FLOW STRUCTURE IN THE LUBBOCK METEORITE, LUBBOCK, TEXAS

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Abstract

The Lubbock meteorite, an aerolite, found near Lubbock, Texas, is unusual in that its internal structure shows the effects of flowage and brecciation. These effects are indicated by the alignment of metallic and non-metallic mineral particles along flowage lines, by an intricate network of small veinlets of nickel-iron and pyrrhotite, and by veinlets of nickel-iron in a "horse-tail" arrangement.

The meteorite described in this paper was found at a point located approximately at Latitude 33°55′ North, Longitude 101°51′ West, which is about one mile south of the city limits of Lubbock, Texas. It is of the aerolite variety, with external features similar to those of other aerolites. However, to my knowledge, its interior structure differs noticeably from that of other aerolites because the arrangement and distribution of the mineral constituents indicates that flowage and brecciation occurred in the stone previous to the time of its flight. The fall was first reported to Mr. H. H. Nininger of the American Meteorite Laboratory by Clifton Morris of the Texas Technological College at Lubbock, Texas, in January 1939, and was subsequently submitted to the writer for detailed examination and description.

Mr. Nininger's general description of the meteorite follows:

> As received at the laboratory, the specimen weighed 1457.8 grams and appeared very unattractive. Only a small part of the surface showed any definite traces of the pitting which is such a prominent feature of certain meteorities. The fusion crust was deeply stained to a distinctly reddish-brown color. In many places this was entirely concealed by a thin coating of oxides. On one side, the specimen showed evidence of having been separated from a larger mass, either late in its flight or after reaching the soil. Long exposure made it impossible to determine which was the case. In spite of its exposure to the weather, the surface of the specimen showed no sign of exfoliation or of fracture.
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> As to form, the stone was very irregular, about twice as long as it was thick, with one end larger than the other. In cross section it was roughly four sided. There was no indication of an oriented flight. Three small deep elongated pits near the smaller end lay closely parallel. These indicated a direction of air currents at an angle of about 30 degrees with the longitudinal axis of the stone. Two more or less circular pits on the large end were not aligned with such a course.

After photographing, the stone was sectioned near the large end at right angles to the longitudinal axis. Three cuts were made and two slices, approximately 5 mm. and 6 mm. thick, respectively, were removed. One of these slices (Fig. 1A) was polished and used for detailed examination. An additional cut was made to obtain a small fragment suitable in size for the preparation of thin sections.

Mineral Composition

The Lubbock, Texas, meteorite contains olivine, enstatite, anorthite, hematite, nickel-iron and pyrrhotite. Of the non-metallic minerals, olivine is the most abundant. Some olivine grains are intimately intergrown with enstatite and the metallic minerals, whereas the majority of them are disseminated throughout an extremely fine-grained and nearly glassy matrix. This matrix probably has a composition approaching the average composition of the contained non-metallic minerals. The majority of the grains range in size from 0.032 mm. to 0.32 mm., but a few of the chondrule type attain a diameter of 1.6 mm. In the latter, the olivine particles are angular in outline and are intimately intergrown with a small amount of enstatite (Fig. 2C).

Enstatite is second in abundance. In addition to constituting a minor part of the olivine chondrules, it occurs rather evenly distributed throughout the mass of the meteorite. Virtually all of the enstatite grains exhibit a fibrous structure. The grains are mostly angular and vary in diameter between 0.16 mm. and 0.64 mm. Only one well developed chondrule of enstatite was observed in the two thin sections examined. This chondrule, also with fibrous structure, is 1.92 mm. in diameter (Fig. 2A). A number of the enstatite grains exhibit fracturing as evidenced by offsetting of the fibers.

Plagioclase feldspar (anorthite) is present but the grains are extremely small and few in number.

Another mineral, reddish-brown in color, which has been assumed to be hematite, occurs as fracture and cavity fillings. In many respects it appears to be of secondary origin. On the walls of small voids, the reddish-brown mineral exhibits a fine concentrically-layered structure, but in the narrow fractures traversing the meteorite the layered structure of the mineral is not evident.

The metallic minerals, nickel-iron and pyrrhotite, also occur in considerable abundance in the stone, but these will be described under "Internal Structure," because of their peculiar arrangement and distribution.

Internal Structure

The polished surface of the Lubbock meteorite presents a structure which is unique, as far as I am aware, among aerolites. It is rather definitely divided into three zones in which the distribution of the nickel-iron and pyrrhotite indicates both definite flow structure and brecciation. These features are illustrated in the accompanying photograph (Fig. 1A), and in the diagrammatic sketch (Fig. 1B).

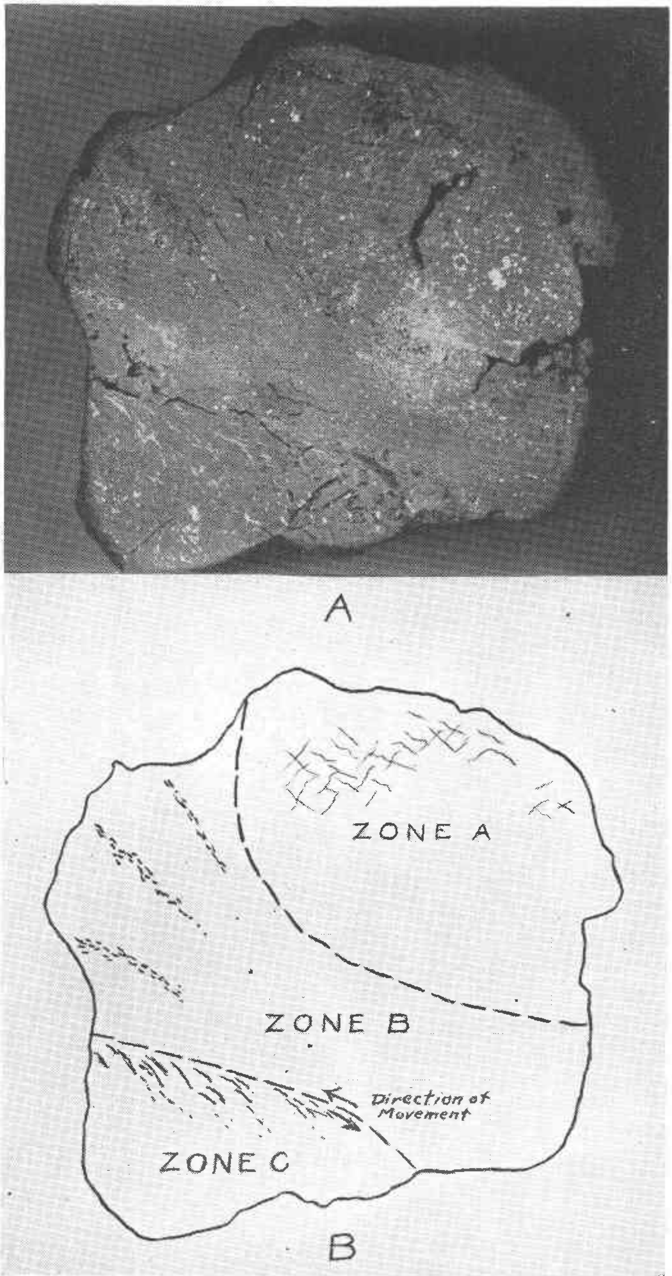

FIG. 1. A. Section of Lubbock meteorite, natural size. B. Diagrammatic sketch of section illustrated in A, showing zones described in article.

Zone *A*, with characteristics typical of many stony meteorites, appears to have been subjected to less disturbance than zones *B* and *C*. Within zone *A* are several chondrules only one of which is evident in Fig. 1A. Nickel-iron and pyrrhotite are rather evenly distributed in this zone. Most of the nickel-iron particles range from 0.2 mm. to 0.4 mm. in

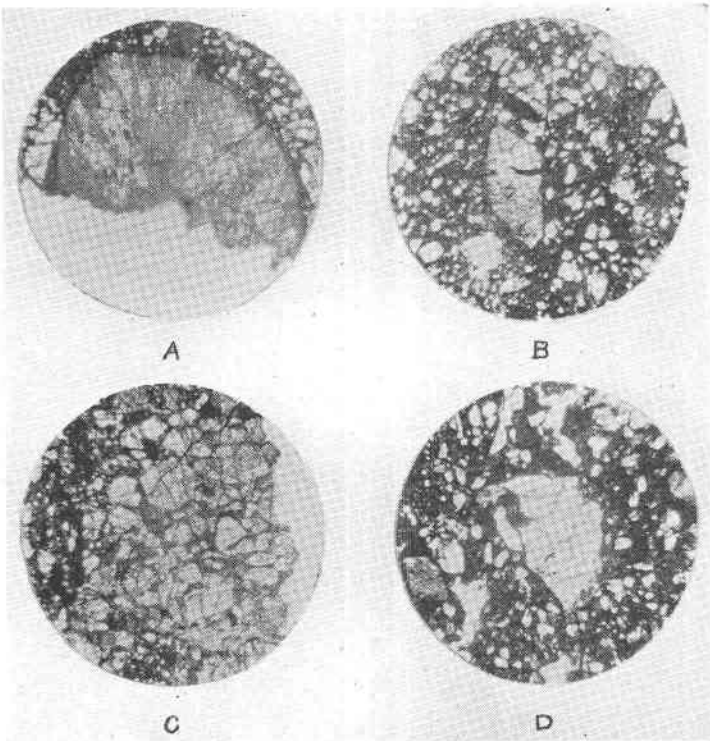

FIG. 2. A. Enstatite chondrule. ×40. B. Broken enstatite chondrule; slight evidence of flowage in right half of illustration. ×40. C. Olivine—enstatite chondrule; alignment of grains indicating flowage near left edge of illustration. ×40. D. Olivine crystal. ×40.

diameter, but some have a maximum diameter of 1.6 mm. In contrast, the pyrrhotite particles are mostly smaller than 0.2 mm. in diameter. Nickel-iron and pyrrhotite, in addition to being rather evenly distributed as individual particles, are also closely associated in minute veinlets which form an intricate network throughout zone *A*. The longer and most evident veinlets roughly parallel the contact between zone *A* and zone *B*, but at approximately right angles to these are numerous smaller veinlets. Some of the veinlets traverse the chondrules of enstatite and olivine. Another characteristic of zone *A* is the slight but apparent increase in pyrrhotite along the outer edge of the meteorite and also near the contact between zone *A* and zone *B*. Hematite in veinlets and in isolated areas is relatively prominent in zone *A*. Its greatest concentration is near the edge forming the outside of the meteorite, and it decreases in amount toward the contact between zones *A* and *B*. The veinlets of hematite, which have a maximum thickness of only 1 mm., are more continuous than those formed by the nickel-iron and pyrrhotite. Most of the longer veinlets are approximately parallel to the outer edge of the meteorite. Throughout zone *A*, the distribution of the minerals suggests fracturing of this part of the stone previous to the introduction of nickel-iron and pyrrhotite. It is also probable that the nickel-iron preceded pyrrhotite in time of crystallization.

Zone *B* is the central part of the meteorite. In it the arrangement and distribution of the mineral constituents are indicative of flow structure. This zone consists of a very fine-grained ground mass in which many of the minute particles of the metallic and non-metallic minerals are in alignment along lines of flowage. In the thin sections the alignment of small broken particles of pyroxene and olivine is less evident than the alignment of nickel-iron and pyrrhotite noticeable in the polished section. Three distinct veinlets of nickel-iron and pyrrhotite are parallel to the flowage lines in the wide part of the zone near the edge of the meteorite (Fig. 1A). A few veinlets of hematite are present in zone *B* but they are far less common than in zone *A*. The intricate network of minute veinlets of nickel-iron and pyrrhotite, which is so prominent in zone *A*, is absent in zone *B*.

Zone *C* with veinlets of nickel-iron arranged in a "horse-tail" manner adjacent to zone *B* (Fig. 1A), is another indication of flowage within the Lubbock meteorite. The "horse-tail" veinlets vary in width from 0.10 to 0.40 mm., and have a maximum length of 5.4 mm. They lose their identity as they approach the central mass of the zone which in general appearance is similar to zone *A*. The "horse-tail" arrangement of the nickel-iron veinlets suggests strongly that flowage caused fracturing of zone *C* adjacent to zone *B*, and that the fractures were slightly curved by dragging either before or after the deposition of nickel-iron. Pyrrhotite in this zone is present as minute particles some of which are arranged in veinlets. The network pattern of the veinlets is not, however, as pronounced as it is in zone *A*.

Conclusion

The flow structure and brecciation in the Lubbock meteorite, as indicated by the arrangement and distribution of the mineral constituents, probably occurred previously to its flight. Deposition of the nickel-iron and pyrrhotite, or at least a re-crystallization of these minerals, took place after some fracturing of the meteorite, as indicated by the veinlets traversing many of the olivine chondrules, and by the network of veinlets so well developed in zone *A*. Characteristics of the contacts between pyrrhotite and nickel-iron suggest that the nickel-iron preceded pyrrhotite in time of crystallization, or that it was partially replaced by pyrrhotite.