PROCEEDINGS OF THE UNITED STATES NATIONAL MUSEUM

issued by the

SMITHSONIAN INSTITUTION
U. S. NATIONAL MUSEUM

Vol. 99 Washington : 1949 No. 3242

THE LINWOOD (NEBRASKA) METEORITE

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The meteorite here described was discovered in 1940 or 1941 on the farm of Joseph W. Vrana, 1¾ miles south and 1¼ miles west of Linwood, Butler County, Nebr., in section 3, township 16, range 4 (latitude 41°26′ N., longitude 96°58′ W.). It was found buried about 7 or 8 inches beneath the surface of the soil while Mr. Vrana was operating a disk harrow.

The meteorite as received by Mr. Perry weighed 46,000 grams and was presented to the United States National Museum intact except for a 1- or 2-ounce fragment removed from one end. The dimensions are approximately 12 by 11 by 5 inches. The surface is evenly covered with iron oxide, and there are no remaining structures of flight markings or original crust. It is definitely not a recent fall. There are many "thumb marks" of varying size on the surface but no unusual features worthy of special note.

The Linwood iron is a coarsest octahedrite with many silicate inclusions (pl. 21, fig. 1). The octahedral pattern is irregular and quite different from the coarse octahedrites of almost identical composition. The kamacite bands are mostly short and vary in width from 2 to 4 mm. or a little more, but in some places polyhedral masses nearly half an inch across are found. The kamacite shows abundant Neumann lines. The individual kamacite areas are not granulated as they would be if there had been reheating followed by quick cooling, yet the general structure of the octahedral pattern gives the impression of being granulated. No taenite lamellae or plessite is visible, though the microstructure shows occasional minute atypical plessite fields with a diversity of structure (pl. 21, fig. 2; pl. 22, figs. 1, 2) and occasional small schreibersite bodies. A few small thin scales believed to be taenite were found attached to the kamacite when the silicate inclusions were broken out for study. No rhabdites were observed. There are veinlets of silicates separating some of the kamacite areas, and in several cases these extend from one silicate area to another, but always around the edges of a kamacite boundary.

The most distinctive feature of this meteorite is the silicate inclusions. These are numerous, colored black with carbon, and of irregular shapes, usually elongated or sprangling, with dimensions up to 2 inches or more. The bodies of the inclusions in many places extend into the octahedral structure as black irregular veins or lines, often of considerable length, and resemble cracks invaded by iron hydroxide. Actually little hydroxide is present except around the edges of the slice close to the outer surface. Occasional particles of silicates are found in the kamacite inclosed in the silicate areas. The structure of the iron indicates that the inclusions segregated before the octahedral structure was fully established. There are, however, some small rounded or irregular-shaped masses of iron apparently isolated within the silicate areas. Although these appear, in the section cut, to be islands of iron, they may be little tongues of metal projecting into the silicate areas from the underside of the inclusion.

To provide a sample for study a slice was cut and etched, and from this slice areas of iron were selected which were free from inclusions. Likewise, portions rich in silicates were cut out to yield suitable material for a study of these inclusions.

COMPARISON OF THE LINWOOD, EL BURRO, AND MURNPEOWIE METEORITES

Element	Linwood, Nebraska (E. P. Henderson, analyst)	El Burro, Mexico (E. P. Henderson, analyst)	Murnpeowie, South Australia (M. H. Hey, analyst)
	Percent	*Percent*	*Percent*
Fe	93.47	93.10	93.88
Ni	5.98	6.02	6.32
Co	0.39	0.34	0.32
P	0.05	0.32	
S	None	None	0.006
Insol	0.01	0.01	0.20
Sp. G	7.813	7.884	
Mol. ratio, $\frac{Fe}{Ni+Co}$	15.63	15.57	15.00

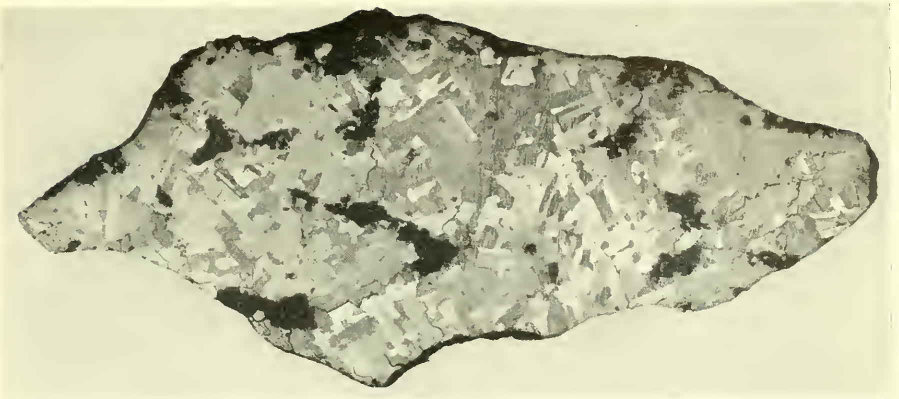

FIG. 1.—Slice of Linwood meteorite showing the well-developed octahedral pattern and the distribution of the silicate inclusions, black because of the large quantity of carbon present. One-half natural size.

FIG. 2.—A light plessite field, the taenite lamella gray because of supersaturation with respect to kamacite. Picral 85 seconds; × about 35.

FIG. 1.—An irregular plessite field containing lamellae of taenite (gray) and small areas of incompletely transformed gamma-alpha aggregate. Small schreibersite bodies surrounded by hydroxide. Picral 85 seconds; × about 35.

FIG. 2.—A plessite field with a pearlitic structure of kamacite and taenite lamellae, almost surrounded by hydroxide. At this magnification it resembles similar areas of pearlitic structure in a number of other irons (e. g., Leeds, Seelasgen, Youndegin) in which the white lamellae are kamacite and the gray are taenite. Picral 30 seconds; × about 40.

FIG. 1.—Part of area in pl. 22, fig. 2, at high magnification. The dark lamellae are shown to be not taenite but kamacite, invaded by hydroxide and wholly altered; the taenite, resistant to oxidation, surrounding hydroxide. Picral 15 seconds; × 300.

FIG. 2.—An area near the edge of a large silicate inclusion. The large black spots are silicates. Picral 30 seconds; × about 45.

FIG. 3.—An area of kamacite showing no octahedral structure, a silicate lamella interrupting the Neumann lines. Picral 30 seconds; × about 45.

FIG. 1.—Irregular edge of an inclusion. The silicate at one point extends in a streamer from the mass. Three small isolated particles of silicate in kamacite. Picral 30 seconds; × about 45.

FIG. 2.—An area at the edge of the slice showing, at lower left, a zone of alteration in which the normal structure has been replaced by a secondary granulation. The dark area at lower right is probably hydroxide; that at upper left is silicate. Picral 120 seconds; × about 30.

The composition of the metallic portion of the Linwood meteorite agrees very closely with that of the El Burro,[1] although in the latter the kamacite bands are very broad (2–3 cm.) and fairly regular in direction. The structure of the Murnpeowie[2] is entirely different, consisting of rounded grains, small to moderate in size, without recognizable octahedral structure.

Qualitative chemical tests were made upon the inclusions in order to determine their nature. Graphitic carbon is present in all the silicate inclusions; troilite was positively identified by collecting the hydrogen sulphide gas liberated when the powder was treated with hydrochloric acid; schreibersite was recognized by its physical habit and its strong magnetic properties. The acid extract from the silicates was found to contain magnesium, calcium, iron, nickel, traces of phosphorus, and soluble silica.

The bulk of the silicates is olivine, but there may be a small quantity of anorthite present since the quantity of calcium found in the acid soluble extract appears too large to be calcium derived from impurities in olivine. The silicates insoluble in hydrochloric acid were washed with dilute sodium-carbonate solution to remove the silica which had separated by acid attack on the olivine, and then air-dried for optical examination. Because of the complex nature of these silicates and the difficulty of obtaining enough material to make mineral separations and chemical analysis, the authors decided that an optical study would give results capable of more accurate interpretation.

The general character of the olivine was determined by assuming that all the magnesium found in the acid soluble portion was derived from olivine, combining it with the total of the acid-soluble silica and then adding enough FeO to give the theoretical olivine ratios.

COMPOSITION OF OLIVINE FROM LINWOOD, NEBRASKA, METEORITE

SiO_2	0.0468 grams	0.1470	1
MgO	0.0707 grams	0.1753	3
[1] FeO	0.1187 grams	0.1187	

[1] Calculated.

The partial analysis given above indicates an olivine with a composition midway between the magnesium and iron ends of the series very close to $Fo_{60}Fa_{40}$.

Optical properties of the silicates in the acid-insoluble residue of the Linwood, Nebraska, meteorite were determined by Miss Jewell J. Glass, of the U. S. Geological Survey, and Dr. Harry H. Hess, of Princeton University, to whom grateful acknowledgment is made. The following data are quoted from their reports:

"Most of the insoluble residue consists of graphite.

[1] Henderson, E. P., Amer. Min., vol. 26, pp. 655–656, 1941.

[2] Spencer, L. J., Min. Mag., vol. 24, No. 148, pp. 13–20, 1935.

"Enstatite. About two-thirds of the nonopaque insoluble material is composed of enstatite. The enstatite grains are minute; the crushed grains show distinct prismatic cleavage. Its color is gray; colorless in thin fragments. Luster vitreous. Transparent to translucent. Optically positive with a large axial angle, $2V=75°-78°$. Dispersion distinct, $r>v$ for most grains. The indices of refraction are: $\alpha=1.659$, $\beta=1.664$, $\gamma=1.670$. The composition of the enstatite, estimated from the optical properties, is $En_{93-94}Fs_{6-7}$.

"Chrome diopside. This green pyroxene is less abundant than the enstatite in the insoluble residue. Its grains are rounded, transparent to translucent. Optically positive; $2V$ approximately 60°. Dispersion distinct, $r>v$. Indices of refraction: $\alpha=1.689$, $\beta=1.695$, $\gamma=1.704$. Birefringence measured in bakelitic mount by comparison with quartz using Berek compensator 0.0264. Optical angle $55°-60°$; $Z\wedge C$ $39°-40°$.

$\alpha=1.6766$, Na light on temperature cell.

$\beta=1.6828$, calculated.

$\gamma=1.7030$, calculated from birefringence.

This pyroxene has enstatite exsolution lamellae perfectly developed paralled to (001), which indicates very slow cooling in its original environment. Estimate composition from the optical properties is $Wo_{46}En_{48}Fs_{6}$.

"Oligoclase. This feldspar is present in amounts equal to the pyroxene. Colorless with a good cleavage. Optically negative; $2V$ moderately large. Indices of refraction are: $\alpha=1.538$, $\beta=1.543$, $\gamma=1.546$. These properties indicate a composition close to $Ab_{80}An_{20}$.

"Maskelynite. A small amount of an isotropic material with an index of refraction of 1.539 was observed which is probably maskelynite."

COMPOSITION OF THE SILICATES IN LINWOOD, NEBRASKA, METEORITE

Olivine	$Fo_{60}Fa_{40}$
Enstatite	$En_{93-94}FsFs_{6-7}$
Chrome diopside	$Wo_{46}En_{48}Fs_{6}$
Oligoclase	$Ab_{80}An_{20}$

Chemically the pyroxenes are in equilibrium.

Carbon is distributed through all the inclusions but not always uniformly within each inclusion. Troilite is usually more or less concentrated around the rims of inclusions, bordering the metal. Only a few schreibersite bodies were observed in these inclusions, but they seem always to occur adjacent to the metallic iron and not as isolated masses in the graphite and silicate material.

U. S. GOVERNMENT PRINTING OFFICE: 1949