TWO APOLLO 12 GRANITE ROCK FRAGMENTS: EVIDENCE FOR THE PROXIMAL COEXISTENCE OF HIGH-TH IMPACT MELT BRECCIA AND GRANITE. S. M. Seddio, R. L. Korotev, and B. L. Jolliff. Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, Missouri 63130 (sseddio@levee.wustl.edu).

Introduction: Lunar granites represent the end-stages of lunar magmatism and give insight into geologic processes occurring at that time. Granite (felsite) is also one of the rare lithologies among lunar samples, and it is therefore important to characterize unstudied lunar granites to better understand their petrologic diversity and relationships. Samples 12023,147-10 (2.7 mg) and 12001,909-14 (7.0 mg) are granitic lithic fragments from the Apollo 12 regolith (Fig. 1). The former is a monomict rock fragment with a granitic composition and mineral assemblage, and the latter is an impact-melt breccia with granitic clasts. Textural and mineralogical similarities warranted investigation as to whether and how these samples might be related.

Methods: 12023,147-10 and 12001,909-14 are part of a set of 400+ 2-4 mm lithic fragments from the Apollo 12 regolith [1]. The bulk compositions (trace elements and several major elements) were determined by INAA (instrumental neutron activation analysis) and by modal recombination for major elements not determined by INAA. Phase compositions were determined by qualitative and quantitative analyses of minerals and glasses and with back-scattered electron (BSE) and X-ray image analyses with an electron microprobe.

Table 1. Modal mineralogies.

Phase	12023, 147-10	12001, 909-14
K-feldspar	45.5	26.2
Silica	36.9	21.9
Plagioclase	14.0	26.4
Pyroxene	2.3	23.0
Olivine	0.8	Abs.
Ilmenite	0.4	0.9
Zircon	Trace	~1
RE-Merrillite	Trace	Trace
Yttrobetafite	Trace	Trace
Thorite	Trace	Abs.
Fe metal	Trace	Abs
Monazite	Trace	Abs.

All values are in vol%.

12023,147-10 consists of ~80% granophyric intergrowths of K-feldspar (Fig. 2) and silica and ~15% granophyric intergrowths of plagioclase and silica. The remainder is composed of hedenbergite (Fig. 4), fayalite ($Fo_{4\text{-}7}$), and ilmenite (modal abundances in Table 1) with trace amounts of zircon, RE-merrillite, yttrobetafite, thorite, Fe metal, and one grain of monazite. There is no evidence of meteoritic contamination (Au, Ir are below INAA detection limits) or brecciation. The Fe metal has a very low content Ni (EDS). It occurs either as rounded grains or vermicular intergrowths with silica and plagioclase.

The thorite in granite 12023,147-10 is the first to be quantitatively reported from any lunar sample and is the subject of another abstract at this conference [2]. The abundance of Th, U, and radiogenic Pb in the thorite, yttrobetafite, and monazite allow us to calculate an age of ~3.88 Ga [2].

12001,909-14 is a breccia consisting of 32% sub-rounded granite clasts, 23% rounded basalt clasts (two), and 45% plagioclase, pyroxene and ilmenite fragments in a granitic matrix.

The granite clasts contain 35% K-feldspar, 34% silica, 23% plagioclase, 4.2% high-Ca pyroxene, 2.5% low-Ca pyroxene, 1.2% ilmenite, and ~1% zircon and are petrographically dominated by granophyric intergrowths of K-feldspar and silica. The largest basalt clast contains 37% plagioclase, 27% low-Ca pyroxene, 16% high-Ca pyroxene, 13% K-feldspar, 4.8% silica, 1.1% ilmenite, 1.1% phosphate, and trace zircon. The smaller basalt clast contains 34% plagioclase, 29.5% K-feldspar,19% low-Ca pyroxene, 11% high-Ca pyroxene, 4.5% silica, and 2% ilmenite with a typical grain size of 5 µm. The remainder of the sample contains 43% plagioclase, 23% silica, 12% K-feldspar, 10% high-Ca pyroxene, 8.3% low-Ca pyroxene, 2.3% ilmenite, 1.2% RE-merrillite, and 0.2% ilmenite. 2.4% of this portion of the sample contains a large (0.2 mm; Fig. 1) fragment of high-Ca pyroxene.

K-feldspar (Fig. 2), plagioclase, low-Ca pyroxene, and high-Ca pyroxene (excluding the highlighted fragment in Fig. 1) compositions have no discernible differ-

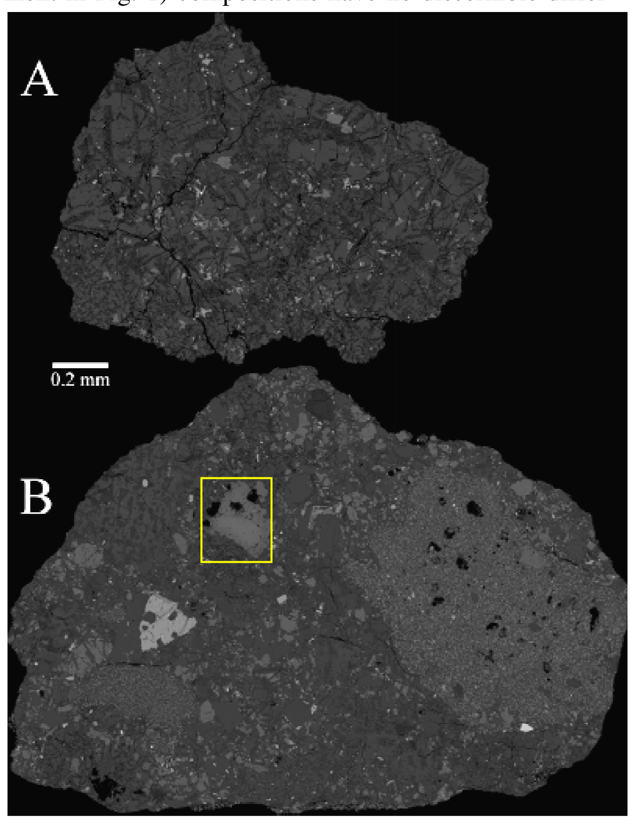

Figure 1. BSE images. **A:** 12023,147-10. **B:** 12001,909-14. Yellow box in B highlights a zoned high-Ca pyroxene that has a hedenbergite core

ences regardless of whether they occur in granite clasts, basalt clasts, or the matrix.

Chemical relationship: If we assume that the breccia as a simple 2-component mixture of the granite and a basaltic component, then the basaltic component must be rich in incompatible elements (Fig. 5). No mare basalt has the implied composition of the high-Fe component. Among KREEP basalts and KREEP-rich impact-melt breccias, only the high-Th impact-melt breccias of Apollo 12 and lunar meteorite SaU-169 [1,3] have major, minor, and trace element concentrations (specifically the REEs) that fit as the non-granitic component of 12001,909-14 (Fig. 5).

Petrologic relationship: Sample 12001,909-14 can be explained as an impact-generated mixture of 12023,147-10 and a significantly more Mg-rich lithology. The large pyroxene fragment of 12001,909-14 (Fig. 1) exhibits zoning with an Fe-rich core (Fs$_{\sim49}$Wo$_{\sim41}$) and an Mg-rich rim (Fs$_{\sim27}$Wo$_{\sim39}$). The composition of the core is identical to the hedenbergite of 12023,147-10,

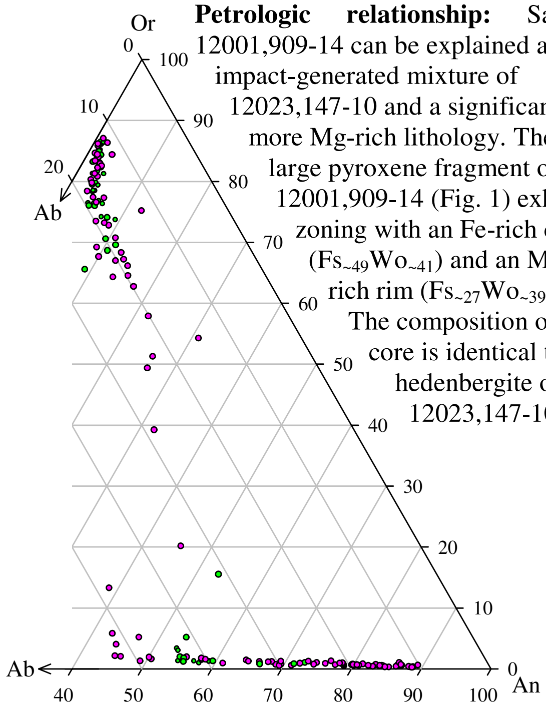

Figure 2. Feldspar compositions in 12023,147-10 (green) and 12001,909-14 (pink).

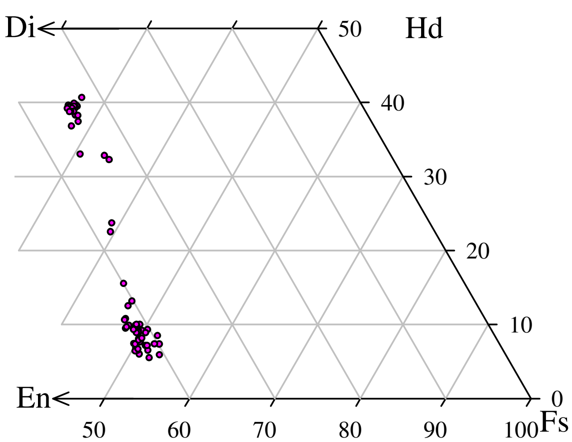

Figure 3. Pyroxenes in 12001,909-14 (pink) excluding the large hedenbergite clast. The two clusters represent exsolution in the pyroxene. Points that lie between the clusters are a result of beam overlap of lamellae.

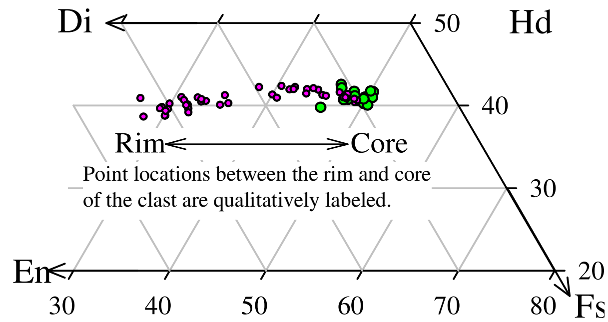

Figure 4. Pyroxene compositions in 12023,147-10 (green) and the large hedenbergite clast in 12001,909-14 (pink).

whereas the rim composition is identical to the other high-Ca compositions of 12001,909-14. The sample must have been heated sufficiently for the hedenbergite and fayalite of the granitic portions to equilibrate with the Mg-rich component. The large, zoned pyroxene was too large to equilibrate as did the other pyroxene grains in the granitic assemblage. The olivine in the granitic clasts would be unstable in the presence of silica after it became more Mg-rich. This process accounts for the presence of low-Ca pyroxene in the granitic clasts of 12001,909-14 but its absence in 12023,147-10.

Conclusions: 12001,909-14 is a granitic impact melt breccia in which the granitic component is that of granite 12023,147-10 on the basis of the striking similarities of their mineral chemistries and textures. The non-granitic component of 12001,909-14 petrographically appears to be basalt; however, the REE concentrations of 12001,909-14 are too high for the breccia to be a mixture of granite and any known lunar basalt (KREEP or otherwise). The best fit for all measured oxide and element concentrations of the non-granitic component is the high-Th impact melt breccias [1]. The breccia became hot enough that the hedenbergite and fayalite of the granite completely equilibrated with the other, significantly more magnesian component (leaving only the core of the largest hedenbergite grain to its original composition). 12001,909-14 implies that its source region must be composed of coexisting granite and high-Th impact melt breccia (or perhaps the parent lithology of the Apollo 12 impact melt breccias). We can also infer that 12001,909-14 is younger than 3.88 Ga.

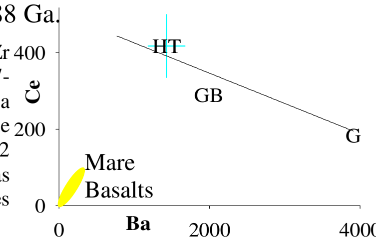

Figure 6. Bulk Ce and Zr (ppm) of granite 12023,147-10 (G), granitic breccia 12001,909-14 (GB), and the average of the Apollo 12 High-Th impact breccias (HT) [3]. Blue lines represent one standard deviation of High-Th impact melt breccia samples [1,3]. The yellow region represents the range of compositions of lunar basalts. Labels represent the data.

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