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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 98 NUMBER 20

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(WITH NINE PLATES)

BY
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Adrian, Mich.

(PUBLICATION 3546)

CITY OF WASHINGTON
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(With Nine Plates)

The Helt Township meteorite, a small but unusually interesting meteoric iron from Indiana, which has a fairly satisfactory history of having been observed to fall, was obtained by the writer in 1927 from William J. Seaver, a mineral dealer of Webster Groves, Mo. It was originally in the geological collection of the late John Collett, who was State Geologist of Indiana from 1878 to 1885, and who died in 1899.

Mr. Seaver stated that Dr. Collett at his death left a large collection of minerals and fossils at Terre Haute, where for many years they were stored in a cellar, suffering from loss and pilferage. All this material was bought by Mr. Seaver in 1915, and included in it was a collection of 13 small specimens of meteorites in a cabinet. Several years later, in a case of Indiana minerals and fossils, this additional specimen was discovered. When obtained by the writer it still bore a gummed label with the words "Vermillion County, Ind." in pencil. Dr. Collett may have kept it apart from the other meteorites because of a special interest in the specimen, arising from the fact that his home and birthplace were in that county, or perhaps because of the circumstances of its acquisition.

On the latter point definite information was furnished by the geologist's nephew, John S. Collett, of Indianapolis, who in 1929 wrote:

> The meteorite now possessed by you was found in Vermillion county, in Helt township, by a farmer who saw it fall and heard the explosion as he was walking from his barn to his house between nine and ten o'clock in the evening. The next day he examined his fields and found a place of fresh earth that looked as if a small blast of explosive had been discharged—a sort of ragged opening like a small post-hole. Upon excavating he found the specimen you now possess, which was brought by the finder in person to the Professor at the State House in this city. The farmer's name as I remember it was Frist, the year about 1883 or 1884.

Correspondence with persons by the name of Frist in that township brought no information other than that they had heard that something had fallen in the neighborhood many years ago.

No further details could be furnished by Mr. Collett. His statement that the farmer "saw it fall" cannot be taken literally, for at that hour of the night he could not have seen it fall after it had ceased to be luminous; and if the appearance had been that of a fireball striking the earth, it actually would have struck many miles away. We may fairly assume, therefore, that it fell nearly vertically and that he saw the light and later heard a noise—perhaps not aptly described by the word "explosion." The hum or swish near the end of its flight perhaps was audible, and so gave him the impression of something falling nearby. At any rate, whatever he observed was such as to convince him that something had fallen and to prompt him to search for it the next morning.

but detonations or at least popping can be heard at point of fall – cf Kendleton, Texas

The meager narrative of this occurrence is quite consistent with the supposition that this small iron fell in the manner above suggested. If any improbability attaches to that supposition, the coincidence of Frist seeing and hearing a meteor, believing it fell close to him, and actually finding an obviously freshly fallen meteorite the next day, would surely be much more improbable. The facts therefore seem to justify adding this to the short list of iron meteorites of which falls have been observed.

It is a flake-shaped mass, flat on one side and slightly convex on the other. It weighed when received 218.5 grams, having lost perhaps 10 or 15 grams when one side was polished by Dr. Collett. It was about 6 by 7 cm. in its larger dimensions and about 1.5 cm. in its greatest thickness.

The surface of the flat side which is covered by a very thin, slightly shining coating of magnetic oxide, shows no rust or abrasions and is characteristically pitted. At one edge a fine crack extends inward about 2 cm. from the edge on the flat side and a shorter distance on the rounded side, which undoubtedly resulted from stresses during its flight flatwise through the air. No evidence of drift is apparent on the fusion crust.

Most of the convex surface had been polished and etched by Dr. Collett, the polished surface following the original rounded contour (pl. 1, fig. 2). In order to provide an adequate surface for study, it was cut in a plane parallel with the flat side, whereby a slice about 5 mm. thick was removed and a surface about 4 by 5 cm. was obtained.

The structure is of the coarsest octahedral type (Ogg), the width of the bands ranging from 2 to 4 mm. They are slightly curved or wavy, of variable width, with irregularly rounded ends. The etched surface corresponds roughly with a cubic plane, and the kamacite bands run in one general direction, with a few short ones at right angles and occasional rounded areas. Most of the bands have an oriented sheen, though not strongly marked; some show little or no variation as the direction of the light changes.

The meteorite consists almost entirely of kamacite, with few plessite fields, a sparing development of taenite, and numerous schreibersite inclusions. Generally, the kamacite bands are not separated by taenite lamellae, but only by invisible boundary lines along which contrasts of structure appear on etching. Often small bodies of schreibersite or of taenite, elongated and of various shapes, appear along such boundaries, but such inclusions are rarely continuous for more than short distances.

Near one corner of the polished surface is an area about 2 cm. square which shows no definite figures. In this area the taenite is in short thin lines, or occasional baguettes or irregular shapes, with one sprangling inclusion about 2 by 5 mm. in size.

Plessite fields are few, consisting mostly of eutectiform areas of taenite lamellae of the type shown in plate 2, figure 1, termed "perlitoid" by some of the German writers. Other areas are filled with coarse oriented skeletal growths (pl. 2, fig. 2; pl. 3). No fields filled with fine taenite particles or threads, nor areas of dark (micro) plessite, were observed.

Plate 5 shows a taenite lamella with breaks suggesting the appearance of faulted rock strata, a result of local deformation. Similar but less conspicuous displacements are observable in other spots (pl. 8, fig. 1). Such displacements always coincide with Neumann lines, and in the area shown in plate 5 a considerable movement took place along the gliding planes marked by some of the lines.

Neumann lines are caused by shock or quick stress, and it has been suggested by various writers that they may have been produced when a mass of meteoric iron struck the earth. In the present case it is clear that the disturbance that produced the displacements (and simultaneously the Neumann lines) must have occurred before the mass reached the earth, and prior to the partial alteration of structure produced by reheating during flight, which in places obliterated the Neumann lines. The shock of the impact of such a small mass upon soft earth would be comparatively slight; but the violent stresses resulting from atmospheric pressure during flight (sufficient often to cause cracks in iron meteorites, and sometimes disruption) would readily account for evidences of deformation, ranging all the way from light Neumann lines to pronounced displacements of structure.

It is to be noted that the granular border or aureole which developed around all inclusions after the formation of the Neumann lines follows the irregularities of the taenite, but the grain boundaries give no evidence of mechanical deformation.

In the Tamarugal (El Inca) iron the fracture of a troilite nodule and the displacement of the broken halves are described and illustrated by Rinne and Boeke.[1] Fractures and displacements in schreibersite inclusions have also been observed by Brezina in the Puquios iron, and by Cohen in that of Chesterville.

Schreibersite and taenite inclusions of similar form are often juxtaposed, or alternate with one another along band boundaries, and the two substances are so nearly identical in appearance that they are not easily distinguished except by selective etching (pl. 4) or by a hardness test.

Numerous schreibersite inclusions, which with ordinary etching appear clear and featureless, reveal a highly developed eutectic structure when etched lightly with sodium picrate (pl. 6). The etching must stop at exactly the proper stage, for a few additional minutes will cause the structure to disappear in a uniform black.

The anomalous structure shown in plate 9 is apparently an area of phosphorus enrichment in kamacite. Except for the peculiar eutectoid appearance the kamacite is little changed, Neumann lines and rhabdites appearing within the area. The rhabdites, it will be noted, are surrounded by phosphorus-poor aureoles, both within and without the area.

Schreibersite in the form of rhabdite is abundantly disseminated through the mass in squares, rectangles, and rhombs, diversely oriented, as shown in plate 9 and plate 8, figure 2. In the latter figure the rhabdites are surrounded by black borders—an optical effect due to the fact that, because of their hardness, polishing left them slightly in relief and thus the light is reflected away from the iron immediately surrounding them.

Two or three minute grains of chromite were observed, but no troilite.

Neumann lines are conspicuous, often running uninterruptedly across several bands with no change, or slight change, of direction at the boundaries.

Superficial heating during flight apparently caused partial or incipient alteration of the kamacite almost throughout the mass by the for-

[1] El Inca, ein neues Meteoreisen. Neues Jahrb. Min., Geol., Pal., Festband 1907, pp. 227-255.

mation of granulated areas in which the Neumann lines are partly or wholly obliterated. In the central part of the polished surface these areas are surrounded by unaltered kamacite in which the lines show no change, but near the edges the alteration is uniform.

Experiments by several investigators referred to by the writer in "The San Francisco Mountains Meteorite,"[2] have established that kamacite is completely altered by heating for the equivalent of about 1,000° for 1 or 2 seconds. In this case the incomplete alteration indicates a minimum degree of heating—probably brief and not far above the alpha-gamma inversion, which for kamacite (with rising temperature) would be about 700°.

Incipient alteration is observable around all inclusions. Wherever taenite or schreibersite appears it is surrounded by granulations. They also appear in stringlike form along the invisible, or barely visible, lines connecting such inclusions (pl. 8, fig. 1), and along the boundaries of kamacite bands where no taenite is visible. In such places a plane of nickel or phosphorus enrichment, although not producing a visible line on the etched surface, was evidently sufficient to initiate the process of recrystallization.

In the aureoles surrounding rhabdite crystals (pl. 8, fig. 2) the grains are noticeably lighter and more homogeneous than the surrounding unaltered kamacite, which is more or less darkened by a profusion of extremely minute particles.

Assuming that such minute particles consist of phosphide, its migration to the rhabdite could account for such a clearing up of the adjacent newly formed grains. Because of the lower melting point of the phosphide the alteration of the kamacite started at the rhabdite crystals, and as it proceeded outward, the newly formed grains gave up their phosphide and became practically pure kamacite. As such migration would take place far below the melting point of kamacite, the process would be relatively slow and could extend only a short distance during the brief period of heating. That the same process should take place around taenite inclusions is not inconsistent, because taenite probably always contains some phosphide and is often distinctly bordered with it, as sodium picrate etching reveals. Plate 4 shows a phosphide eutectoid area in taenite.

Vogel[3] holds that the larger crystals and masses of schreibersite

[2] The San Francisco Mountains Meteorite. Amer. Journ. Sci., vol. 28, p. 216, Sept. 1934.

[3] Eine umfassendere Deutung der Gefügeerscheinungen des Meteoreisens . . . Abh. Ges. Wiss. Göttingen, Math.-Phys. Klasse, III Folge, Heft 6, 1932.

Über die Strukturformen des Meteoreisens . . . Ibid., Neue Folge, Band XII, 2, 1927.

originate in the melted stage, citing the fact that they are often surrounded by a granular area corresponding with a phosphorus-poor zone, which would indicate a rapid separation of the schreibersite as the cooling progressed; but that nevertheless such areas can arise from incipient solution of the crystals in a solid state, which process with a rising temperature in an alloy of the composition of kamacite would begin at around 700°. The temperature named by Vogel is the alpha-gamma inversion point on heating; on cooling that point would be about 200° lower, so the process would be correspondingly prolonged.

Either of Vogel's explanations of the origin of such granular kamacite areas involves phosphorus impoverishment near the schreibersite masses. In the present instance, since the alteration which produced the new grain boundaries was the result of reheating after the Neumann lines were formed, it is possible that the migration of phosphide from the surrounding kamacite accompanied the formation of the grains.

An interesting analogy is presented by the process of recrystallization in cast iron, as shown by a sample that had been subjected to more and more extended annealing at a temperature of about 800°. Graphite nuclei grew by accretion, carbon being absorbed from the cementite in the surrounding areas, until finally granulation was complete, the graphite nuclei had absorbed all the carbon, and the ground mass consisted of grains of pure ferrite. The later stages of the process produced granulated aureoles around the graphite nuclei much resembling those surrounding the rhabdites in the iron here described.

The more remote the rhabdite crystals are from the surface of the mass, the less granulation appears around them. The surface left after removing the slice, which is perhaps half an inch below the highest part of the original surface of the mass, shows in its central portions many rhabdite crystals with little or no surrounding granulation.

Plate 7, figure 1, shows a very minute schreibersite inclusion of unusual character, its edges having a prickly appearance due to a slight extension of phosphide into the surrounding iron at grain boundaries. The phosphide also appears segregated along certain grain boundaries at some distance from the inclusion.

This inclusion is close to the surface of the mass, where the effect of the temporary reheating during flight was greatest, and the invasion of the iron by the phosphide at grain boundaries is obviously due to a brief melting of the schreibersite. As its melting point is below 1,000°, a reheating sufficient to produce granulation in the kamacite would also be sufficient for such fusion. Slight traces of a similar incipient diffusion may be seen in plate 6, figure 2. Schreibersite inclusions presenting exactly the same appearance are observable in hexahedrites and nickel-poor ataxites that have been altered by reheating.

Plate 7, figure 2, shows a larger schreibersite inclusion close to the edge of the slice, which after fusion solidified with a eutectoid structure. While liquefied it dissolved some of the surrounding iron, which later separated in minute droplike particles.

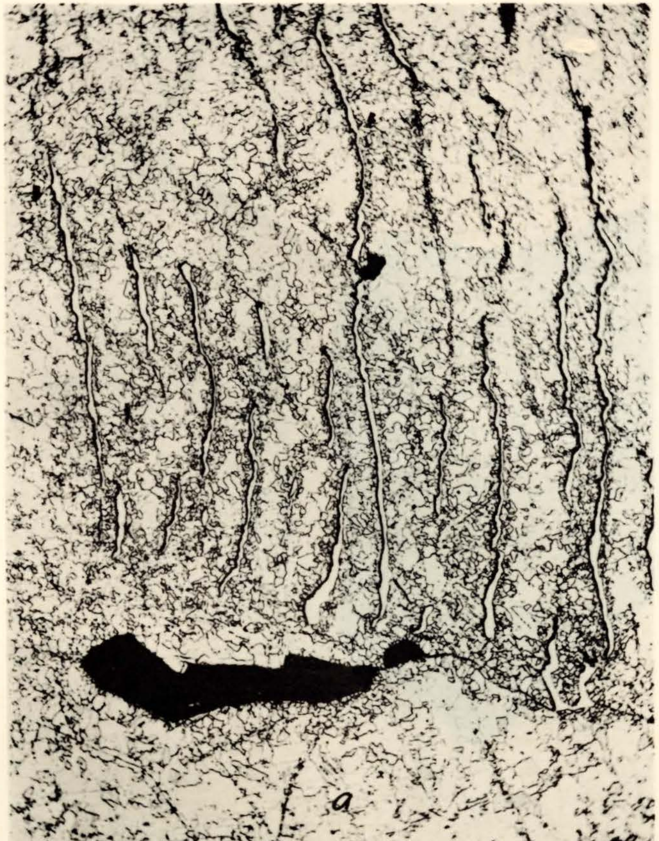
At one point at the edge of the polished slice melted magnetic oxide, produced superficially during flight, has invaded the mass slightly. One of the larger schreibersite masses enveloped in the oxide is scarcely altered, but one or two rhabdite crystals were observed to have become rounded into droplike form.

Because of the small size of this iron, no analysis was made. Its structure would indicate approximately the usual nickel content of coarsest octahedrites, a substantial amount of phosphorus, and little or no sulphur.

The name Helt Township is chosen for this meteorite, the main part of which has lately been given by the writer to the United States National Museum. It is the ninth meteorite, and the fourth siderite reported from Indiana.

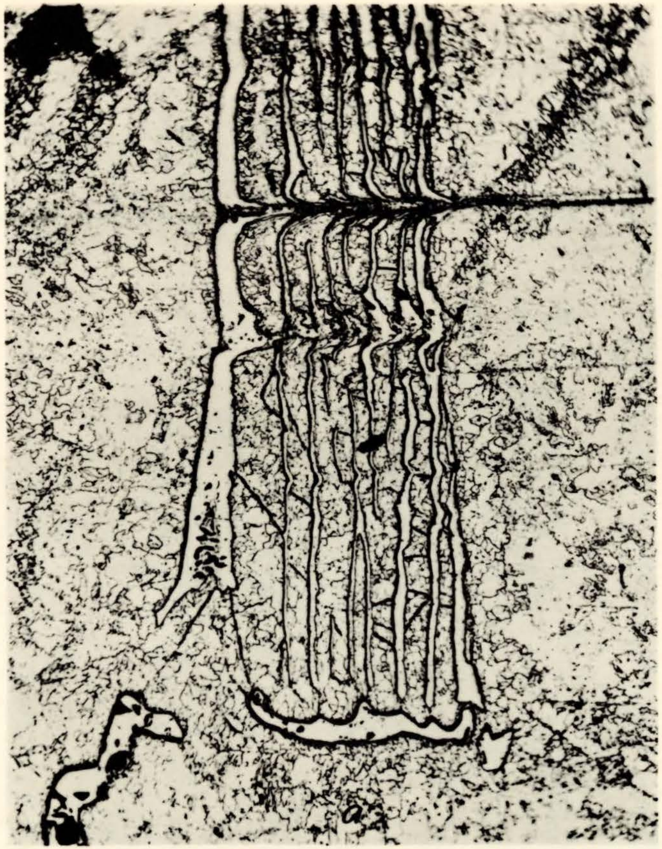
1. FLAT SIDE OF HELT METEORITE
About natural size.

2. ROUNDED SIDE OF HELT METEORITE
Partly polished and etched.



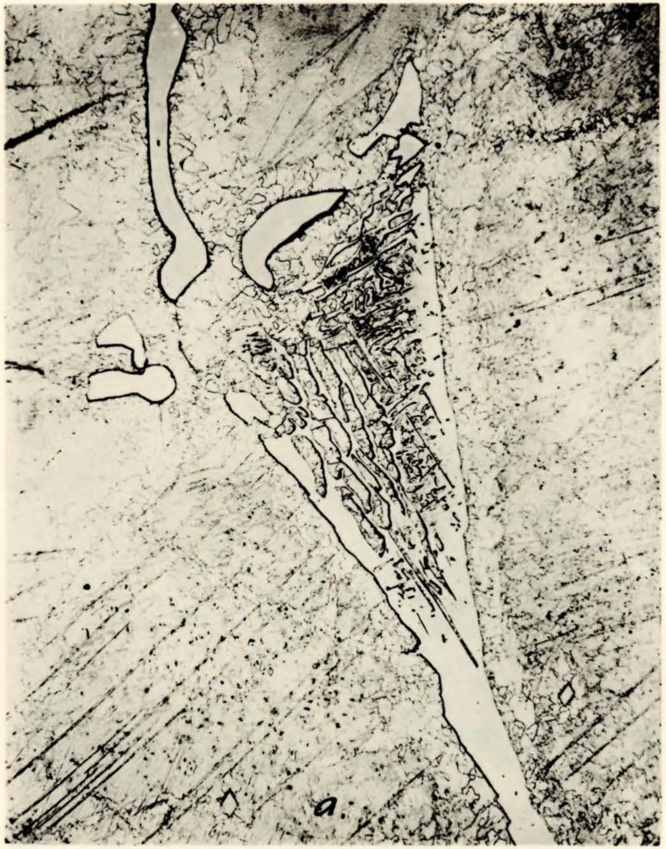
1. COARSE EUTECTIFORM ("PERLITOID") PLESSITE FIELD; SCHREIBERSITE APPEARS BLACK
Picral and 10 minutes sodium picrate, x 100.

2. COARSE SKELETAL GROWTH OF TAENITE, ENCLOSING EUTECTOID PHOSPHIDE AREAS
Picral, x 100.

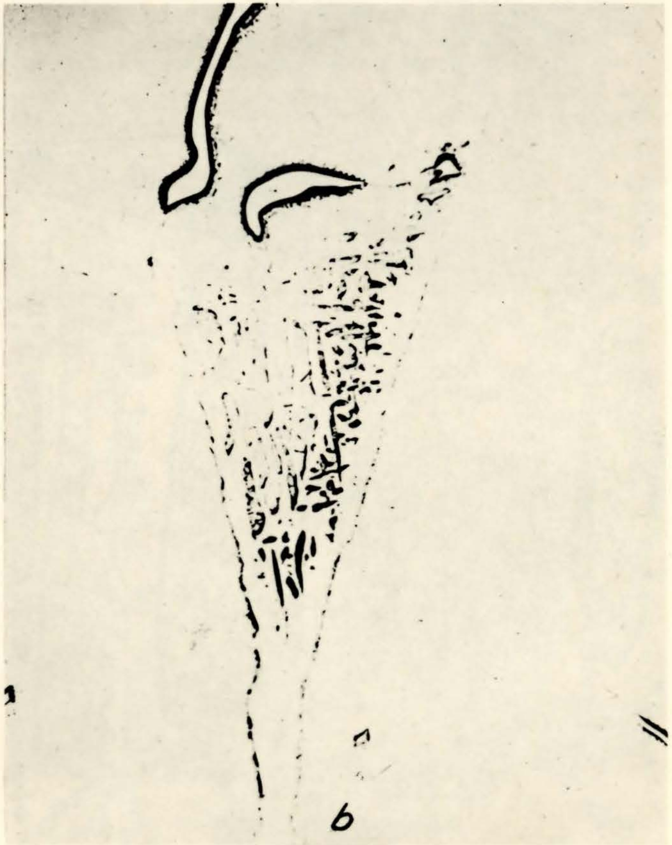


1. SKELETAL GROWTH OF TAENITE. THE IRREGULAR INCLUSIONS AT BOTTOM AND AT LOWER LEFT CORNER ARE SCHREIBERSITE
Picral, x 100.

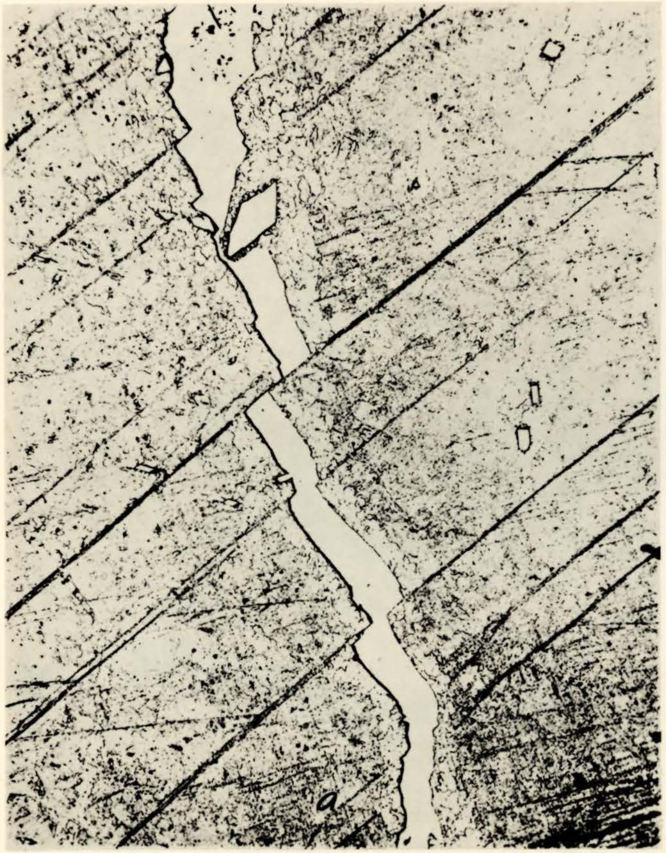
2. SKELETAL GROWTH OF TAENITE ENCLOSING EUTECTOID PHOSPHIDE, PORTION OF A LARGER AREA
Picral and 10 minutes sodium picrate, x 250.



1. WEDGE-SHAPED END OF TAENITE LAMELLA ENCLOSING EUTECTOID PHOSPHIDE AREA
Picral, x 100.

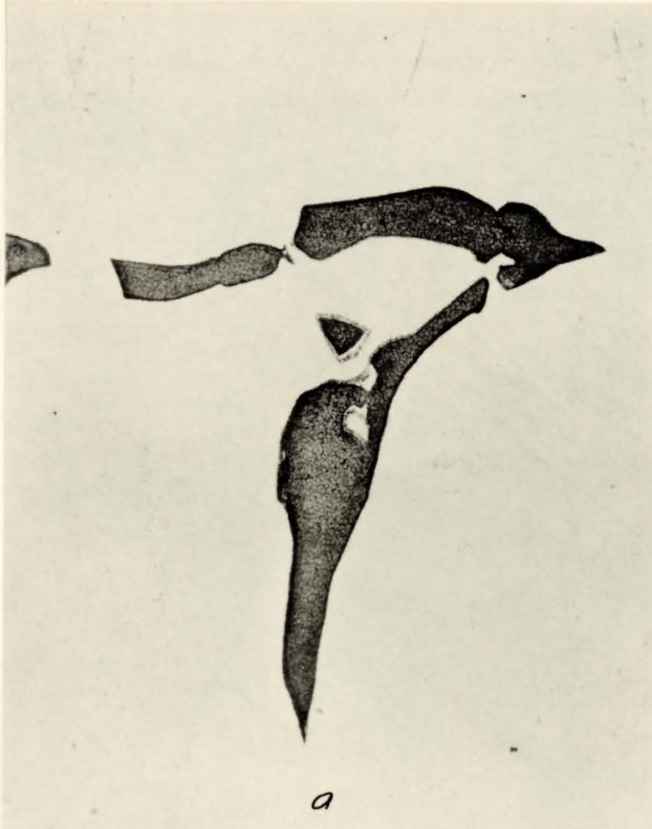


2. THE AREA SHOWN IN FIGURE 1
Sodium picrate, x 100.

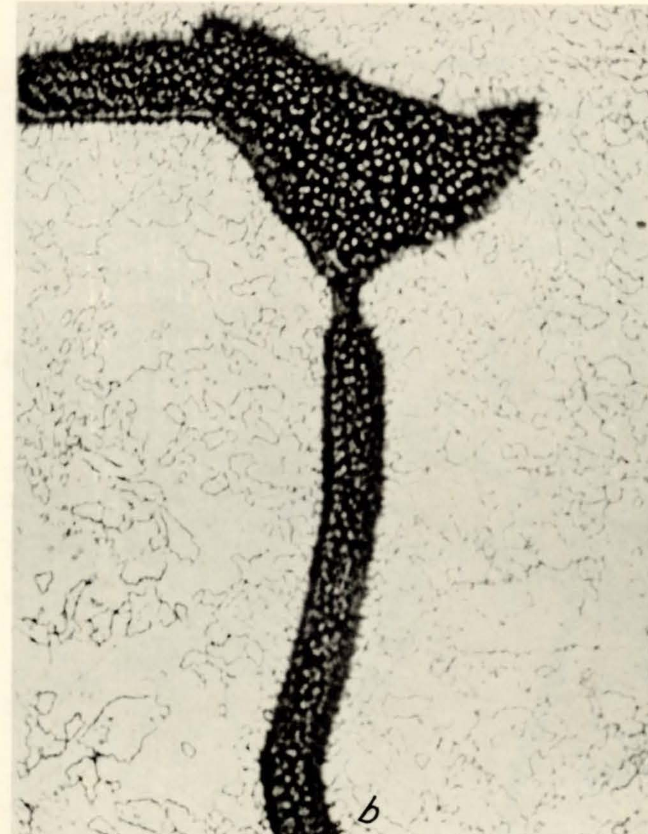


1. DISPLACED TAENITE LAMELLA
Picral, x 100.

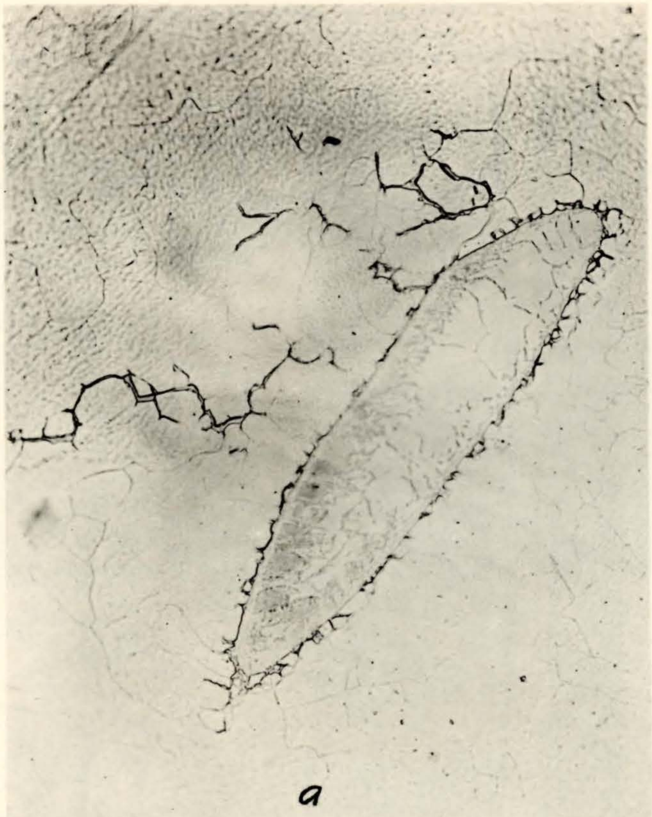
2. PART OF AREA SHOWN IN FIGURE 1
x 500.



1. EUTECTIC STRUCTURE IN SCHREIBERSITE
Sodium picrate 10 minutes, x 100.

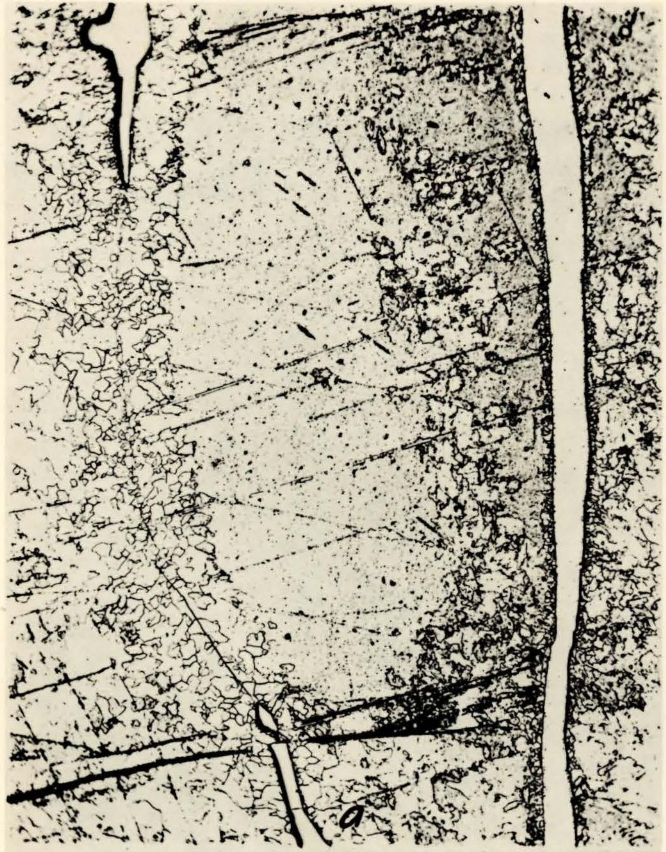


2. AN AREA SIMILAR TO FIGURE 1
Picral and 15 minutes sodium picrate, x 250.



1. SCHREIBERSITE INCLUSION
Picral, x 500.

2. SCHREIBERSITE INCLUSION
Picral, x 250. The round black spot is a glassy bleb.



1. GRANULATION IN KAMACITE ALONG LINE CONNECTING TWO SCHREIBERSITE INCLUSIONS. THE BAND AT RIGHT IS TAENITE
Picral, x 100.

2. INCIPIENT GRANULATION AROUND RHABDITES
Picral, x 200.

AREA OF PHOSPHORUS ENRICHMENT IN KAMACITE
Sodium picrate 7 minutes and picral 10 seconds, x 100.