1-2 mm bars and globules. They are apparently monocrystalline and contain parallel daubreelite lamellae 10-100 μ wide.

Cohenite was detected twice as 400-600 μ subangular blebs intergrown with rhabdite hooks and platelets. The cohenite is harder (HV 1050 ±50) than the phosphides and usually shows stronger anistrophy. It was precipitated upon the rhabdites after these had almost stopped growing. Scattered carlsbergite platelets, 10 x 1 μ in size, also occur in the kamacite phase. These are often overgrown by phosphides, so they must be early precipitates.

Lick Creek is a normal hexahedrite which is severely weathered. The fusion crust and the heat-affected α_2 zones are entirely lost, and chloride ions have been introduced with the ground water during long terrestrial exposure. Lick Creek is related to Bruno, Calico Rock, Murphy and the North Chilean hexahedrites, and belongs to the resolved chemical group IIA.

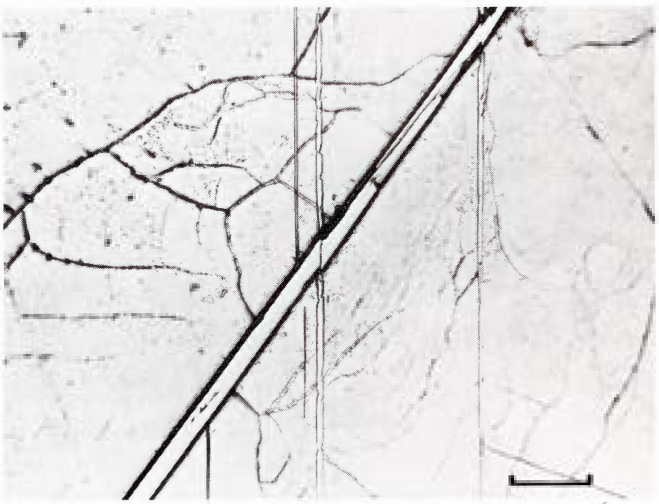

Figure 1055. Lick Creek (Chicago no. 1074). A schreibersite platelet which is shear-displaced by Neumann bands in two places. Subboundaries in the kamacite. Etched. Scale bar 50 μ.

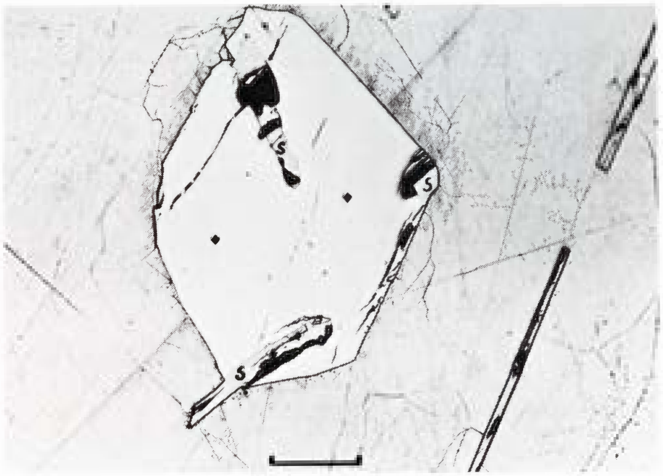

Figure 1056. Lick Creek (Chicago no. 1074). A cohenite crystal with two minute, square hardness indentations. The cohenite has grown around – and partly swallowed – three schreibersite crystals (S). To the right a schreibersite platelet. Etched. Scale bar 200 μ.

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

9 g bar-shaped slice (no. 1067, 3 x 0.7 x 0.4 cm)

Lime Creek, Alabama, U.S.A.

Approximately 31°31'N, 87°31'W

Nickel-rich Ataxite, D. Scattered 0.01 mm wide kamacite platelets in a tempered martensitic matrix. HV 192±6.

Anomalous. 29.5% Ni, 0.19% P, 15.5 ppm Ga, 28.5 ppm Ge, 1.1 ppm Ir.

The synonyms Claiborne and, later, Limestone Creek have been widely used.

HISTORY

A mass of unknown weight was found by Mr. Hubbard before 1834 on the surface near Lime Creek and Claiborne, in Monroe County. Since the mass was inconvenient to transport, it was broken with a sledge hammer and only a fragment of 28 ounces (800 g) was carried away. The rest was left where it was found and has never been heard of since. The material was in 1834 acquired by Jackson who described it (1838) and gave the approximate dimensions of the lost mass as 10 inches long and 5-6 inches thick. From these data the original weight may be estimated to have been 20-30 kg.

Jackson was the first to record the presence of iron chloride in meteorites, noting that freshly prepared surfaces of Lime Creek became covered with grass-green liquid drops. While Shepard (1842) was very sceptical with respect to the cosmic origin of the chlorine, most other authors accepted the identification here and in other meteorites, and the allegedly cosmic mineral $FeCl_2$ was named lawrencite by Daubrée (1877c) and was incorporated in all standard textbooks on mineralogy (Mason 1962a: 60; Mason 1967a; Ramdohr & Strunz 1967: 471; Strunz 1970: 157). The present study reveals the chlorides of iron meteorites to be of terrestrial origin.

Partsch (1843: 133) described a 7 g specimen in Vienna, but due to the fine details of the meteorite, his structural description was inadequate. About this time the Walker County hexahedrite was found, cut and circulated, and this introduced considerable confusion. As both meteorites came from Alabama and neither of them gave etching figures of the usual octahedral type, the two became much interchanged. As late as 1894, Cohen published a paper on "Lime Creek, Claiborne", which was actually based on Walker County material. Cohen (1905: 128, 166) was, however, the first to correct matters again. He gave a full history with references to older work; further summaries are to be found in Wülfing (1897: 204) and Farrington (1915: 269). Farrington pointed out that the locality was probably Limestone Creek which runs into the Alabama River at Claiborne. The coordinates given above are those of Claiborne.

Perry (1944: plates 31 and 32) examined a specimen (Me 937) in Chicago and presented eight photomicrographs, but otherwise very little is known of the meteorite.

COLLECTIONS

New York (129 g), Chicago (84 g), Yale (64 g), Amherst (54 g), London (19 g), Paris (13 g), Vienna (5.1 g, mentioned in Partsch 1843: 133 and Cohen 1905: 130), Washington (2.9 g). In this list only samples which have been rechecked as authentic Lime Creek specimens are included. More must exist, but the main mass was probably never retrieved.

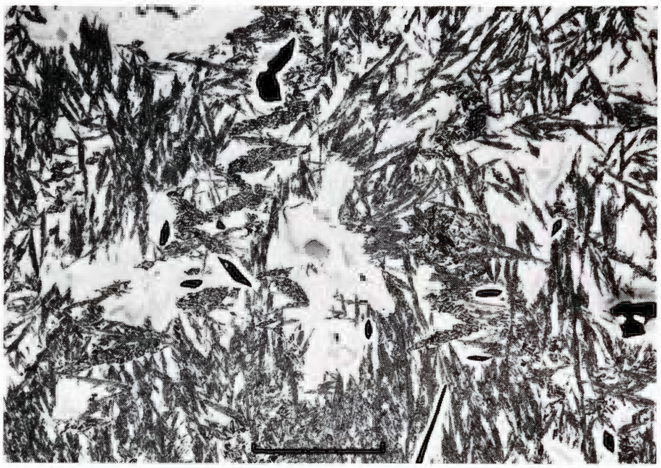

Figure 1057. Lime Creek (Vienna no. A 352). A general view of the very anomalous meteorite. Haxonite (brilliant white) with schreibersite (angular gray) has nucleated narrow kamacite rims. The matrix is tempered martensite or bainite. Polished only; natural corrosion has selectively converted much of the α-phase to limonite (black and gray). Scale bar 200 μ.

DESCRIPTION

According to Jackson (1838) the lost main mass was irregular, triangular and about 10 inches long and 5-6 inches thick. It probably weighed 20-30 kg. The preserved specimens are usually small weathered fragments which continue to disintegrate under normal museum conditions. They are, therefore, difficult to label; after a number of years the painted number or the adhesive label spalls off and is easily lost. This is an obvious cause of mislabelings. During this study the two specimens in Washington, No. 379 (269 g; Merrill 1916a: 96) and No. 998 (3.7 g; Shepard Collection No. 24), were thus found to be mislabeled samples of Walker County and Deep Springs, respectively. Before the mislabelings were realized much time and effort had, as is the case with mislabelings, been wasted.

The kind assistance of the curators Dr. E. Olsen, Chicago, and Dr. G. Kurat, Vienna, helped to overcome this unfortunate situation by allowing me to examine their specimens, Me 937 (84.5 g) and A 352 (5.1 g). The last one was the same sample that Partsch (1843) and Cohen (1905) worked with. It originally weighed only 7 g.

Lime Creek is a nickel-rich ataxite. On etching, the sections become somewhat frosty and rather monotonous in appearance, except for scattered troilite, haxonite and schreibersite aggregates. High magnification reveals a number of slender kamacite platelets, precipitated in the

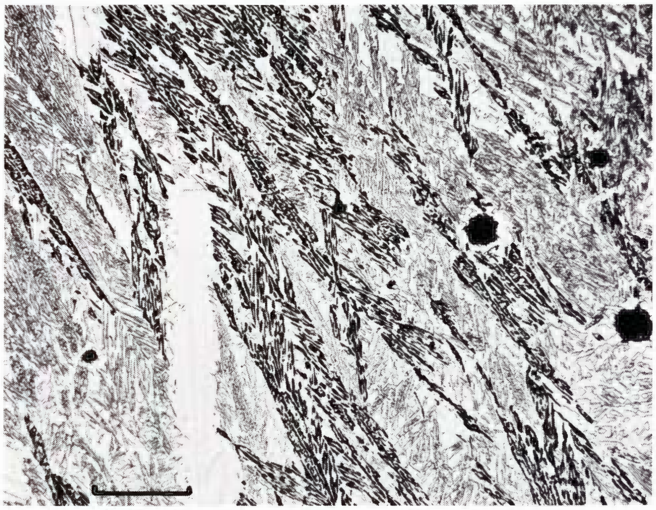

Figure 1058. Lime Creek (Vienna no. A 352). Three kamacite needles on left and three graphite spherulites in right of picture. Lightly etched. Scale bar 40 μ.

LIME CREEK – SELECTED CHEMICAL ANALYSES

References	percentage Ni	Co	P	ppm C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Knauer in Cohen 1905	30.0	1.48	0.19									
Scott et al. 1973	29.1								15.5	28.5	1.1	

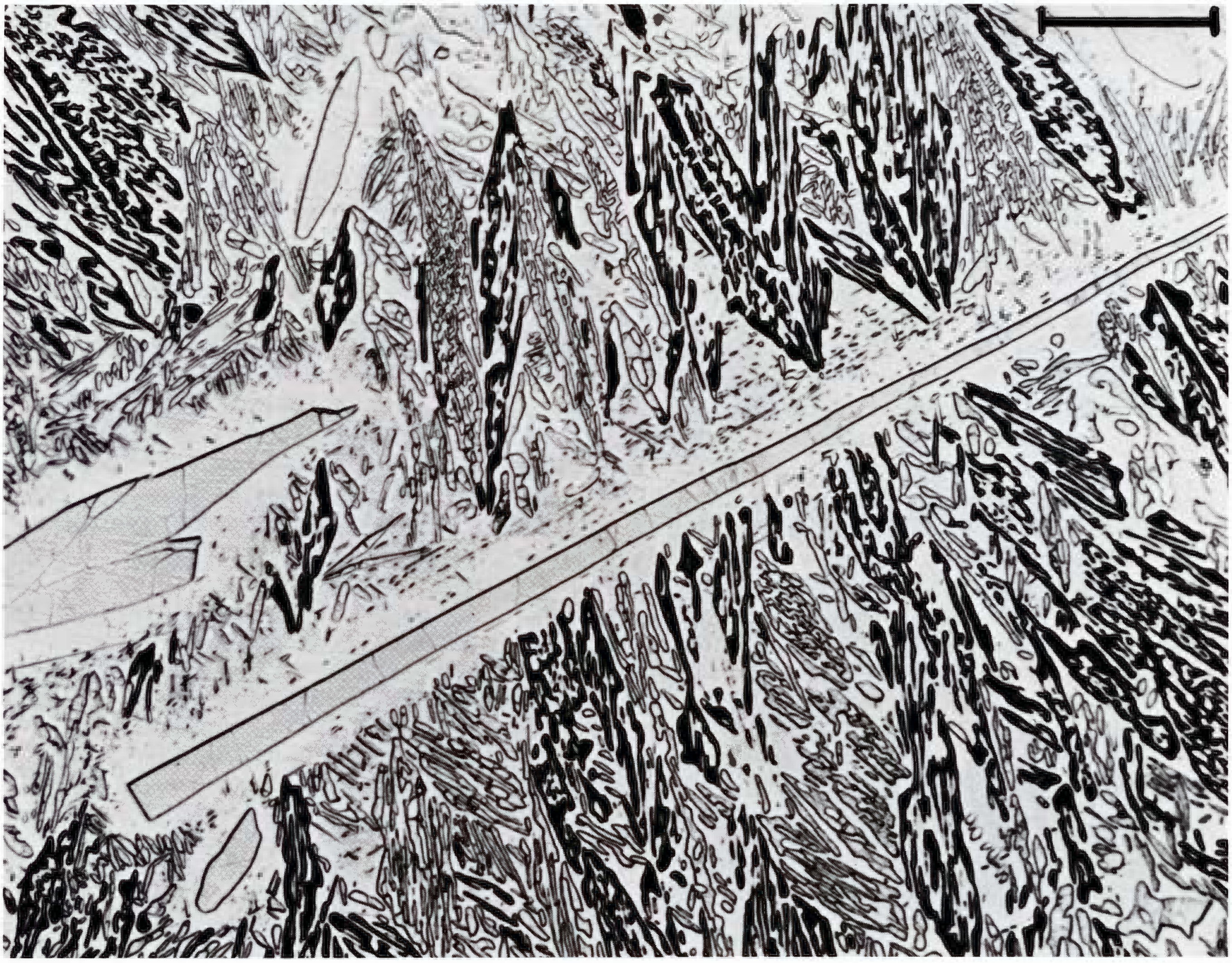

Figure 1059. Lime Creek (Vienna no. A 352). Kamacite spindles with subboundaries. Adjacent taenite rims under decomposition to α along $(111)_\gamma$ grids. Terrestrial corrosion (black) serves to develop the annealed matrix. Lightly etched. Oil immersion. Scale bar 20 μ.

Widmanstätten planes of the precursor taenite crystal. This was larger than 4 cm across, since grain boundaries were not detected on any of the sections. The α-platelets occur with a frequency of about 25 per mm^2 and are usually 5-15 μ thick and 25-200 μ long. They are bordered by 1-3 μ wide nickel-rich taenite rims. Neumann bands are absent.

The matrix between the α-platelets constitutes 90-95% by volume and appears at low magnification to be martensitic. The martensite platelets may be 5 μ wide and as much as 200 μ long, and they are developed in a multitude of directions. On magnification, the martensite is seen to be thoroughly tempered. All platelets are decomposed to kamacite and taenite, both components forming continuous, intergrown networks with widths of 0.5-2 μ. The hardness of the tempered matrix is 192±6. The previous massive taenite rims around the kamacite platelets are also annealed: they display 0.5-2 μ angular α-windows and a distinct parallel grid, indicating the orientation of one or two of the slipplanes of the precursor taenite crystals.

Schreibersite occurs as 5-75 μ irregular particles, rather evenly scattered over the sections. Occasionally they reach 0.5 x 0.1 mm in size. All phosphides are enveloped in rims of swathing kamacite that may reach widths of 100 μ. The kamacite is annealed or recrystallized to almost equiaxial grains only 5-50 μ across. The microhardness is correspondingly low, 146±4. From the schreibersite crystals, particularly from the smaller, nickel-rich ones, a number of irregular 1-3 μ wide taenite particles have been detached. This is an indication that late cosmic annealing caused the phosphides to reduce their nickel contents according to the equilibrium diagram. Similar developments are present in, e.g., Ballinoo, Roebourne and Oscuro Mountains.

Haxonite is rather common as ductile, hard (HV 830±30) crystals of high brilliance in reflected light. They are up to 4 x 0.3 mm in size but usually form 5-100 μ irregular, isotropic particles, intergrown with schreibersite. They are enveloped in 20-50 μ wide rims of swathing kamacite, now partly limonitized.

Troilite occurs as 0.2-1.5 mm nodules which were once monocrystalline and enveloped in schreibersite and haxonite. A cosmic shock event has, however, transformed the troilite to fine-grained iron-iron sulfide eutectics with dis-

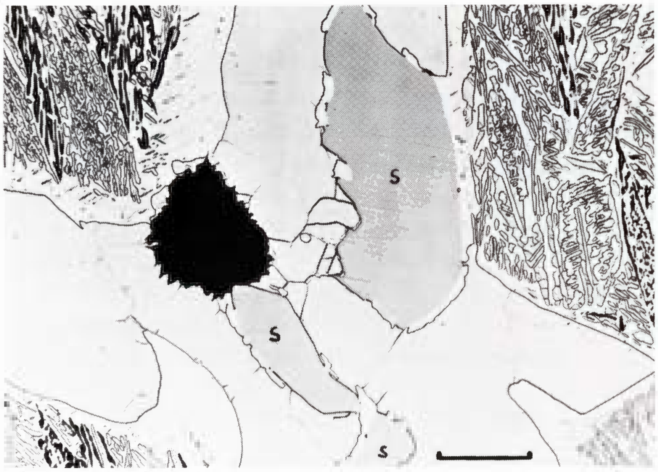

Figure 1060. Lime Creek (Vienna no. A 352). Schreibersite crystals (S) which have adjusted their composition upon annealing, segregating γ-particles (white) along their periphery. A graphite spherulite was formed in the kamacite during the same annealing period. Etched. Oil immersion. Scale bar 20 μ.

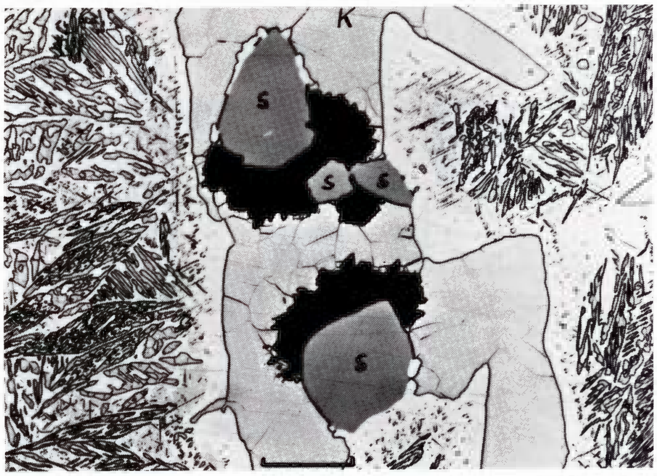

Figure 1061. Lime Creek (Vienna no. A 352). Kamacite spindle (K) with subboundaries and four schreibersite crystals (S). The γ-particles and spherulitic graphite have precipitated on the schreibersite. Note the annealed, decomposing taenite rims. Etched. Oil immersion. Scale bar 20 μ.

persed subangular schreibersite fragments and 5-20 μ graphite spherules.

Graphite also occurs in a very unusual form, as nodular clusters, 5-25 μ across, within the metallic matrix. The graphite nodules are always situated in kamacite, having been nucleated by either a schreibersite-kamacite or a taenite-kamacite interface.

Chromite is present as 100-300 μ long, but very thin (1-3 μ) platelets. With the chromite and the schreibersite-troilite-graphite aggregates, coke-gray or bluish minerals often occur. They usually show rust-red internal reflections in polarized light; they appear to be terrestrial limonitization products, mainly having replaced previous kamacite areas.

The preserved specimens are all much weathered. No fusion crust and no heat-affected rim zones could be detected, and cracks and fissures are filled with terrestrial corrosion products. The relative ease with which the finder was able to split the mass was probably caused by the presence of these corroded crevices. The amount of chlorides varies with the degree of corrosion. Jackson (1838) found 1.48% Cl in a specimen which must have been significantly weathered, since the specific gravity was only 6.50. On the other hand, no chlorine was detected in an uncorroded specimen which yielded 29.99% Ni (Knauer, in Cohen 1905). The chlorides must have been introduced with the ground water during very long terrestrial exposure.

Several centimeters below the present surfaces the swathing kamacite has been transformed to limonitic products. Under the microscope the matrix is also seen to be corroded in places which macroscopically appear undamaged. Although part of the corrosion on cut and polished museum specimens has occurred after preparation of the surfaces, the major attack clearly occurred before the meteorite was discovered. The tempered martensite is partially oxidized to a depth of 2-3 mm so that its structure is beautifully developed. Its hardness has, by internal oxidation, increased about one hundred units, to 300±20. It is remarkable how oxygen has, at low temperature, been able to penetrate into the meteorite without the presence of grain boundaries. There are no indications of artificial reheating.

Lime Creek is a very unusual meteorite. However, there are a few other meteorites with a similar high-nickel content, San Cristobal (25.6%), Twin City (30.0%), Tishomingo (32.5%) and Santa Catharina (35.3%). Each of these displays characteristic developments dating from the primary cooling period, but all, except Tishomingo, have a number of fine kamacite platelets and swathing kamacite rims in common. Evidently Tishomingo had a significantly higher primary cooling rate than the other four. Lime Creek seems to be more related to San Cristobal than to any of the others mentioned; it is, however, peculiar in having been exposed to a cosmic shock with subsequent thorough annealing that tempered the martensite and the taenite,

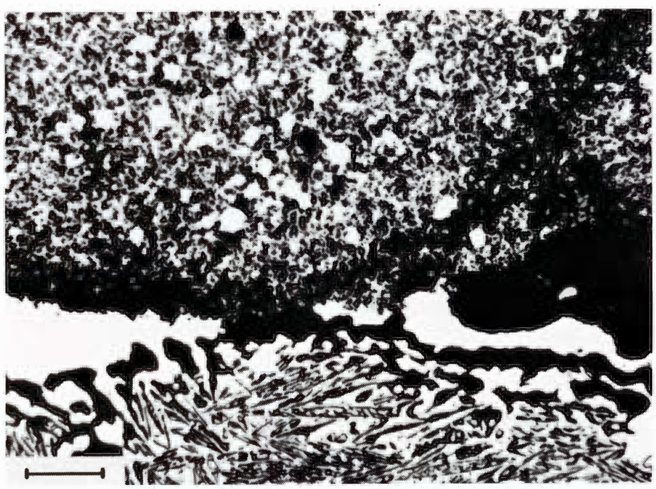

Figure 1062. Lime Creek (Vienna no. A 352). The edge of a shock-melted troilite nodule (above). It now consists of an iron-sulfur eutectic with dispersed schreibersite fragments and graphite spherules. Etched. Scale bar 20 μ.

decomposed some haxonite and caused graphite spherulites to precipitate and phosphides to alter their composition.

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

2.9 g part slice (no. 1183, 17 x 11 x 3 mm). The specimen was found in the collection, mislabeled Wooster.

Linville, North Carolina, U.S.A.

35°52'N, 81°55'W; approximately 1,000 m

Polycrystalline, nickel-rich ataxite. α-spindles 30±10 μ wide. α_2 matrix. HV 230±25.

Probably anomalous, judging from the structure. About 16% Ni, 0.25% P.

The mass has been reheated by a blacksmith to about 1000° C.

HISTORY

A mass of 442 g was found in 1882 on Linville Mountain, in Burke County (Kunz 1888). Linville Mountain is the name of a short section of the Blue Ridge, Appalachian Mountains, extending for a few miles in a southwesterly direction from Linville Falls, and forming the western edge of Burke County. The corresponding coordinates are given above. The mass passed through several hands before it was acquired by Kunz, who described it with a woodcut of the exterior, and with an analysis by Whitfield. Brezina (1896: 234, 295) obtained the main mass and, erroneously, included it in the hexahedrite group, although Whitfield had reported about 15% Ni. Cohen (1898a: 145; 1905: 119) confirmed the high-nickel value and classified Linville as a nickel-rich ataxite, similar to Morradal, Deep Springs and others. Perry (1944: plate 24) gave two photomicrographs. Ramsden & Cameron (1966) discussed the possible existence of kamacite and taenite superstructures and examined selected meteorites with X-ray powder photographs. Since their evidence for the superstructures are particularly based upon Linville material, and this, as shown here, is artificially reheated to 1000° C, it is clear that the interpretations of the X-ray photographs need revision.

COLLECTIONS

Vienna (214 g), New York (60 g), Chicago (27 g), Ottawa (22 g), London (21 g), Washington (15 g). The balance has mostly been lost in cutting and analyzing.

DESCRIPTION

The conical mass had, according to Kunz (1888), the overall dimensions of 65 x 35 x 38 mm, and it weighed 442 g. According to Cohen (1898a) the fusion crust should be preserved over considerable parts. However, what appears to be a 0.4 mm thick, metallic fusion crust is, in fact, an artificially created melt crust, rich in phosphides. A close inspection shows that all phosphides to the center of the mass have been melted, and that those phosphides open

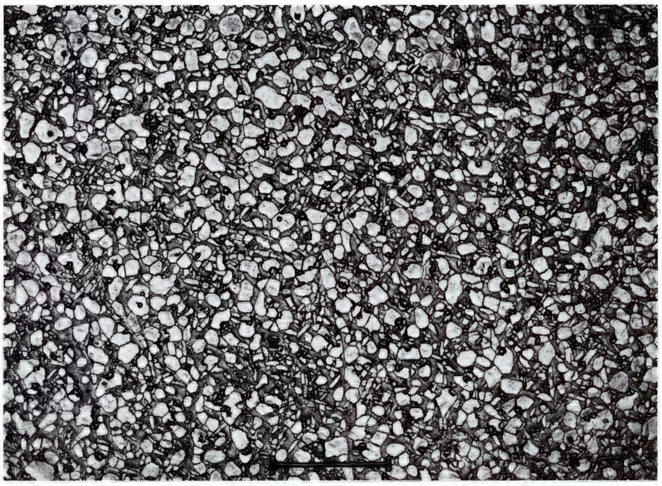

Figure 1063. Linville (U.S.N.M. no. 551). Duplex structure of kamacite (white) and taenite (gray). Also numerous schreibersite crystals (indistinct, black). Etched. Scale bar 500 μ. (Perry 1950: volume 3.)

Figure 1064. Linville (U.S.N.M. no. 551). The horizontal kamacite band is located along a former γ-γ grain boundary. The two original taenite crystals are randomly oriented as may be deduced from the Widmanstätten patterns. The kamacite is transformed to unequilibrated α_2 by artificial reheating. Etched. Scale bar 200 μ. (Perry 1950: volume 3.)

LINVILLE – SELECTED CHEMICAL ANALYSES

	percentage			ppm							
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Sjöström in Cohen 1898a	16.32	0.76	0.23	1100	200		200					

A nickel-confirmation and a trace-element analysis are needed. The carbon value appears high for the structure.

to the surface sweated out and partially covered the weathered surface and reacted with the corrosion products. A genuine fusion crust normally displays a laminated structure of fine dendritic to cellular material, and the individual laminae terminate in a well defined way against the unmelted matrix. The Linville crust is rather a coarse-grained reaction zone between phosphide-rich melts on the surface and the underlying, partly corroded matrix.

Etched sections appear structureless, ataxitic to the naked eye, except for a few, 1 mm thick schreibersite crystals and holes from such schreibersite that sweated out. Adequate magnification reveals that Linville originally was composed of several austenite crystals which, upon cooling, independently developed a microscopic Widmanstätten structure. The parent γ-grains range from 1-20 mm in size, and they are separated by 30-50 μ wide, kamacitic grain boundaries. In some parts of the boundaries 20-50 μ wide schreibersite are precipitated, and are enveloped in 30-50 μ swathing kamacite. No significant growth of Widmanstätten lamellae has started from the boundary zones.

Throughout the mass rather evenly distributed, tiny schreibersite nodules, 10-30 μ across, are seen. Upon cooling, each of these developed a shell of kamacite, and only later did the residual austenite matrix partially transform to octahedrally arranged kamacite lamellae, which are 20-40 μ wide and have a length-width ratio of about 10. The Widmanstätten lamellae evidently nucleated homogeneously, little influenced by the already existing schreibersite-kamacite nodules. The resulting mixture of rounded α-grains, which are 25-75 μ in diameter and provided with more or less well-centered nuclei of schreibersite, and of oriented α-needles with little or no schreibersite, is very characteristic for Linville and not common in any other meteorite. The total amount of kamacite is about 50% by area. All kamacite is now transformed to serrated α_2 grains, due to artificial reheating and rapid cooling. The microhardness is 230±25.

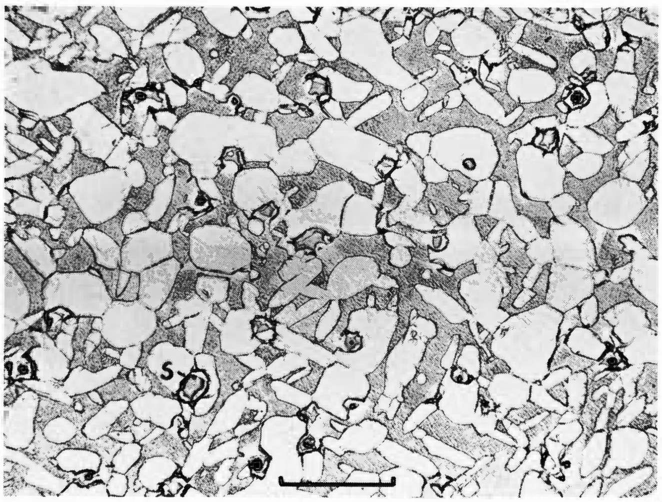

Figure 1065. Linville (U.S.N.M. no. 551). The tiny schreibersite grains, e.g., at S, are entirely melted and rapidly solidified to fine-grained eutectics. The artificial reheating was evidently carried to above 1000° C. Etched. Scale bar 100 μ. (Perry 1950: volume 3.)

The residual taenite is in the shape of concave, very irregular, but generally quite wide fields of sizes comparable to the kamacite units. They may have had internal duplex $\alpha + \gamma$ structures, but due to the artificial reheating the morphology is diffuse. Many thorny spikes along the taenite edges also indicate severe reheating.

The mass is so small that a thorough reheating in the atmosphere may have taken place, as is the case, e.g., with Föllinge, which is an undamaged, well-preserved find of similar size and nickel level. By comparison with Föllinge we find, however, that Linville does not display any thermal gradients from, say, 1500° C at the surface to low temperatures in the interior. Linville's structure rather indicates an even temperature of about 1000°-1050° C, held for a length of many minutes, a condition which is impossible during atmospheric penetration. Significantly, high temperature reaction products may be identified between terrestrial oxides and meteoritic minerals, an observation which conclusively proves that the meteorite weathered for a considerable length of time before it was reheated. It is not difficult to point to the responsible person, since Kunz (1888) in his original report mentions that, for a while, Linville was in the possession of a country blacksmith, although no heating was suspected. But how could a blacksmith ever possess a piece of iron of unknown origin and quality without heating it and probing it!

Linville is a polycrystalline, nickel-rich ataxite. Due to artificial reheating to about 1000° C the schreibersite is melted and the kamacite is converted to α_2, but the original parent structure is still visible and indicates that Linville is an unusual iron. It has been compared to Morradal, Ternera, Smithland and others, but the resemblance lies more in the approximate nickel level than in structure and morphology. Structurally, it resembles Mount Magnet more. It will probably turn out to be an anomalous iron, also with respect to trace element concentrations.

Specimen in the U.S. National Museum in Washington:
15 g part slice (no. 551, 2.5 x 1.5 x 0.5 cm)

Linwood, Nebraska, U.S.A.

41°26'N, 96°58'W; 400 m

Polycrystalline, coarse octahedrite, Og. Bandwidth 2.8±0.9 mm. Neumann bands. HV 190±10.

Group I. 6.6% Ni, 0.50% Co, about 0.2% P, 91 ppm Ga, 374 ppm Ge, 2.7 ppm Ir.

HISTORY

A mass of 46 kg was found in 1940 or 1941 on the farm of Joseph W. Vrana, about 3 km southwest of Linwood, Butler County. It was found buried about 20 cm beneath the surface while Mr. Vrana was operating a disk harrow. Probably because of Nininger's lecturing tours in the prairie states Mr. Vrana was aware of the importance of his find and reported it (H.H. and A.D. Nininger 1950:

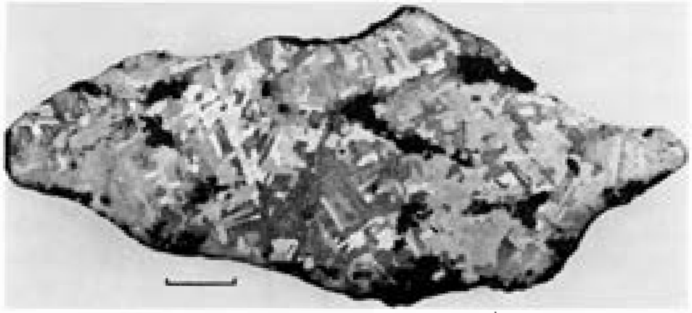

Figure 1066. Linwood (U.S.N.M. no. 1416). A full slice through a coarse octahedrite of group I. Linwood is composed of inch-sized precursor taenite crystals each of which has developed independent Widmanstätten patterns. Black denotes silicate-graphite aggregates. Deep-etched. Scale bar 30 mm. S.I. neg. 37546C.

113). The meteorite was purchased by S.H. Perry and donated to the U.S. National Museum where it was fully described by Henderson & Perry (1949b), with photomicrographs and with identifications of the silicate inclusions. Lovering (1962) interpreted the texture of the metal-silicate phases as indicating that an enstatite achondrite parent mass had been intruded by a liquid metal phase. Mason (1967a) deduced the composition of the olivine, enstatite, diopside and plagioclase by measuring the refractive indices of the minerals. Herr et al. (1961) determined the osmium and rhenium abundances. Voshage (1967) found too small $^{40}K/^{41}K$ concentrations for establishing a cosmic ray exposure age.

COLLECTIONS

Washington (35.3 kg), Harvard (1,607 g), New York (1,083 g), Chicago (777 g), Kwasan Observatory, Japan (752 g), Sydney (600 g), Calcutta (571 g), Moscow (463 g), Madrid (352 g), Rio de Janeiro (154 g), Sarajevo (123 g), Tempe (42 g), London (17 g).

DESCRIPTION

The overall dimensions of the angular mass are about 30 x 27 x 14 cm. It is covered with regmaglypts which range from 2.5-8 cm in diameter, with most of them being 3-4 cm across and rather shallow. The fusion crust is seen in many places as a warty, 0.1-0.5 mm thick layer, but it is corroded and not conspicuous. Sections through the surface show that the heat-affected α_2 zone is preserved in varying thicknesses, from 0.1-2 mm. It is interesting to note that the troilite inclusions are so rich in graphite and silicate that they were sufficiently refractory to be left behind in slight relief, when the surrounding metallic matrix ablation-melted in the atmosphere. Corrosion has attacked the mass, particularly along the grain boundaries and around the phosphides. Also, the complex inclusions do contain significant amounts of terrestrial oxides, and the troilite is veined with oxidation products.

Etched sections display a coarse Widmanstätten structure of straight, short ($\frac{L}{W} \sim 8$) kamacite lamellae with a width of 2.8±0.9 mm. Local grain growth has created numerous, almost equiaxial grains, 5-20 mm in diameter. From the orientation of the Widmanstätten pattern it is evident that Linwood at higher temperature was a polycrystalline aggregate of austenite, with the individual grains ranging from 2-6 cm. Some of the former austenite grain boundaries are marked by extra thick kamacite ribbons, some by troilite-graphite-silicate inclusions, while some are little marked, except for the abrupt change in the Widmanstätten directions across the boundary. Linwood resembles very much the El Taco specimen of Campo del Cielo, and also Pine River and Copiapo.

The kamacite has a profusion of Neumann bands and also many subgrain boundaries, decorated with rhabdites. The hardness is 190±10. Taenite and plessite cover 2-5% by area, mostly as isolated comb plessite wedges and taenite ribbons, more or less engulfed by growing kamacite. Some of the wider taenite wedges have interiors of pearlitic plessite with 1 μ wide taenite lamellae, or of spheroidized plessite with 10 μ spherules of taenite. A similar morphology is present in Seeläsgen, Campo del Cielo, Copiapo and a great many other group I meteorites.

Schreibersite is present as 20-100 μ wide grain boundary precipitates and as 0.1-1 mm thick, discontinuous rims around the dark inclusions. It is monocrystalline but heavily fractured. Rhabdites are common as 1-10 μ wide prisms. The bulk content of phosphorus is estimated to be 0.2%.

Troilite does not occur as well-defined spherules but is present as an essential part of the dark inclusions, that are mainly located in the former austenite grain boundaries. The dark inclusions range from a few millimeter in size to

LINWOOD – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Goldberg et al. 1951	6.64	0.50							96.3			
Wasson 1970a	6.4±0.2								90.4	374	2.7	

irregular patches, 4 x 2 cm across, and they cover 5-10% of the sections. They are extremely disordered aggregates of troilite, graphite, forsterite (Fa_4), chrome diopside (Fe_3), enstatite (Fs_6), schreibersite, and a little chromite, kamacite and plagioclase (An_{12}). The compositional data are from Mason (1967a). It appears that every single phase may occur as an inclusion in any one of the others. The troilite is polycrystalline but in rather coarse, 50-300 μ units. The graphite is normally microcrystalline, but all border zones against kamacite and troilite are composed of well-developed, cliftonitic crystals, 50-200 μ across. Cliftonite also occurs as angular units of the same size in the adjacent, swathing kamacite rims. The schreibersite is monocrystalline but frequently seriously fragmented and dispersed through the graphite and the sulfide. Cohenite appears to be rare; it was observed only once as a 50 μ wide rim zone upon schreibersite. Many of the dark patches are connected by zigzagging, 50-500 μ wide veinlets of fragmental debris, mainly of troilite, schreibersite and graphite, but the exact composition is blurred by the terrestrial corrosion products also present.

Linwood's structure may perhaps be best understood if we assume that it, at some high temperature on its parent body, consisted of large austenite crystals with scattered troilite-graphite-silicate nodules but that relative displacements of the overburden hot-worked the mass. Thereby the inclusions were deformed and the austenite matrix broken down into smaller units, the renewed growth of which was impeded by the debris from the nonmetallic inclusions. The troilite was perhaps partly squeezed out, but the remainder filled the interstices in the spongy silicate-graphite material. The absence of any alignment of the inclusions indicate that the movements were relatively small.

Another, more remote, possibility is that Linwood represents a rather early development, the result of sintering a mixture of metal-, sulfide- and silicate-grains. From this point of view Linwood never melted, but compression and sintering at temperatures, peaking at 1000°-1100° C, led directly to a polycrystalline austenite aggregate with unequilibrated grain boundary material, rich in troilite, graphite and silicate.

Linwood is a polycrystalline, coarse octahedrite with irregular patches of complex troilite-graphite-silicate inclusions, which constitute 5-10 volume percent of the mass. It is structurally closely related to Campo del Cielo and Seeläsgen, Pine River and Copiapo, and, chemically, it belongs to the high gallium-germanium end of group I. Its polycrystallinity and inclusion morphology are believed to be the result of plastic deformation in the austenite range on its parent body.

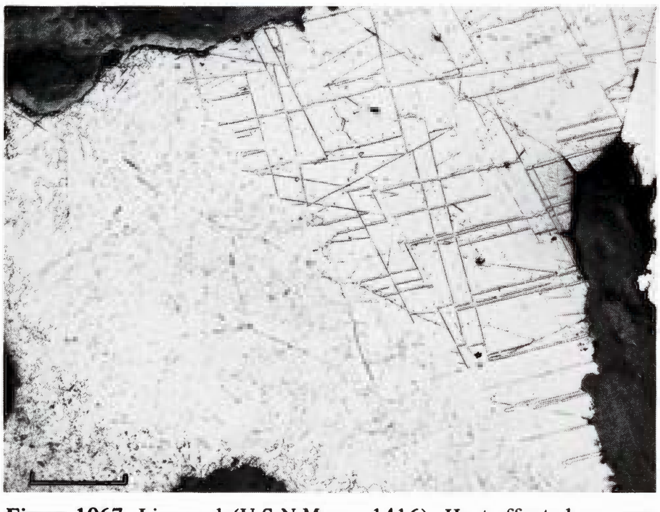

Figure 1067. Linwood (U.S.N.M. no. 1416). Heat-affected α_2 zone to the left, with terrestrial corrosion and silicates (above). Kamacite with rhabdites and Neumann bands to the right. Etched. Scale bar 400 μ. (Henderson & Perry 1949b.)

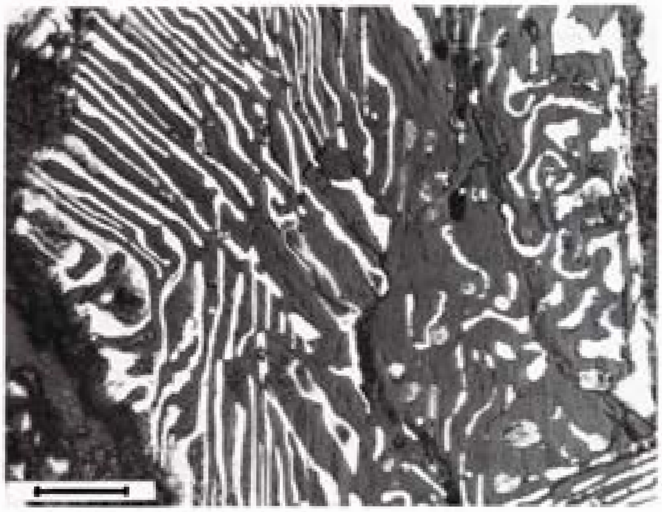

Figure 1068. Linwood (U.S.N.M. no. 1416). Pearlitic plessite invaded by terrestrial corrosion products. Kamacite is converted to limonite (black), while taenite is only little altered. Etched. Scale bar 30 μ. (Perry 1950: volume 6.)

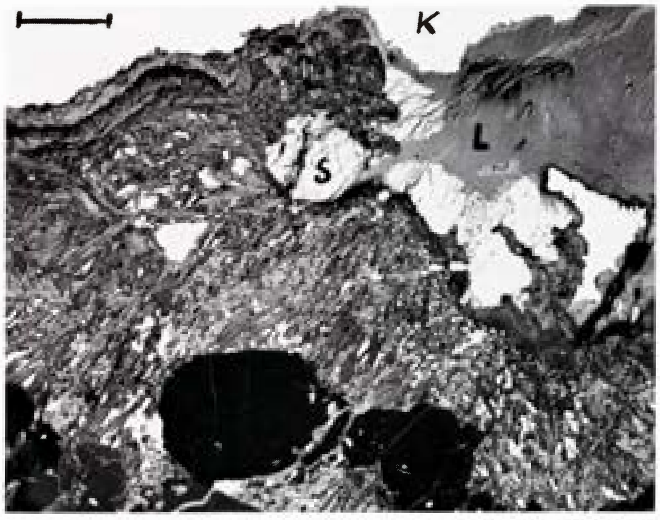

Figure 1069. Linwood (U.S.N.M. no. 1416). Edge of a complex silicate nodule. Silicates are glossy black, graphite forms fan-shaped aggregates (gray) with inclusions of metal and troilite particles (white). On the left of letter K the graphite forms cliftonitic aggregates. Schreibersite (S), limonite (L) and kamacite (K). Lightly etched. Scale bar 200 μ. (Henderson & Perry 1949b.)

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

33.43 kg		main mass (no. 1416, 30 x 21 x 14 cm)
1,485	g	slice (nos. 1416, 1661; 30 x 12 x 0.8 cm)
175	g	part slice (no. 1416, 9 x 4 x 1 cm)
99	g	slice (no. 1416, 9 x 4.5 x 0.4 cm)
150	g	fragments and separated minerals (no. 1416)

Lismore, Victoria, Australia

Approximately 35°57'S, 143°20'E

Medium octahedrite, Om. Bandwidth 1.00±0.15 mm.

Probably a normal group IIIA iron. About 7.8% Ni, 0.15% P.

HISTORY

A mass of 22 pounds (10.0 kg) was found about 1958 by a farmer, J.E. Spinks, of Selkirk, in one of his paddocks. The locality was approximately 2 km west of the township of Lismore, with the coordinates given above. "Mr. Spinks was removing some stones from the paddock by hand, and was amazed when his hand came up without this one." The mass was acquired by the University in Melbourne, Victoria, where it was divided into two halves, analyzed and described. Two photographs of the exterior shape and a macrograph of an etched slice were attached (Edwards 1960).

COLLECTIONS

The mass, or at least samples from it, appear to be in the Institute for Mineragraphic Investigations, the University, Parkville, Victoria.

ANALYSES

Edwards (1960) reported the following analysis: 91.40% Fe, 7.79% Ni, 0.56% Co, and traces of phosphorus and sulfur.

DESCRIPTION

Since material from this meteorite was not available for examination, the following is based upon Edward's paper (1960).

The meteorite is a sub-pyramidal mass of iron with three roughly equal uneven faces rising from a somewhat rounded base. Its maximum dimensions in three perpendicular directions are 14 x 14 x 13 cm, and the weight 10.0 kg. It is weathered and covered with limonitic scale and exudes copious droplets of ferric chloride, which rapidly oxidizes to ferric oxide, causing the iron to rust and scale. Polished sections rust within a few days.

The description indicates that Lismore has been exposed to terrestrial ground water for a long time; the chloride introduced with the water causes the meteorite to rust when kept unprotected indoors.

An etched section discloses a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 25$) kamacite lamellae with a width of 1.00±0.15 mm. Taenite and plessite cover 30-40% by area mainly as comb and net plessite.

Schreibersite is not present as large crystals but occurs as occasional grain boundary veinlets. Rhabdites were not mentioned. The bulk phosphorus content evidently lies in the 0.1-0.2% range, probably close to 0.15%.

One, or perhaps two, large troilite nodules were visible in the weathered surface. The only section taken passed through a troilite nodule, about 15 mm in diameter. It showed prominent cleavage traces and was corroded.

Lismore appears to be a normal medium octahedrite, closely related to, e.g., Cape York, Casas Grandes, Henbury and Merceditas. In its trace element composition it will probably be found to be a typical member of the resolved chemical group IIIA. It is an entire meteorite and not a fragment of any of the other iron meteorites from Southeastern Australia, Wedderburn, Yarroweyah, Corowa, Cranbourne, Delegate, Rhine Valley and Coolac.

Livingston (Montana), Montana, U.S.A.

45°36'N, 110°35'W; 1,500 m

Medium octahedrite, Om. Bandwidth 0.95±0.10 mm. ε-structure. HV 330±25.

Group IIIA. 7.40% Ni, 0.45% Co, 0.09% P, 19.6 ppm Ga, 35.4 ppm Ge, 9.3 ppm Ir.

Perhaps a paired fall with Hayden Creek.

HISTORY

A mass of 1.6 kg was, in October 1936, found in an Indian grave, 10 km south of Livingston, Park County. It was later identified and purchased by Nininger (H.H. & A.D. Nininger 1950: 69, 113). I am indebted to Dr. Nininger for the following additional information: the grave was at an altitude of 1,500 m, on an eastern slope 400 m west of the Yellowstone River. The grave, which was examined by Charles F. Miller of Livingston, was not dug, but a pile of rocks heaped up around the remains. The bones were all decomposed. A few pieces of deer or elk horn were present and also some carved bone that went to pieces while being cleaned. In the grave were the meteorite,

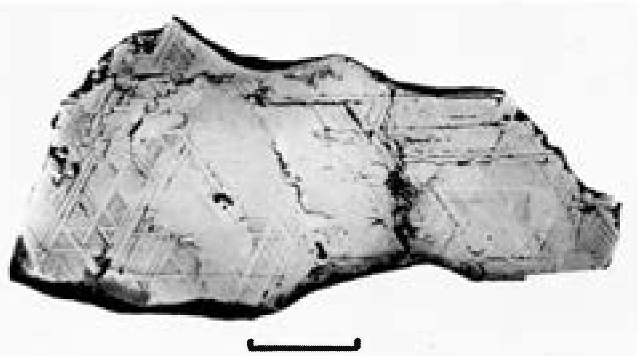

Figure 1070. Livingston (Montana) (U.S.N.M. no. 1703). Cut almost parallel to $(111)_\gamma$ so that the fourth set of Widmanstätten lamellae appear as irregular plumes, occupying an unusually large fraction of the section. Deep-etched. Scale bar 20 mm. S.I. 44088F.

a grooved stone hammer, a stone knife, two stone hide scrapers, 14 arrowheads, a perfect pair of red standstone shaft straighteners and numerous pieces of clay pottery. It appears to be the only grave in this locality that had clay pottery in it – and a meteorite. The coordinates given above are for the place of find.

COLLECTIONS

Tempe (728 g), London (424 g), Washington (294 g).

DESCRIPTION

The small mass has the approximate dimensions of 11 x 6 x 5 cm and weighs 1.6 kg. It displays a few shallow depressions, 2-4 cm across, while one side, 8 x 5 cm, almost flat and severely corroded, is parallel to one of the four octahedral planes of the Widmanstätten structure. At the pointed end a fragment of 20-30 g has been broken off, probably by the early possessor. The mass has been exposed to terrestrial weathering for a long time and is now covered with 0.1-1 mm thick oxide shales. On sections it is seen that corrosion penetrates along grain boundaries to the center of the mass, particularly converting the alpha phase of the plessite fields to limonite. The troilite is veined by yellowish pentlandite. The corrosion continues somewhat under ordinary room conditions. The fusion crust and the heat-affected α_2 zone appear to have been lost long ago.

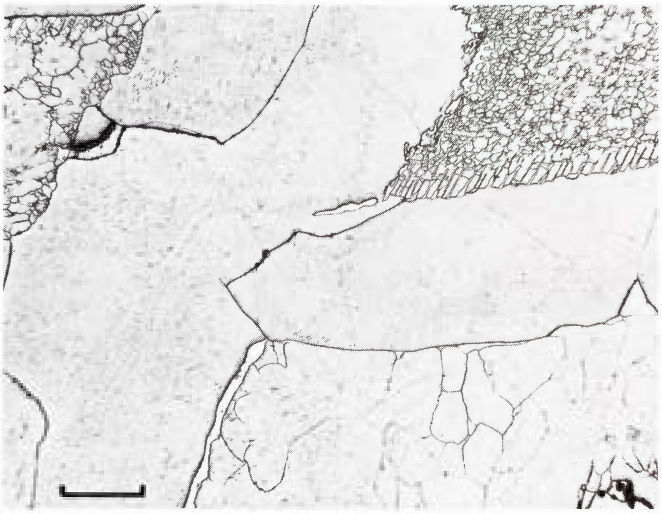

Figure 1071. Livingston (Montana). Detail of Figure 1070. Degenerated, almost resorbed net plessite fields. The lower one is no more than a mesh of subboundaries. Etched. Scale bar 500 μ.

Etched sections display a medium Widmanstätten structure of straight, long ($\frac{L}{W} \sim 20$) kamacite lamellae with a width of 0.95±0.10 mm. In certain areas that may be up to 3 x 3 cm in size, the taenite and plessite are almost fully resorbed; and ferritic grain growth has resulted in irregular, large kamacite units with little evidence of the previously existing Widmanstätten structure. Subgrain boundaries, decorated with 1 μ rhabdites, are common. All kamacite is due to shock above 130 k bar converted to an acicular ϵ-structure. The hardness is 330±25 corresponding to extreme shock-hardening without annealing. Plessite and taenite cover about one-third of the area. The comb and net plessite fields are very open-meshed and their framing taenite is discontinuous. A few high-nickel taenite wedges display dark-etching interiors of various grades of martensite and partly unresolvable $\alpha + \gamma$ mixtures.

Schreibersite is only present as occasional, 10-20 μ wide grain boundary veinlets and as 2-15 μ thick, vermicular bodies in the plessite interiors. It is monocrystalline but

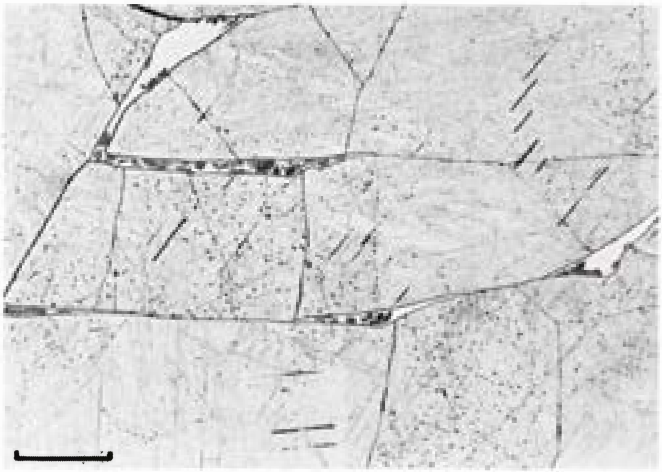

Figure 1072. Livingston (Montana). Detail of Figure 1070. Cloudy taenite lamellae. Shock-hardened kamacite with numerous streaks of oriented carlsbergite platelets. Etched. Scale bar 200 μ.

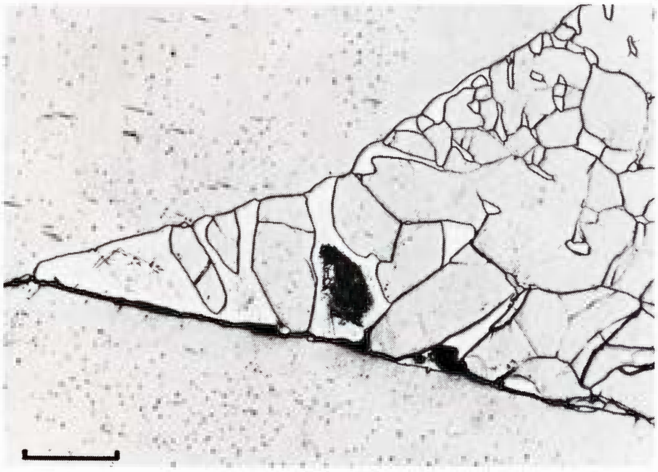

Figure 1073. Livingston (Montana). Detail of Figure 1070. Almost resorbed net plessite field and carlsbergite platelets in kamacite. Corrosion along lower boundary. Etched. Scale bar 100 μ.

LIVINGSTON (MONTANA) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
References	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Moore et al. 1969	7.57	0.45	0.09		360							
Scott et al. 1973	7.22								19.6	35.4	9.3	

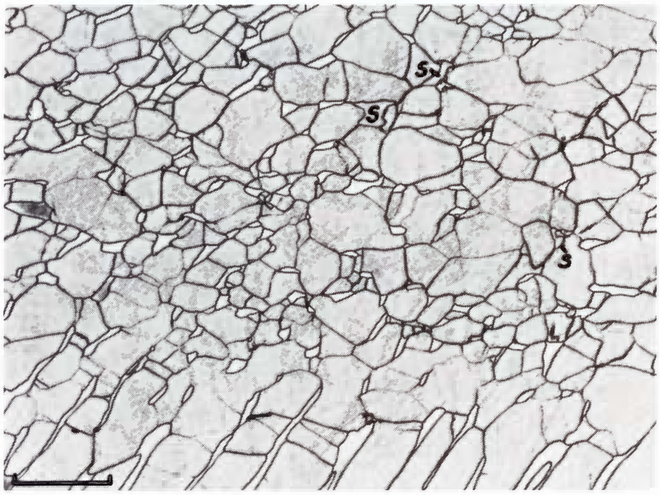

Figure 1074. Livingston (Montana). Detail of Figure 1070. The interior of an almost resorbed net plessite field. A few angular schreibersite crystals (S). Etched. Scale bar 100 μ.

slightly fractured. Rhabdites occur as 1-3 μ thick prisms, which frequently are distorted due to slight plastic deformation of the surrounding matrix.

Troilite occurs as scattered, lenticular bodies, e.g., 5 x 0.5 mm and 3 x 0.8 mm in cross section. They have no or very modest schreibersite rims due to the low level of phosphorus in the meteorite. The troilite is monocrystalline and contains about 10% daubreelite in the form of parallel, 10-300 μ wide bars. Daubreelite is further present as 10-200 μ blebs in the kamacite with very minor troilite present. Locally, a stack of parallel daubreelite units are much indented by kamacite and even separated by 1-4 μ wide kamacite channels, in much the same way as in, e.g., Cape York, Gibeon and others.

Fine hard plates, about 20 x 0.8 μ in size, occur scattered in the alpha phase, sometimes bent and distorted. They are identical to the chromium nitrides examined in Cape York, Schwetz and others, and recently named carlsbergite.

Livingston (Montana) is a shock-hardened medium octahedrite with ϵ-structure, closely related to Costilla Peak, Henbury and Williamstown. Chemically, Livingston is a typical group IIIA iron. Compare also Hayden Creek.

Specimen in the U.S. National Museum in Washington:
294 g endpiece (no. 1703, 11 x 4 x 1 cm)

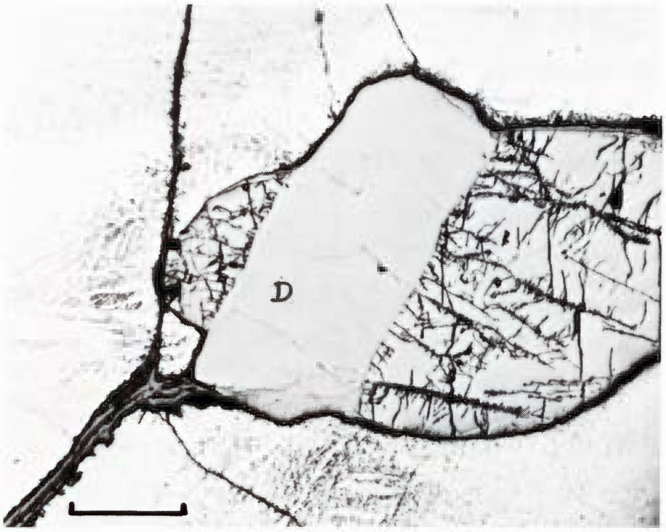

Figure 1075. Livingston (Montana) (U.S.N.M. no. 1703). Troilite-daubreelite (D) crystal, the troilite showing multiple twinning. Corroded grain boundary. Etched. Scale bar 100 μ.

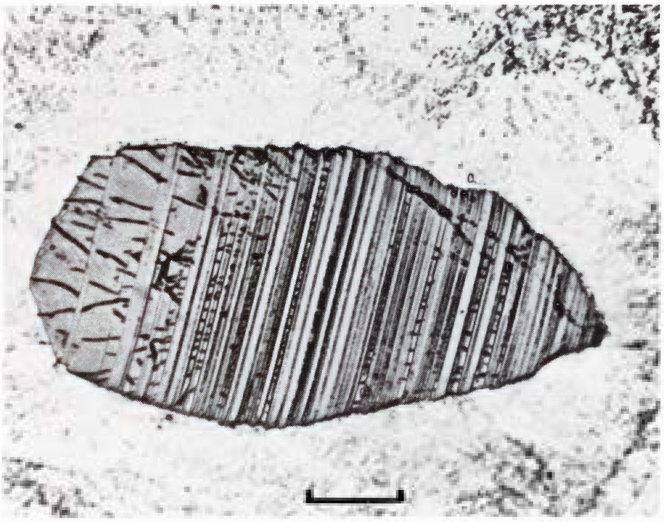

Figure 1076. Livingston (Montana) (U.S.N.M. no. 1703). A composite of alternating parallel troilite and daubreelite lamellae in shock-hardened kamacite. Etched. Scale bar 20 μ.

Livingston (Tennessee), Tennessee, U.S.A.

36°26′N, 85°17′W; 250 m

Anomalous medium octahedrite, Om. Former bandwidth 0.8±0.2 mm. Recrystallized. HV 170±10.

Group unknown, probably anomalous. 7.45% Ni, 0.48% Co, 0.25% P.

LIVINGSTON (TENNESSEE) – SELECTED CHEMICAL ANALYSES

	percentage			ppm								
Reference	Ni	Co	P	C	S	Cr	Cu	Zn	Ga	Ge	Ir	Pt
Perry & Henderson 1948	7.45	0.48	0.25									

HISTORY

A mass of about 12 kg (25-30 pounds) was found in 1937 by Sherman Smith on his farm 3 km west of Monroe, in Overton County. It lay on the rocky bank of Eagle Creek which flows through a narrow valley at that place. The corresponding coordinates are given above. Unfortunately, the farmer lost track of the mass when he moved his house a few years later, but a couple of fragments, broken off the main mass and amounting to about 200 g, were acquired by Perry and donated to various museums. The fragments were described by Perry & Henderson (1948) with photographs and with an analysis.

COLLECTIONS

Washington (108 g), Chicago (57 g), Harvard (18 g).

DESCRIPTION

According to Sherman Smith, as cited by Perry & Henderson (1948), the mass was shaped somewhat like a pancake, thicker in the center, and about 40 cm in diameter. Only little significance can be attached to the estimated weight and dimensions which are in conflict, unless the specimen really was about 40 cm in diameter and less than 2 cm thick, and thus as exceptional as Arlington, Tawallah Valley and a few others. The fragment in the National Museum is corroded, without fusion crust and with a few hammer and chisel marks. The surface shows an intercrystalline fracture and clearly indicates that at least part of the mass is composed of 0.5-2 mm equiaxial grains. Terrestrial oxides are locally 4 mm thick, and on sections it is seen that the corrosive attack has formed 10-50 μ wide, oxidic veinlets along the grain boundaries. Also, the annealed Neumann bands are attacked along both sides of the 2-4 μ wide ribbons.

Etched sections display an irregular, medium Widmanstätten structure which, in places, merges with completely granular areas. The kamacite lamellae pinch and swell as a result of variable grain growth of the individual sectors of the lamellae. From the disposition of the larger schreibersite units and some of the taenite, which still feebly suggest the former, regular Widmanstätten arrangement, a bandwidth of 0.80±0.20 mm may be estimated. The recrystallized grains are 0.5-2 mm in cross section and approach equiaxial dimensions. Full equilibrium is, however, not attained. There are numerous subboundaries, decorated with less than 1 μ precipitates, and there appears to be a dense population of still smaller precipitates within the matrix of most kamacite. The individual kamacite grains display Neumann bands, but these have all been modified by annealing; and some precipitation has taken place along both sides. No indications of artificial reheating are present, and the observed structures are all preatmospheric. The kamacite has a hardness of 170±10.

No ordinary plessite fields are present. Instead there occur well-rounded taenite blebs, 10-300 μ across, in the grain boundaries, or, occasionally, inside the kamacite grains. The taenite fields constitute 1-2% by area, and they all resemble each other closely, not showing the wide variation present in most octahedrites. They are zoned, with a frame of grayish tinted taenite, followed by a yellow, structureless taenite (HV 235±10), which merges via a martensitic zone with the dark-etching interior (HV 350±20), a poorly resolvable, duplex $\alpha + \gamma$ mixture. The metallic structures seem to have developed by recrystallization of the ferrite and dissolution and spheroidization of the plessite fields, but the structure deserves further study.

Schreibersite occurs as skeleton crystals, the largest of which are platy and approximately 25 x 10 x 1 mm in size. It is monocrystalline and closely associated with graphite and a little troilite. These minerals are located near and in the fractured surface, so perhaps larger nodules were present in the now lost material. Schreibersite is further common as 10-50 μ wide veinlets that line the recrystallized grain boundaries and probably precipitated from solid

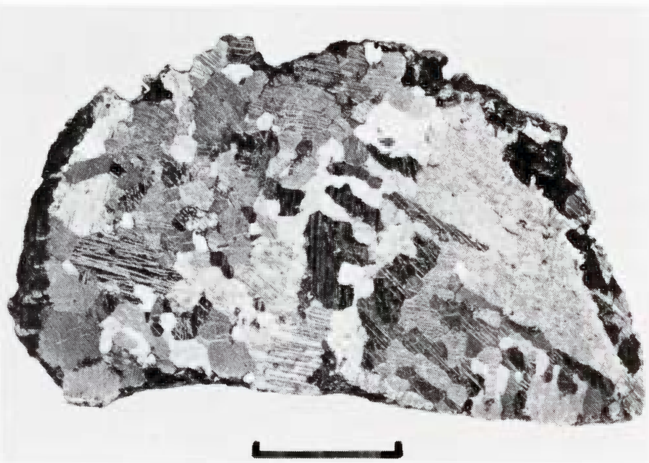

Figure 1077. Livingston (Tennessee) (U.S.N.M. no. 1420). An anomalous medium octahedrite with recrystallized portions. Deep-etched. Scale bar 10 mm. S.I. neg. 37102.

Figure 1078. Livingston (Tennessee). Detail of Figure 1077. An almost taenite- and plessite-free meteorite with subboundaries and Neumann bands in the kamacite. Schreibersite veins (S). Etched. Scale bar 400 μ. (Perry 1950: volume 6.)

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. α_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

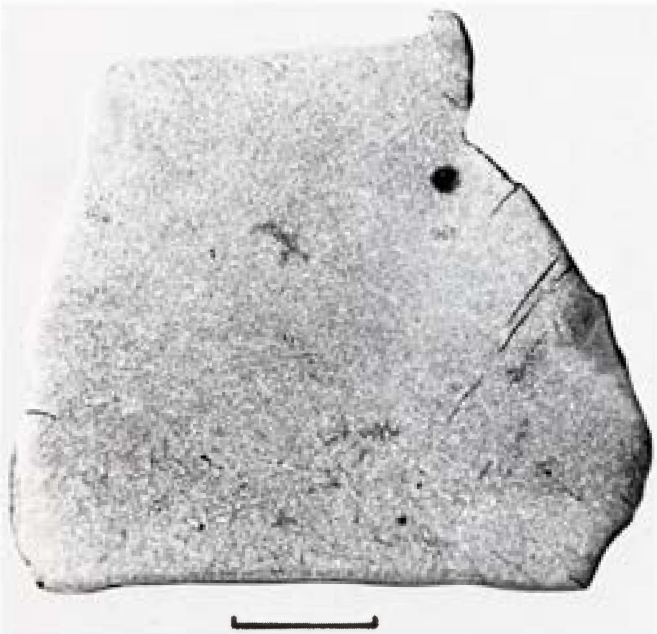

Figure 1079. Locust Grove (Vienna no. G8418). An 8 mm thick slice, somewhat flattened by forging. The structure is entirely altered from that of a normal hexahedrite, due to artificial reheating above 1000° C. Deep-etched. Scale bar 20 mm.

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	