GRAPHIC GRANITE FROM THE MOON

One of the most important rock types in Earth’s crust is granite. Most of the oldest rocks of Earth’s crust are granitic gneisses. Before the late sixties, there were many who believed that granitic rocks were predominant in the lunar crust. However, very few granites have been found among lunar samples, and until now they all have been either obviously polymict fragmental breccias (e.g., 12013c), or breccia clasts so small that they could easily be unrepresentative pieces of diorites. Even the tiny mesostasis portions of fine-grained basaltic rocks have been widely discussed under the heading of "lunar granites." Valuable information has been derived from such samples, but until now there have been no large, pristine lunar granite samples available for study. In the course of a survey of potentially, pristine clasts among Apollo-14 breccias, we recently discovered two pristine granites, one of which is "large" by lunar sample standards. At present, a chemical analysis is available only for the "large" granite clast C11, so in this abstract we will focus most of our attention on it.

14321,1027 The "large" (1.9 g) granite is one of the hundreds of diverse clasts which occur in breccia 14321 (alias "Big Bertha"). It outcrops over a 16 x 7 mm area of the breccia's surface. It is a granite in the strictest sense of the word. Not counting the portion that is shock-melted glass (about 30%), about 60% of the combined area (about 25 sq. mm) of our three thin sections is K-feldspar, 40% is silica, as one of several different polymorphs, and less than 1% is Fa98 olivine. However, the norm of the analysis of C11 of the clast contains 3.6% ferrosilite, so apparently the overall clast is somewhat more Fe-rich than the thin sections indicate. The silica polymorphs are roughly 75% quartz, 20% a phase that is biaxial, and hence possibly tridymite (however, it seems to have a higher birefringence than tridymite), and (5% a low-birefringence, uniaxial(-) phase, probably cristobalite. Also present are traces of ferrohedenbergite, ilmenite and Fe-metal. The K-spar averages Or(89)Ab(11), with 0.5% BaO. The metal averages only 0.3% Co and 0.1% Ni.

The clast is clearly pristine, judging from its low Au concentration [11], its nonmeteoritic metal composition, and despite the high content of shock-melted glass, also by virtue of its texture. In the less severely brecciated portions of our thin sections the original igneous texture is plainly visible (Fig. 1). In such areas, the K-spar and the silica are generally found in large intergrown crystals --- i.e., the texture is "graphic." The scale of these intergrowths is noteworthy. The largest and best known lunar granites until now were several clasts from 15405 (6 x 2 mm and 3 x 2 mm), the 0.02 g felsite clast from 73215, and the adulterated granite that is a major component of the large but obviously polymict breccia 12013. The original texture of the 12013 granite is totally obscured. There are K-spar-silica intergrowths in the 15405 and 73215 clasts, but in the 15405 clasts their scale is only "on the order of a few microns" [23], and in the 73215 felsite their scale is only 10-20 microns [31]. In our 14321,1027 thin sections crystals of both K-spar and quartz are in optical continuity as much as 1.8 mm apart, and the width of the silica blebs inside the K-spar averages about 0.15 mm.

A controversy has long raged over whether the parent liquids of lunar granites formed by crystal-liquid fractionation or by liquid immiscibility. As Fig. 2 shows, the granitic materials from 12013, 14321, and 73215 all are quite similar to one another (even though 12013c is definitely nonpristine, and 73215c is very tiny and very severely shock-melted), and all three are quite dissimilar to the most abundant incompatible-element-rich lunar rock type, KREEP. Due to its high K/REE ratio, the felsite's analysts [41] concluded that it is a product of liquid immiscibility. The K/REE ratio of 14321,1027 is even higher than that of 73215c, it also has unusually high Rb/REE and Cs/REE ratios (G.W. Kallemeyn, unpublished data), and based on the
complete absence of apatite in our thin sections, an unusually low P/REE ratio, all of which also suggests that liquid immiscibility played a part in its formation. However, as Fig. 2 shows, all three clasts in question (particularly the pristine one, 14321~) also have exceptionally high U/REE, Th/REE and Sm/Eu ratios, which should be low in a granitic immiscible melt, based on the theory that the charge density of a cation can serve to predict its liquid-liquid distribution coefficient ($f_5, 61$). Either this theory is very imperfect, or the composition of 14321,1027, at least, is not due directly to liquid immiscibility.

14303,204 This clast was found as an 11 x 6 mm outcrop on breccia 14303. It is not very thick, and its mass is estimated to be only 170 mg. The content of our 12 sq. mm thin section (not counting shock-melted glass, which amounts to about 50%) is roughly 45% K-spar, 30% quartz, 20% plag., 4% high-Ca pyroxene, 1% ilmenite, plus traces of zircon, Fe-metal, trolite, apatite and olivine. The olivine, Fo(41), occurs as a single 15 x 7 um crystal, suspiciously situated in a severely shock-melted area along the edge of the section; we doubt that it is indigenous to the clast. However, everywhere else in the section the lithology appears to be monomict (pristine), and the nonmeteoritic composition of the metal (avg. Ni = 0.92%, max. = 2.8%) seems to confirm this. The K-spar is very rich in BaO (avg = 3.2%) compared to the K-spar of 14321,1027. One large plag. grain is highly zoned, from An(83) at the core to a "ternary" composition, An(21) at the rim. Very similar zoning occurs in some of the 2 mm sized Apollo-17 granitic clasts described by (7). The pyroxene occurs mainly as a single 0.8 x 0.4 mm crystal, which is also zoned, from En(31)Fs(23)Wo(46) to En(20)Fs(36)Wo(45). In places, this clast, like 14321,1027, still retains clear vestiges of its original igneous texture. Essentially intact crystals are up to 2 mm across. There are several relatively mildly shocked areas where K-spar and quartz occur as graphic intergrowths, exactly the way they do in 14321,1027, except at a scale only about half as coarse.

Most terrestrial graphic granites are found in pegmatites, which typically contain evidence of abundant crystallization from volatile-rich fluid phases. Many of the various hypotheses for the origin of the texture (reviewed by (83)) emphasize the importance of solid-liquid-vapor interactions. Yet these first two reasonably "large" lunar granites both feature classic graphic granite texture, and neither appears to bear the slightest evidence of crystallization from a hydrothermal fluid (e.g., none of the mafic phases are hydrous; no fluorine-rich phases are present).


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