To Oscar
with the writers'
best regards

La Lande, N. Mex

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The La Lande, New Mexico, Chondrite (ECN = +1041,344)*

CARL W. BECK,† RALPH G. STEVENSON, JR.,‡ *and* LINCOLN LAPAZ§
University of New Mexico, Albuquerque

ABSTRACT

In this paper are given details concerning a chondritic meteorite found in 1933 near the La Lande post office in De Baca County, New Mexico. Macroscopic and microscopic mineralogical examinations and chemical analyses are given. The meteorite is composed chiefly of olivine and enstatite (variety, hypersthene), lesser amounts of a dispersed metallic phase, and small percentages of enstatite-clinoenstatite intergrowths and secondary hematite. On the basis of this investigation, the La Lande meteorite is classified as a hypersthene-olivine chondrite (Chy). Evidence is presented to indicate that the La Lande aerolite may not be a distinct fall, but may be simply a member of the widely scattered Melrose, Curry County, New Mexico, shower. Three (3) figures and 2 tables are given.

INTRODUCTION

The Joe R. Heaston Collection of New Mexican Meteorites (purchased from H. H. Nininger, now of the American Meteorite Museum near Winslow, Arizona) at the University of New Mexico contains 2 aerolitic specimens designated as follows:

15. La Lande, De Baca County, 1933, stone, 77 pounds (single mass), Specimen 464.50, weight 3¾ pounds [= 1.700 kg.].
16. Melrose, Curry County, 1933, gold-bearing stone, 84 pounds (several masses), Specimen 174.92, weight 7½ pounds.

Essentially the same information regarding these 2 meteorites is given by Northrop.[1] Specimen 464.50, which also carries the registration number IOM-6 in the collection of the Institute of Meteoritics, was studied in this report.

The foregoing facts represent essentially all of the information that has previously been available on the La Lande meteorite (ECN = + 1041,344). Mention of it was made by Nininger[2] in his paper on the nearby Melrose, Curry County, New Mexico, meteorite (ECN = +

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†Department of Geology and Research Associate, Institute of Meteoritics.

‡Department of Geology.

§Department of Mathematics & Astronomy and Director, Institute of Meteoritics.

1036,344; cl. = chondrite, C). Because of the similarity of the La Lande and Melrose meteorites, the question naturally arises as to whether or not they are distinct, or are simply widely separated members of the same meteoritic shower. If the latter possibility can be proved to be a fact, then the name *Melrose* should probably take precedence for both, by reason of priority. The one distinct difference should be the presence of gold in Melrose, called "the only gold-bearing meteorite in America."[3] Recent chemical analyses in this laboratory of 4 representative fragments of the Melrose meteorite, in which the Purple of Cassius and phenylhydrazine-acetate methods of testing for gold were utilized, have failed to show any gold content. Analyses of La Lande also have failed to indicate any gold.

Macroscopic Examination

In shape, the 1.700-kg. La Lande specimen studied in this report closely resembles a crude oblique pyramid with a rounded apex (Fig. 1B). Approximately half of the lateral area is occupied by a gently rounded surface; the remaining half is divided between 2 smaller faces containing angular pits and projections. These latter 2 faces meet at an angle equal roughly to 65°. The entire basal area is composed of the flat surface left by the saw when the specimen was cut from the larger mass (Fig. 1A).

The area of the base is approximately 100 square cm. The altitude of the pyramid is 11 cm. The slant-height of the large rounded surface is slightly under 18 cm.

The appearance of the large rounded surface differs somewhat from that of the more angular surfaces, and the basal face, being an interior face, naturally differs from all the others, inasmuch as they have been exposed to conditions inducing alteration, whereas the base has been protected.

The large rounded surface is reddish-brown; it has the general appearance of an unsorted, ferruginous sandstone and is covered with fine pits and an occasional large one. A rather granular appearance with some observable chondrules is presented entirely over this surface, which is apparently a portion of the original surface that was most exposed to the rigors of high-velocity flight thru the outer atmosphere.

The other exterior surfaces exhibit a mottled, red-brown color similar to that of the large surface, but they have a much less eroded appearance. No chondrules were noted. The difference in surface texture between the gently rounded surface and the more angular ones may be due to either one of two causes. It may be a result of the shattering, or the explosion, of a larger mass in the atmosphere. This would offer fresh surfaces to erosion but would not halt erosion on the older surfaces. The new surfaces would thus suffer much less alteration than the older ones. A similar alternative lies in the possibility of explosion or shattering on contact with the ground. This would leave fresh sur-

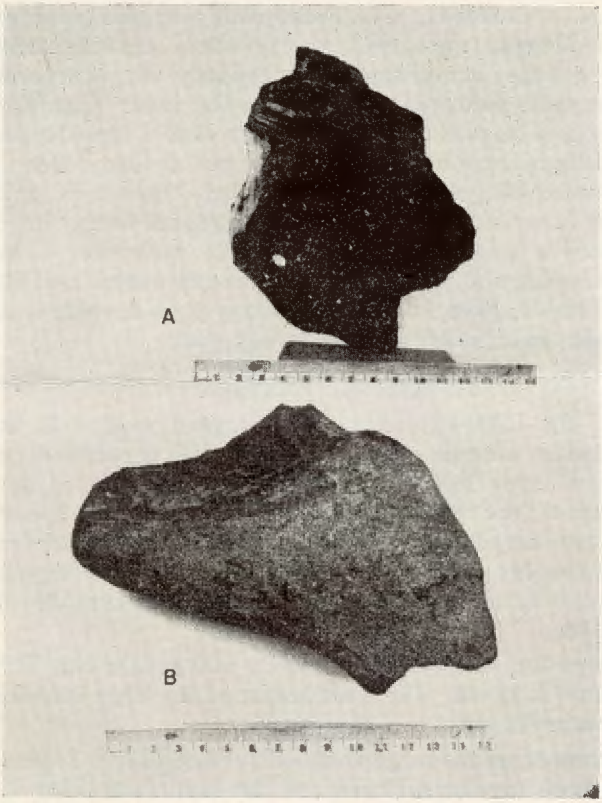

FIG. 1
THE LA LANDE METEORITE: A. SAWED SURFACE SHOWING DISPERSED METALLIC PHASE; B. EXTERIOR SURFACE

faces exposed to weathering forces and would produce an alteration differing from that on the pre-shattering exterior surfaces.

The interior of the stone, as exposed on the cut, is deep brownish-green, with scattered metallic nodules ranging from microscopic size to 6 mm. in diameter. A few of the larger metallic nodules show troilite surrounded by kamacite (Fig. 1A). Individual minerals are not generally distinguishable. An iron-oxide stain is seen to cause the reddish color of the exterior surfaces. This color extends only a very slight distance into the body of the stone; it is generally vanishingly small as viewed in cross-section, being at most only a few tenths of a millimeter thick. This iron oxide follows a few cracks into the interior of the stone to the full depth of the cracks. Within the oxidized portion of one small crack near the surface of the stone there appears to be a local concentration of extremely fine metallic particles. This is thought to be a "residual concentration," and indicates a profusion of fine metallic particles evenly distributed thruout the body of the stone.

No fusion rind is visible on macroscopic examination. Because it is not known how long this specimen had lain in the ground before its discovery in 1933, it seems entirely possible that such a feature may have weathered away. There is, however, no evident reason for postulating that such is the case.

Microscopic Examination

Thin-Section Analysis.—Thin-section analysis of the La Lande aerolite shows it to be composed of olivine and enstatite (variety, hypersthene), with a small percentage of enstatite-clinoenstatite intergrowths, secondary hematite, and opaque metallic grains. Under plane light, the minerals are seen to be strongly stained by an iron oxide, hematite. Because olivine is readily altered to hematite, it is believed that it, rather than the metallic phase or external causes, is the source of most of the

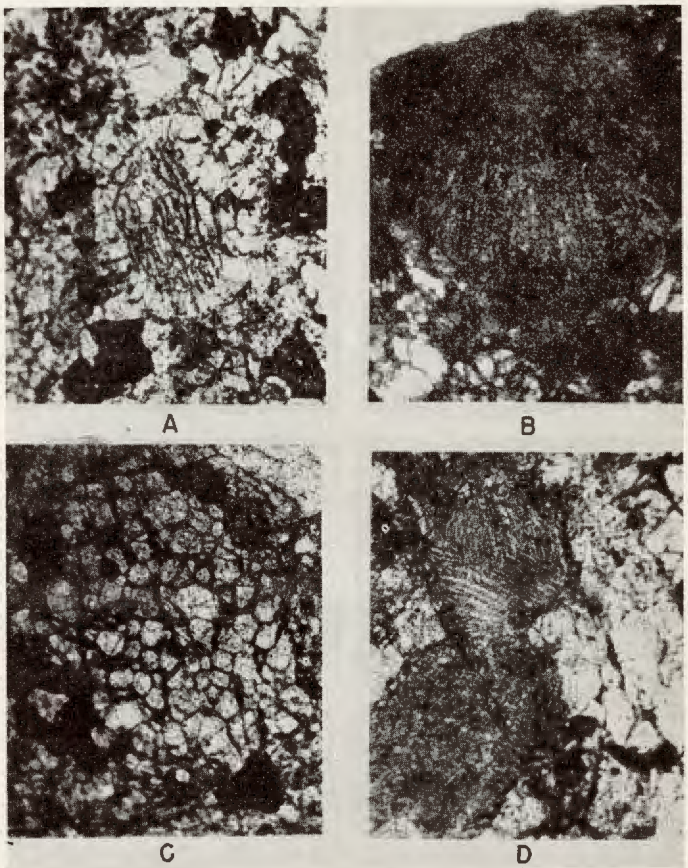

Fig. 2
Typical La Lande Chondrules (See text for Explanation.) × 100:

iron oxide. The alteration of hypersthene to iron oxide along cleavage planes also is evident.

Examination of the thin-section under crossed nicols shows that the forenamed 2 minerals are present in the proportions of about 40% olivine and 60% hypersthene. The grains of both minerals are generally fragmental, altho some subhedral and euhedral olivine grains were noted. At one place, several olivine grains appear to be set in a matrix of randomly oriented, fibrous hypersthene.

Many distinct chondrules, comprizing approximately 15% of the section, were noted. These are composed generally of globular aggregations of mineral particles, and may consist of one or several minerals. There is a wide range of internal structure. The majority of the chondrules noted in this section are composed primarily of small olivine fragments, generally with a small amount of hypersthene, and are mostly imperfectly developed (Fig. 2C). Examples of well-formed chondrules were noted, however. These are composed usually of a fibrous intergrowth of hypersthene and clinohypersthene, with a well-displayed radiate structure (Figs. 2B and 2D). The different character of the constituent minerals is shown by the inclined extinction of some of the radiating fibers as contrasted with the parallel extinction of normal hypersthene displayed by the rest of the fibers. A barred chondrule is illustrated in Fig. 2A. According to Merrill,[4] the barred forms are limited mainly, if not wholly, to monosomatic forms composed of olivine. The chondrule illustrated is, however, composed of hypersthene with alternating bars of iron oxide.

Oil-Immersion Analysis.—Altho the oil-immersion analysis was rendered more difficult than usual by the masking effect of the abundant iron oxide, it was possible to obtain detailed optical constants for the non-opaque minerals.

The olivine gave the following optical constants: $\alpha = 1.683$, $\beta = 1.702$, $\gamma = 1.721$; optical character, negative; axial angle, 85°; dispersion, $r < v$, weak; optical orientation, $X = b$, $Y = c$, $Z = a$; axial plane, {001}. These constants indicate an olivine with a molecular percentage of Fe_2SiO_4 equal to 24.2, and a specific gravity of 3.65. The corresponding percentage by weight of FeO is 22, and of MgO, 39.

The hypersthene gave the following optical constants: $\alpha = 1.704$, $\beta = 1.713$, $\gamma = 1.718$; optical character, negative; axial angle, 70°; dispersion, $r < v$, weak; optical orientation, $X = a$, $Y = b$, $Z = c$; axial plane, {010}. These constants indicate hypersthene with a molecular percentage of $FeSiO_3$ equal to 32.5, and a specific gravity of 3.45. The corresponding percentage by weight of FeO is 21, and of MgO, 24. The usually diagnostic pyroxenic prismatic cleavage {110} was seldom evident. The lower interference colors of the hypersthene provided the only easily discernible, distinguishing feature for differentiation between olivine and hypersthene under crossed nicols. No pleochroism, so characteristic of hypersthene, was noted, altho this may well have been present but masked by the omnipresent iron-oxide stain. Some of the hypersthene grains exhibited an undulatory extinction. This is probably an indication that these grains are under some strain.

Some shards of glass were noted in the oil-immersion analysis. The refractive index of this glass is 1.551. Some evidence of strain in the glass is the lack of complete extinction under crossed nicols. Because the glass could not be distinguished in thin-section, the relationship it bears to the other minerals of the meteorite could not be ascertained. According to Farrington,[5] meteoritic glass "abounds as inclusions and intergrowths in chrysolite [olivine], taking, in this association, a great variety of forms." This association is not, of course, universal. The occurrence of glass is taken as an indication generally of "a rapid crystallization or cooling of the meteoritic substance."[6]

FIG. 3
THE LA LANDE METEORITE: KAMACITE, GRAY; TAENITE, WHITE; AND PLESSITE, BLACK, SURROUNDING WHITE TAENITE. NITAL, 15 SEC. × 50:

Polished-Section Analysis.—A polished section of the La Lande meteorite was prepared and studied to obtain information relating to the metallic phase of the specimen. The section was etched with nital for 15 seconds to bring out the relationships of the components. A photomicrograph of a portion of this section is shown in Fig. 3 and demonstrates the relationship of kamacite, taenite, and plessite. The majority of the metallic nodules in the section consist entirely of kamacite. A very few show taenite and even fewer exhibit plessite. No troilite was noted in the section, but it can be seen occasionally, inclosed in kamacite, on macroscopic examination of the sawed surface of the large specimen (Fig. 1A). The metallic nodules can be seen to have a random distribution thruout the specimen.

Chemical Analyses

Quantitative chemical analyses of the metallic phase, the non-metallic phase, and the undifferentiated entirety of the meteorite were made and are shown in Tables 1 and 2. Molecular proportions of the metallic phase and a normative calculation of the non-metallic phase are shown in Table 2. It will be noted that the mineral diopside is in the normative calculation, altho that mineral was not found in the thin-section analysis; it is entirely a normative mineral, used to help explain the chemical analysis. Of course it is possible that diopside is present in the meteorite and was overlooked, but it is more probable that the Al_2O_3, CaO, K_2O, Na_2O, and MnO are present as isomorphic substitutes in the olivine and the hypersthene. These analyses are in agreement with the microscopic studies.

Table 1

Chemical Analysis of the La Lande Chondrite

	Percent
Silica, SiO_2	28.33%
Iron oxide, Fe_2O_3	31.20
Aluminum oxide, Al_2O_3	6.05
Calcium oxide, CaO	2.53
Magnesium oxide, MgO	24.81
Potassium oxide, K_2O	0.21
Sodium oxide, Na_2O	1.81
Nickel, Ni	1.42
Cobalt, Co	0.62
Manganese, Mn	1.01
Sulfur, S.	1.21
Chlorine, Cl	1.23
Titanium, Ti	0.00
Phosphorus, P	0.45
Carbon, C	none detected
Total	100.88%

TABLE 2
CHEMICAL ANALYSES OF THE METALLIC AND NON-METALLIC PHASES OF THE LA LANDE CHONDRITE

Metallic Phase	
Fe	88.08%
Ni	7.89
Co	0.64
P	0.47
S	1.22
Cl	1.34
C	0.00
Total	99.64%

Molecular Proportion: $\frac{Fe}{Ni} = 11.73$

Molecular Proportion: $\frac{Fe}{Ni + Co} = 10.86$

Non-Metallic Phase	
SiO_2	32.01%
Fe_2O_3	27.81
Al_2O_3	6.34
CaO	2.86
MgO	28.04
K_2O	0.20
Na_2O	2.05
MnO	1.14
TiO_2	0.00
C	0.00
Total	100.45%

Normative Calculation	
Hypersthene	42.17%
Olivine	41.20
Diopside	9.86
Hematite	6.77

Metallic Phase ....17.98% by weight
Non-Metallic Phase ......82.02% by weight

SUMMARY AND CONCLUSIONS

On the basis of the foregoing studies, we classify the La Lande meteorite as a hypersthene-olivine chondrite (Chy), following the Leonard classification.[7] The strong alteration of olivine to iron oxide is taken to indicate that the stone fell a considerable time prior to its discovery in 1933. In accordance with the "meteorite-planet" hypothesis originated in 1850 by Boisse, advanced independently by Farrington in 1901, and recently strongly supported by Brown[8] from thermodynamic considerations, this stone would have come from the exterior mantle of the hypothetical meteorite-planet. This conclusion is thought to be true because the meteorite-planet is supposed to have had a core of nickel-iron with a gradation to an exterior mantle of enstatite and olivine; therefore, the less the metallic phase present, the farther from the center of the planet did the meteorite have its origin.

It has been recognized at the University of New Mexico that the La Lande and Melrose meteorites are strikingly similar. Specimens of both stones are seen to possess an essentially identical overall color on cut surfaces—a deep brownish-green. The mineral composition of the non-metallic phase of both stones shows great similarity. The amount and the distribution of the metallic phase of both specimens, as shown on cut surfaces, reveal close similarity. Both meteorites exhibit the relatively unusual feature of macroscopically observable troilite nodules surrounded by kamacite. The only observable difference between the two meteorites is a difference in surface coloration, which might easily have arisen from dissimilar environmental circumstances after arrival on the Earth.

This paper represents part of a careful study that is being carried out by us, of the possibility that these two stones belong to the same fall. On the basis of the complete La Lande study and the studies already made on the Melrose aerolite, it is believed, at the present time, that La Lande is not a distinct fall, but is simply a member of the widely scattered Melrose shower. Since, according to Leonard,[9] the longitude of the Melrose find, to the nearest tenth of a degree, is + 103°.6, whereas that of the post office at La Lande, New Mexico, near which the La Lande specimen was found, is approximately + 104°.1, it follows that the linear extent of the Melrose strewn field is of the order of 28 miles, and hence that this fall is the most extensive of all the recognized meteoritic showers.

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