LUNAR GRANITE CLASTS WITH UNIQUE TERNARY FELDSPARS, Douglas B. Stoesser, Graham Ryder, and Ursula B. Marvin, Center for Astrophysics, Harvard College Observatory and Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, Massachusetts 02138

Detailed study of four samples (72215, 72235, 72255, 72275) taken from Boulder 1, Station 2, Apollo 17, a KREEPy, low-grade, fragmental breccia, shows that one of the most distinctive features of the latter is the occurrence of numerous clasts of granitic composition (1,2). These are common in samples 72215 and 72235, constituting about 5% of the clast population (>0.2 mm) overall, and up to 23% in one portion of 72215. In 72255 and 72275 granitic clasts are sparser, averaging only about 1-2% of the clast population. In all samples these clasts are small; the largest observed is 2 mm and most are less than 0.5 mm.

We have classified the granitic clasts as holocrystalline or glassy, and as mafic or non-mafic. The mafic-free varieties are mineralogically simple, containing only a silica mineral (apparently cristobalite) and two types of feldspar: barian K-spar (1.1-3.6 wt. % BaO), and a unique type of ternary feldspar described below. The mafic-bearing granites are more complex, containing barian K-spar, plagioclase (zoned to ternary feldspar), various iron-rich pyroxenes (Fig. 1A), olivine (Fo~75, Fig. 1B), ilmenite, troilite, Fe-metal, whitlockite (~10-12 wt. % REE oxides), and zircon. Texturally, the holocrystalline varieties commonly consist of an intergrowth of parallel plates of silica, often optically continuous, embedded in grains of subpuikilitic to poikilitic potash feldspar that may be >0.5 mm in dimension. The glassy granitic clasts can be subdivided into two main types on the basis of mineralogy. The first type consists of silica, usually occurring as sets of subparallel plates, in a matrix of pale brown glass. This type appears to be the melt equivalent of the mafic-free holocrystalline variety. The second type of glassy clast consists of mafic silicates, commonly quench-textured augite, various opaques, and sparse large plagioclases (phenocrysts)?, set in a glassy groundmass. We assume that some clasts have experienced different cooling histories than others because of the occurrence of augite-pigeonite pairs and subcalcic augite with similar Mg/Fe ratios (Fig. 1A). A sparse subvariety of the second type of glassy clast occurs as glasses so densely charged with very fine opaques (mainly sulfide) that they appear nearly opaque in transmitted light.

The granite clasts from all four samples contain "ternary feldspars" that we believe have not been reported previously. They are intermediate in composition between orthoclase and anorthite and have a minor albite content. There are two types of occurrence of these ternary feldspars: (1) in mafic-free holocrystalline clasts and (2) as zones on large plagioclases. In (1) these feldspars appear to be quite uniform in composition (~An~0.3Or~0.3Ab~0) in any particular clast (Fig. 2A). In (2) they usually occur as a narrow rim (<20 µ) on plagioclase where it is adjacent to the granitic groundmass, and show a continuous change in composition from normal plagioclase values to a ternary feldspar composition with maximum orthoclase content of An~0.3Or~0.3Ab~0 (Fig. 2B, C).

Optically the ternary feldspars appear homogeneous. The plagioclase of the second type of feldspar typically shows polysynthetic (albite) twinning and contains abundant small (<1 µ) inclusions. A few granitic clasts contain a perthite-like intergrowth consisting of fine, parallel, intercalated lamellae of K-spar and plagioclase (Fig. 2A). These intergrowths could represent either mixing of the two or primary intergrowths. Although we presently have no direct evidence, we suggest that the ternary feldspars may be submicroscopic epitaxial intergrowths of K-spar and plagioclase rather than a single homogeneous feldspar. Since disequilibrium growth is suggested by
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their compositions, perhaps they formed as a result of super-saturation in a viscous silicic melt.

The Boulder 1 granites are chemically similar to other granitic clasts and veins found in Apollo 12, 14, and 15 breccias, although they seem to have less sodium than these others (3, 4, 5, 6). As might be expected from their mineralogy, the mafic-free granitic clasts of Boulder 1 are essentially devoid of anything but SiO2, Al2O3, CaO, K2O, and BaO. The mafic-bearing granitic clasts are not only richer in FeO and MgO than the mafic-free clasts, but also contain more P2O5, TiO2, and S. FeO shows a positive correlation with K2O (Table 1). It seems possible that the mafic-bearing granitic clasts are either somewhat less fractionated than the mafic-free clasts or are contaminated by mafic material with a very high Fe/Mg ratio. Because of the small size of most of the clasts, it is difficult to be sure that analyses of them are truly representative, but on the whole the granitic clasts of Boulder 1 tend to cluster in the region of the eutectic in the system KA1Si2O9-CaAl2Si2O8-SiO2, which has the approximate molecular proportions 3An:4:SiO2:56Or (7).

A number of workers have noted a positive correlation between the amount of granitic material and the KREEP content of Apollo 12, 14, and 15 breccias, and have hypothesized that lunar granite in general is a late-stage fractionation product of KREEP magma, possibly involving liquid immiscibility. There is little direct evidence for an immiscibility origin (8) other than the low P2O5 content of the Boulder 1 granitic clasts. In Boulder 1, as in other granite-bearing breccias, granites occur as isolated clasts and cannot be directly related to any other lithology. The notion of a KREEP parentage is supported by the occurrence of relatively large potassic plagioclases and iron-rich pyroxenes (largely augitic). In addition, Boulder 1 contains a number of clast lithologies which might be related to the plutonic crystallization of KREEP magma, for example bimineral (cumulate?) norites and iron-rich ilmenite KREEP microgabbros (1, 2). Because the clasts of Boulder 1 are generally smaller than 1 mm, coarse KREEP fractionates (which would occur mainly as large monomineralic fragments) are difficult to detect. The abundance and ubiquitous distribution of the granitic clasts in the Boulder 1 samples strongly suggests that significant amounts of granitic material existed in the portion of the crust from which the boulder was derived.

References

Fig. 1. Compositions of pyroxene and olivine from mafic-bearing granitic clasts. As pyroxenes quadrilateral. Pyroxene from individual clasts are enclosed by field boundaries. Quenched pyroxene are indicated by dashed lines. The lines are also shown for clasts with a large range of compositional line showing the range of composition for olivine from three different clasts.

Table 1. Electron microprobe defocused-beam analyses of representative granitic clasts. Analysis numbers in the key below indicate the sample, split (thin section), and clast no. (e.g. 15-180-9 indicates sample 72215-thin section-18-clast 9).

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Table 2. Compositions of the ternary fields as plotted on the An-Or-Ab diagram. A: Type 1 ternary field; (chief) by point; and first analyses of the An-Or-Ab components (indicated by pluses). B and C: Going trends for two type 2 ternary fields.

Key to Table 1:
1. 15-180-9, mafic-free holocrystalline granite (av. of 20 100x DBAs).
2. 15-180-7, mafic-free holocrystalline granite (av. of 19 100x DBAs).
3. 55-95-33, mafic-free holocrystalline granite, composed of silica plus ternary feldspar (av. of 21 250x DBAs).
4. 55-95-3, mafic-free glassy granite, composed of silica plus glass (av. of 9 100x DBAs).
5. 15-180-19, mafic-bearing holocrystalline granite, with 350x zoned plagioclase (not included in analysis) (av. of 11 100x DBAs).
6. 15-180-22, mafic-bearing holocrystalline granite, with 400x zoned plagioclase (not included in analysis) (av. of 11 100x DBAs).
7. 15-180-11, mafic-bearing glassy granite, with quench augite (av. of 18 100x DBAs).
8. 15-180-10, sulfide charged quench granite (av. of 13 100x DBAs).
9. 55-95-2, mafic-bearing, partially devitrified glassy granite with quench augite (av. of 44 100x DBAs).
10. 15-180-19, sulfide charged quench granite (av. of 3 100x DBAs traverses).