some material may have survived relatively unaltered, with only moderate shock damage. Petrographers should be on the lookout for xenoliths of "meteoritic" mineralogy.

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6. As emphasized by a referee, we cannot be absolutely sure that this is true. Perhaps the Ir, Re, and Au in Apollo 14 soil are indigenous and were depleted only by a factor of about 10^{-2} in the initial metal-silicate segregation on the moon that produced the pre-Imbrian crust. This seems rather unlikely because Ca-rich achondrites, representative of metal-silicate segregation on bodies smaller than the moon, typically are depleted in Ir by more extreme factors, 10^{-3} to 10^{-4} (J. C. Laul, R. R. Keays, R. Ganapathy, E. Anders, J. W. Morgan, *Geochim. Cosmochim. Acta*, in press). Lunar and terrestrial basalts show still greater depletions, by factors of 10^{-4} to 10^{-5}.
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29. We are indebted to astronauts Alan B. Shepard, Edgar D. Mitchell, and Stuart A. Roosa and the Lunar Sample Analysis Planning Team for providing the samples used in this study. Ursula Marvin and John A. Wood skillfully separated texturally well-defined samples from the lunar gravel. Sandra Cromartie did much of the literature research and provided overall coordination. Preparation of the report was materially aided by the splendid climate of the Engadine. This work was supported in part by NASA grant NGL-14-001-167. Some of the equipment used in this work was furnished by the AEC under contract AT(11-1)-382.

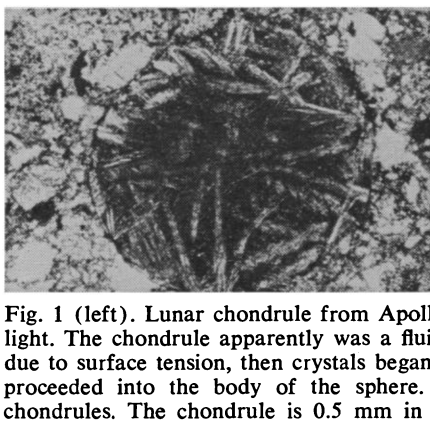
27 September 1971; revised 19 November 1971 ■

Chondrules in Apollo 14 Samples: Implications for the Origin of Chondritic Meteorites

Abstract. *Chondrules have been observed in several breccia samples returned by the Apollo 14 mission. These lunar chondrules are believed to have formed during a large impact event, perhaps the one that formed the Imbrian Basin. This suggests that some meteoritic chondrules are also formed by impact processes such as crystallization after shock melting and abrasion and diffusion in base-surge and fall-back deposits generated by impacts on planetary surfaces.*

Glass spherules, some of which are partially devitrified, have been observed in samples from Apollo 11 and 12 by previous investigators of lunar samples (*1, 2, 3*, and others). However, few of these spherules, if any, have the textures that are typical of most meteoritic chondrules. In some of the Apollo 14 breccias there are abundant spherical and rounded bodies with radiating lath-like crystals, brown turbid glass, aggregates of grains, and many of the typical textures of meteoritic chondrules (Figs. 1, 2, and 3). Lunar chondrules have been reported by Butler *et al.* (*4*), Kurat *et al.* (*5*), Fredriksson *et al.* (*6*), and von Engelhardt *et al.* (*7*).

Abundant chondrules and chondrule-like bodies have been observed in lunar samples 14313, 14318, and 14301, and



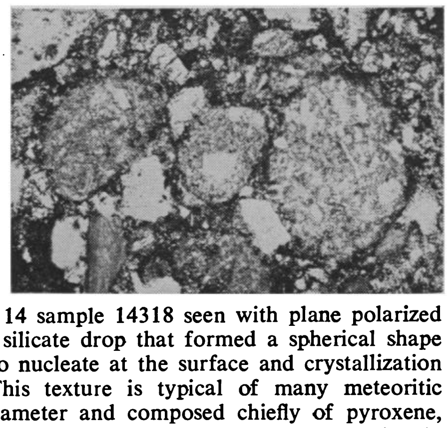


Fig. 1 (left). Lunar chondrule from Apollo 14 sample 14318 seen with plane polarized light. The chondrule apparently was a fluid silicate drop that formed a spherical shape due to surface tension, then crystals began to nucleate at the surface and crystallization proceeded into the body of the sphere. This texture is typical of many meteoritic chondrules. The chondrule is 0.5 mm in diameter and composed chiefly of pyroxene, plagioclase, and brown turbid glass. Fig. 2 (right). Three lunar chondrules in Apollo 14 sample 14313 seen in plane polarized light. These chondrules do not appear to have been fluid drops, but instead appear to be rounded rock fragments of both breccias and igneous rocks. These fragments may have been rounded by abrasion in the movement of the base-surge deposits from the Imbrian impact. The length of the field of view is 0.8 mm.

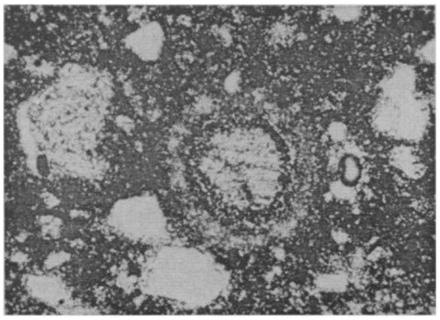


Fig. 3. Lunar chondrule (seen in plane polarized light) in an Apollo 14 sample similar to some chondrules found in primitive types of meteorites. This type of chondrule does not appear to be a rounded rock fragment or crystallized silicate droplet, but may be formed by diffusion around a rock fragment core rich in olivine in impact-generated base-surge or fall-back deposits that have cooled slowly. Length of the field of view is 0.8 mm.

rare to moderately abundant objects similar to chondrules have been found in samples 14305, 14306, and 14311. These samples are thought to be genetically different from the previously described samples from Apollo 11 and 12 mainly because they have been seriously shock metamorphosed by a large impact, probably the large impact that formed the Imbrian Basin (*8*). Although the use of the term "chondrule" for these objects causes some problems in nomenclature, this usage seems justified because of the extreme textural similarity of these objects with meteoritic chondrules. The Apollo 14 samples are the first naturally occurring materials, except for recognized meteorites, that have been observed to contain chondrules.

At least three mechanisms may exist for the formation of chondrules in large impacts: (i) impact melting, rapid cooling, and subsequent crystallization of silicate spherules (*9*) (Fig. 1); (ii) rounding of rock fragments by abrasion in base-surge deposits that result from impacts (Fig. 2); and (iii) diffusion around rock fragments and mineral grains in impact-generated base-surge and fall-back deposits that are at elevated temperatures (Fig. 3).

If these lunar chondrules have been formed by the mechanisms accompanying a large impact, then at least some, and perhaps many, meteoritic chondrules may have been formed by the same process. Thus, some fraction of the meteoritic chondrules, and hence some fraction of the chondritic meteorites, may have been formed by large impacts on the surface of medium to large sized terrestrial planetary bodies The production of chondrules and chondritic rocks may be an inescapable result of the terminal stages of accretion of silicate planetary bodies.

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X-ray Structure of Racemic Glycerol 1,2-(Di-11-bromoundecanoate)-3-(-p-Toluenesulfonate)

Abstract. *The single crystal x-ray structure of racemic glycerol 1,2-(di-11-bromoundecanoate)-3-*(p-*toluenesulfonate), a sulfolipid analogous to the membrane phospholipids, reveals a folded conformation.*

In our studies on the crystal and molecular structure of model compounds for biological membrane components, *rac* glycerol 1,2-(di-11-bromoundecanoate)-3-(*p*-toluenesulfonate), hereafter referred to as compound **1**, was synthesized. Compound **1** crystallizes as triclinic needles from a 50 percent (by volume) aqueous alcohol solution. The space group is *P*1 with cell constants $a = 8.070(2)$ Å, $b = 5.463(14)$ Å, $c = 40.91(9)$ Å, $\alpha = 93.23(9)°$, $\beta = 96.21(3)°$, $\gamma = 85.18(11)°$, cell volume $= 1782$ Å^3, $Z = 2$, $d_m = 1.39$ g cm^{-3}, $d_c = 1.396$ g cm^{-3}. The crystal structure was solved by the heavy atom method and refined by full matrix least squares to $R = 0.11$ (*1*) by use of three-dimensional x-ray diffractometer data.

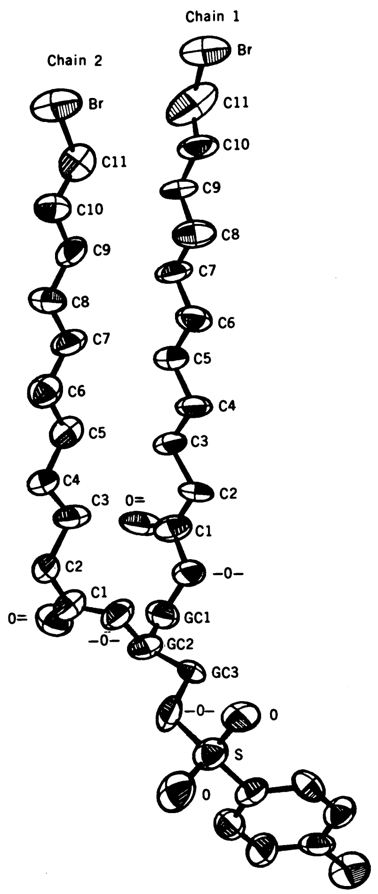

Fig. 1. The molecular structure of *rac* glycerol 1,2-(di-11-bromoundecanoate)-3-(*p*-toluenesulfonate) (**1**).

A folded conformation was found (see Fig. 1). The bond lengths and angles are within expected values (*2*).

The least-squares planes (*3*) for the two fatty acid chains intersect at a dihedral angle of 79°; the hydrocarbon subcell chain packing is the orthorhombic perpendicular type (*3*). The long molecular axes (*3*) of the two hydrocarbon chains are nearly parallel showing a slight divergence of 4.5° from the glycerol region toward the terminal ends. The fatty acid chain attached to carbon-1 of glycerol is slightly helical, having a pitch of about 160 Å. The polymethylene chain twists 30° between the carboxyl group and terminal end. In contrast, the fatty acid chain attached to carbon-2 of glycerol is planar (standard deviation = 0.04 Å) and exhibits no significant deviations from its least-squares plane. The conformation