

THE IRON METEORITE FROM NORDHEIM, TEXAS

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During 1936, the University Centennial Exposition secured a much-corroded iron weighing 34 pounds from Hugo Schlosser, a farmer who lives 3 miles south of Nordheim, DeWitt County, Texas. This fall is located at approximately $28^{\circ}52'$ N. Lat. and $97^{\circ}37'$ W. Long. Figure 98 is a map showing its location.

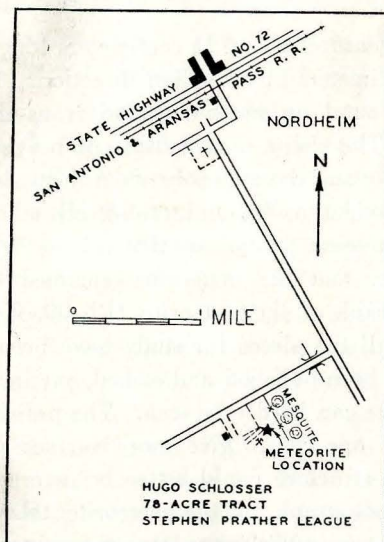


Fig. 98. Map showing the location where the Nordheim iron meteorite was found.

The meteorite was found in a cotton field on Mr. Schlosser's farm during August, 1932, and apparently had been brought to the surface by a plow earlier that year. This field was cultivated for the first time during the 1932 season, and evidently the meteorite had lain just beneath the surface for many years. Mr. Fred Oehler of San Antonio was the first to identify this find as a meteorite. He secured it as a loan for about three years before Mr. Schlosser disposed of it to the University Centennial Exposition. This iron

was brought to the attention of the University authorities by Mr. E. H. Sternberg, principal of the Nordheim high school.

When received, the meteorite was covered by loosely attached magnetic scale from 2 to 4 millimeters thick, most of which came off in the course of handling. Two small pieces of metal weighing probably less than a total of 20 grams were removed before the specimen was received. A 13-gram piece was taken for analysis, and an equal amount was removed for study under the metallographic microscope. The remaining mass weighs 33.3 pounds (15.11 kilograms). This iron is easily cut by a hacksaw and is malleable.

The meteorite measures about 21 centimeters long, 13 centimeters thick, and 19 centimeters in a median direction. It has the usual type of surface found on much-corroded irons that are free of troilite nodules. The shape is irregular sub-polyhedral with most of the faces concave and the angles between them sharp. One point is rounded, but oxidation has obliterated all other evidence that might have been present to indicate that this is the brustseite, providing, of course, that the meteorite remained oriented during flight. A photograph of the meteorite (Pl. 29, fig. 1) shows one side from which all the pieces for study have been removed. The cut surfaces have been polished and etched, yet in this photograph the etched structure can hardly be seen. The polishing was carried past the edges of one cut to give more surface area so that the orientation of the structure could better be determined. Plate 29, figure 2, is a photograph of the meteorite taken from another direction showing, in addition to the shape, some of the scale which still adheres.

This iron can be polished to a bright mirror-like surface. A few barely visible schreibersite plates are present, but no troilite or other minerals are recognizable. At least two sets of parallel cracks are present. One of these can be seen in figures 3, 4, and 5 of Plate 29. After being cut, and upon standing for a while, a few small, barely visible spots of exudation appeared upon the surface, indicating the presence of lawrencite.

Etching, using 6 per cent nitric acid, brings out several sets of schlieren-like streaks or bands. These streaks are visible only when the incidence of the light is in certain directions. With certain

other directions of illumination, the etched surface appears structureless and has an appearance suggestive of the presence of a thin coat of varnish. Only a few of the schlieren-like directions are visible at the same time. For this reason the three photographs, figures 3, 4, and 5 of Plate 29, are used to show all the directions present upon one of the surfaces. The streaks, depending upon the direction of lighting, either have a sheen or are dark. In Plate 29, figure 4, the lighting is so arranged that the groundmass reflects with a slight silvery sheen, and most of the streaks are dark. Altogether, ten different structural directions can be seen in these three photographs. In Plate 29, figure 3, two parallel lines, one reflecting light (extreme right) and the other dark, are present. The two sets, even though parallel in section, dip at different angles.

These streaks are not sharply bounded as are the lamellae of the octahedral irons. In the photographs it is seen that they vary in width within a set and in some places entirely disappear. The edges of the streaks have a slightly frayed appearance when observed with a hand lens. The several sets vary in width, depending upon the angle at which they intersect the etched surface.

Under the microscope at low magnification, the etched iron appears structureless. Using 200 diameters magnification, a structure can be seen which stands out even more clearly at higher magnifications. The fragment studied has two surfaces intersecting at about 30° . On one of these surfaces in Plate 30, figure 3, four directions of microscopic structure can be seen. Two directions are nearly parallel, and the other two directions are at a very slight angle to each other. These two sets of directions are roughly at right angles to each other. The other surface of this fragment shows slightly more divergence between the lines. One direction was traced on both surfaces, and the fragment cut parallel to the plane designated in this manner. The etch pattern of the new surface reveals three microscopic structural directions at nearly 60° to each other. The microscopic structure, therefore, must be octahedral, but, unlike that of the normal octahedral iron, the structure is invisible to the unaided eye.

The visible schlieren-like streaks do not coincide with this structure. One streak, so situated that its orientation could be reasonably well ascertained, appears to intercept the axes of the microscopic

The two most common constituents are designated for convenience as taenite and kamacite, and these outline the octahedral structure. The taenite is in thin plates and is the constituent that gives the direction to the octahedral structure. The kamacite is of a more granular equidimensional character and occupies the space between the taenite plates. The intermediate constituent has apparently separated out along planes parallel to the faces of a tetrahedron and takes the form of more or less equidimensional grains which are separated in places by irregular thin taenite layers. The orientation and irregular distribution of this constituent causes the schlieren-like appearance observed without magnification.

Upon weathering, the kamacite is first removed, leaving a delicate network of taenite. As the weathering progresses the network is broken, and with more weathering only small, brightly reflecting points are left. In detached pieces of scale, areas are present in which the taenite forms a network. It also outlines areas originally occupied by schreibersite crystals. Plate 30, figure 6, is a photomicrograph of a polished surface on a 3-millimeter thick piece of scale showing the taenite network preserved in the oxidation products of the other constituents. The magnetic properties of meteoritic scale may be due in part to the presence of finely divided taenite rather than to the presence of magnetic iron oxide formed during oxidation, as suggested by Shannon.¹ In Shannon's paper the problem is attacked from the chemical standpoint, and the scale was not polished and examined under high magnification using a reflecting microscope. Until this is done it will be uncertain whether the magnetic properties of the scale that he examined are due to magnetic iron oxide or to minute particles of unoxidized nickel-iron.

F. A. Gonyer analyzed 13 grams of the Cuero meteorite, freed as nearly as possible from rust, and reports the following composition:

¹Shannon, E. V., The oxidation of meteoric irons with comparative descriptions of two new examples of magnetic iron oxide from terrestrial sources: U. S. Nat. Mus., Proc., vol. 72, art. 21, pp. 1-15, 1927.

	<i>Per cent</i>
Fe	87.79
Ni	11.69
Co	0.51
Cu	trace
Mn	none
Cl	0.02
C	none
P	0.04
S	trace
Insoluble	0.01 (mostly Fe ₂ O ₃)
Total	100.06

This analysis is calculated to the following mineral constituents:

	<i>Per cent</i>
Fe-Ni-Co-Cu	99.74
Schreibersite (Fe, Ni, Co) ₃ P	0.22
Lawrencite (FeCl ₂)	0.04
Troilite (FeS)	trace
	100.00

The specific gravity of this iron is 7.84.

This meteorite, on the basis of meteorites described previously, for the present will be included under the nickel-rich ataxites of the Rose-Tschermak-Brezina² classification and in the Cape group (Dc). The Cape group is defined as being nickel-rich and having "sharp (hexahedral?) etch bands in a dull groundmass." Cohen³ combines this group with the Shingle Springs (Dsh) group of Rose-Tschermak-Brezina, which contains etch bands and spots that are not sharply bounded, defines this entire group as "granular to dense ataxites with (?) hexahedral schlieren," and designates this group as the Cape iron group with symbol (DsC). The classification of Rose-Tschermak-Brezina is the one usually accepted, but in this case the modification by Cohen appears more logical. Meteorites falling into the DsC group of Cohen are the Cape of Good Hope, Kokomo, and Iquique (Dc); and Shingle Springs and Ternera (Dsh).

The analyses of these irons are compared with that of the Nordheim in the following table:

²Brezina, Aristides, The arrangement of collections of meteorites: Proc. Amer. Phil. Soc., pp. 211-247, 1904.

³Cohen, E. W., Meteoritenkunde, Heft 3, pp. 138-164, Stuttgart, E. Schweizerhart'sche Verlags-handlung (E. Nägele), 1905.

(Dc)			(Dsh)			
I CAPE OF GOOD HOPE	II KOKOMO	III IQUIQUE	IV SHINGLE SPRINGS	V TERNERA	VI NORDHEIM	
<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	
Fe 82.87	83.24	83.49	82.21	82.17	87.79	
Ni 15.67	15.76	15.41	16.69	16.22	11.69	
Co 0.95	1.07	0.94	0.65	1.42	0.51	
Cu 0.03	0.01	0.02	0.02	trace	trace	
Cr. 0.04	0.00	trace	0.02	n.d.	
C 0.03	n.d.	0.03	0.03	0.00	
Cl 0.01	n.d.	n.d.	0.00	0.02	
P 0.09	0.08	0.07	0.34	0.11	0.04	
S 0.00	trace	0.02	0.05	0.13	trace	
	96.69	100.16	99.98	100.01	100.05	
Sp. Gr.	7.8543	7.8606	7.8334	7.8943	7.694	7.84

- I. Analysis by Fahrenheit, p. 87; E. Cohen, *Meteoreisen-Studien* 10th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 15, pp. 79-88, 1900.
- II. Analysis by Sjöström, p. 153; E. Cohen, *Meteoreisen-Studien* 8th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 150-153, 1898.
- III. Analysis by Sjöström, p. 156; E. Cohen, *Meteoreisen-Studien* 8th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 153-156, 1898.
- IV. Analysis by Sjöström, pp. 479-480; E. Cohen, *Meteoreisen-Studien* 9th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 477-481, 1898.
- V. Analysis by Lindner; C. Klein, *Die Meteoritensammlung der Königlichen Friedrich-Wilhelms-Universität zu Berlin* am 21 January 1904, *Sitzungsberichte der Königl. preussi Akademie der Wissenschaften zu Berlin*, Bd. 4, p. 151, 1904.
- VI. Analysis by F. A. Gonyer.

The chief difference is that Nordheim is lower in nickel and cobalt and higher in iron. The minor constituents do not vary appreciably, except that the Dsh group has a higher phosphorous and sulphur content. The average nickel-cobalt in the first five meteorites is 16.96 per cent, compared with 12.20 per cent in the Nordheim, a difference of 4.76 per cent. The nickel-cobalt content of Nordheim is below that of the schlieren-containing ataxites and is near the boundary for that of the structureless nickel-rich ataxites. Several of the fine and finest octahedrites have a higher nickel content than does the Nordheim iron.

In discussing the Kokomo iron, Cohen⁴ makes the following statement:

Under a moderately strong magnifying power Kokomo appears as an entirely homogeneous mass, with the exception of extraordinarily small,

⁴Cohen, E. W., *Meteoreisen-Studien* 8th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 150-153, 1898.

strongly reflecting points. At first, by the employment of a magnifying power of about 200 diameters, one sees a succession of dark, faint, and bright, glistening particles; since one cannot distinguish a distinct line of demarcation between one and another of them, it is not possible to determine definitely whether the structure is granular or whether the appearance is due to etching pits. I consider the former the more probable.

He also mentions that the "stripes" are darker or brighter according to the position of the plate with reference to the light; that with a certain position of lighting the entire surface is uniform; and that upon etching, the iron takes on a varnish-like luster. These properties are also found in the Nordheim meteorite. Under magnification, the same effect was obtained as noticed by Cohen of "extraordinarily small, strongly reflecting points" when the Nordheim was etched to bring out the schlieren-like lines. It was found that 3 per cent nitric acid acting for about 1 or 2 seconds is sufficient to bring out the microscopic structure, whereas 6 per cent nitric acid acting for 15 to 20 seconds is necessary to bring out the schlieren-like structure. A slight burnishing after etching helps to make a more distinct surface for study.

Cohen's⁵ description of Cape of Good Hope, Iquique, and Shingle Springs contain very similar statements to the above, and he thinks that the separation of these meteorites into two groups is not advisable. He states:

If no especial weight be given to the kind of edging of the bright portions, this meteoric iron [Shingle Springs] may be included in a well-defined group with the following common characteristics: high percentage of nickel; bright etching bands and spots; dense structure of the nickel-iron. Such a grouping appears to me more natural than the division into two groups by Brezina. The latter unites the Cape, Iquique, and Kokomo irons in the Cape group, and arranges Shingle Springs and Ternera under the Chester-ville group, which, in consequence of this, acquires quite a heterogeneous composition.

Considering the octahedral structure of the Nordheim, which is visible under high magnification, it seems that it should be placed in a new division of microscopic-structured octahedrites rather than with the ataxites. It is possible that a restudy of the meteorites

⁵Cohen, E. W., *Meteoreisen-Studien* 9th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 477-481, 1898.

of Brezina's Dc and Dsh groups under high magnification and with properly etched surfaces might reveal a similar structure. If they do have an octahedral structure they should be removed from the nickel-rich ataxites and should be placed with the octahedrites in a new group defined as microscopic-structured octahedrites with schlieren-like streaks. If the schlieren-like streaks can be correlated with a definite crystallographic direction—for example, if they are parallel to the face of a tetrahedron—then the qualifying word "tetrahedral" can be inserted before "schlieren-like streaks." If, however, the present terminology is retained, in which octahedral structure visible without magnification denotes an octahedrite, then, under the Rose-Tschermak-Brezina classification, the Nordheim will have to be classified as a nickel-rich ataxite, group Dc.

The writer wishes to express his appreciation to Dr. H. B. Stenzel and the Committee on Geological Exhibits for the University Centennial Exposition for the opportunity to examine this iron, and to The University of Texas Committee on Research Grants and Publication, Dr. J. T. Patterson, chairman, for a grant to cover the cost of an analysis.

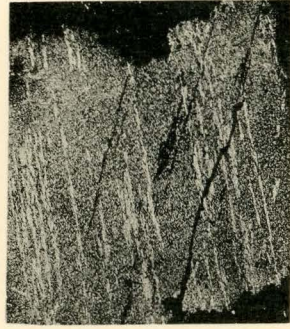
PLATE 29

Photographs of Nordheim meteorite.

1. View showing character of surface and parallel cracks in the polished areas. x4/10.
2. End view showing character of surface and some loosely-attached scale. x4/10.
- 3, 4, 5. Polished and etched surfaces lighted in each photograph from a different direction to bring out the large number of structural directions. The type of reflection depends on the direction of lighting. In figure 4 the two prominent directions are lighted to bring out the reverse of the effect seen in figure 3. About x1.5.



1



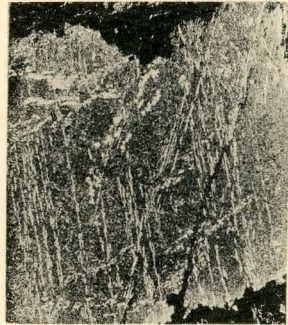
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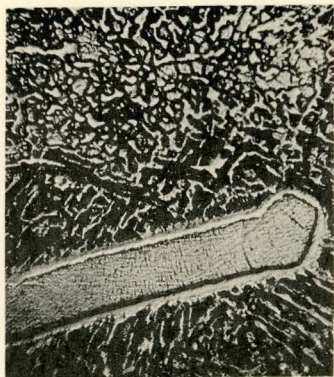


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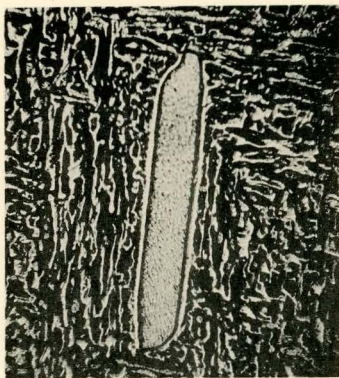
PLATE 30

Photomicrographs of polished and etched surface of Nordheim iron and scale.
About x230.

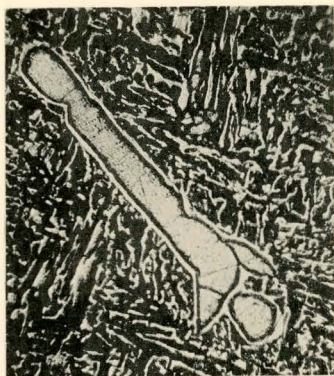
1. A schreibersite crystal surrounded by taenite which is continuous with the taenite that forms the octahedral structure. In the upper part of the photograph is a portion of a schlieren-like line.
2. A schreibersite crystal parallel to one direction of the microscopic structure.
3. A schreibersite crystal group and four definite directions of microscopic structure.
4. A peculiar type of schreibersite crystal and a few grains of the intermediate constituent which forms the schlieren-like bands.
5. A portion of a schlieren-like line. The bright granular material of this line is probably a material intermediate in composition between taenite (long bright plates) and kamacite (black). In the upper right corner taenite borders some of the intermediate material. In the lower right and upper left corners normal octahedral structure is present.
6. A polished surface of scale in which taenite is preserved in the oxidation products of other constituents. This surface shows three prominent structural directions.



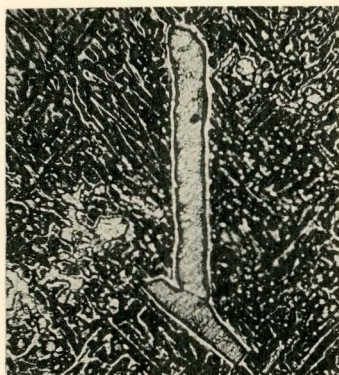
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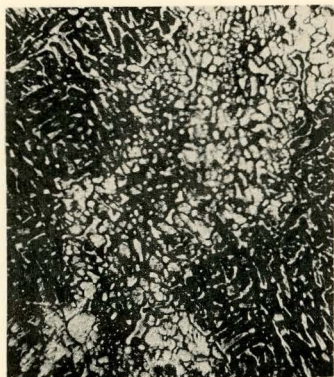
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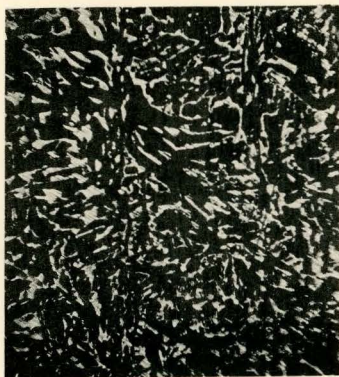
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6