NEW COMPOSITIONAL DATA FOR APOLLO 12 SAMPLES 12013 and 12033: INSIGHTS INTO PROTO-LITHOLOGIES. S. N. Valencia[1], B. L. Jolliff[1], R. L. Korotev[1], and S. M. Seddio[2], [1]Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri, 63130 (svalencia@levee.wustl.edu), [2]Thermo Fisher Scientific, 5225 Verona Rd, Madison, WI, 53711.

Introduction: Granite is one of the rarest lithologies on the Moon [1]. Lunar granite is thought to have formed as a product of SLI (silicate liquid immiscibility) [2]. Also, it is known that there is both a spatial and a chemical relationship between lunar granite and KREEP [3,4]. In order to extend our knowledge about lunar granitic systems, we obtained compositional data by INAA (instrumental neutron activation analysis) for two granite-rich Apollo 12 samples, 12033 and 12013.

Samples: Sample 12013 is a unique sample within the Apollo sample collection and has been extensively studied [e.g. 5,6,7]. 12013 is an 82.3 g mingled mixture of two polymict breccias, a black breccia and a gray breccia, each generated by impact. Historically, the black breccia has been described as being composed predominately of norite rocks, quartzofeldspathic rocks and plagioclase fragments, and has a groundmass similar in composition to KREEP basalt. The gray breccia has historically been described as being composed predominately of basalt and gabbro fragments and a granitic lithology. Granitic material occurs in both the black and gray breccias, although it is much more common in the latter, in which it forms in large patches [7]. Understanding the relationship between the different lithologies of 12013 is important because these lithologies are juxtaposed in a rock created by impact. As such, there was a spatial relationship among proto-lithologies, and possibly a petrogenetic relationship as well [7]. We were allocated 1.6 g of material from 12013.

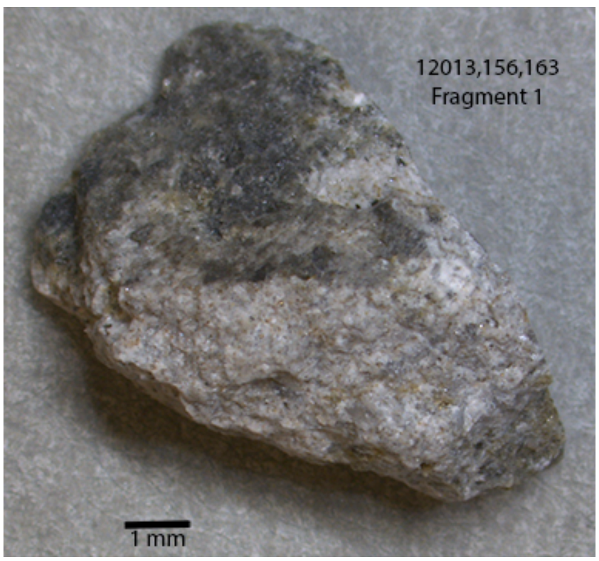

Figure 1. A large fragment from sample 12013,163, showing mingled black and gray breccias. This fragment was subdivided into six subsamples for INAA.

Sample 12033 is a 450 g trench soil collected from 15 cm below the surface near the rim of Head Crater [8]. Compared to most other Apollo 12 soils, it contains a greater proportion of nonmare material, mainly KREEP impact-melt breccias, alkali anorthosite, norite, granite, and quartz monzogabbro [10]. We analyzed 9 hand-picked fragments (seeking likely nonmare lithologies) from 12033,654 and 12033,655 (10–45 mg) for this study.

Methods: Samples 12013,163 and 12013,161 are from the main mass of 12013. Six of the INAA subsamples come from the same fragment of 12013,163 (designated “Fragment 1”, Fig. 1) and are therefore known to be spatially related. All samples were photographed and sub-split into samples ~3–45 mg in mass. Trace elements and some major elements were measured by INAA.

Results and Discussion: Sample 12013 is a complex, multicomponent rock. Despite extensive study on this sample, some parts of 12013 remain not well understood, particularly the mafic portion.

Compositionally, 12013 is composed of at least three lithologic components, which, in turn, make up the black and gray breccias: granite (red squares in Fig. 2), impact melt (blue squares in Fig. 2), and a mafic component (purple squares in Fig. 2). There is a mixing trend between the granitic component and the mafic component, and also between the impact melt and the mafic component. There appears to be no mixing between the granitic and the impact melt components within the 12013 breccia (Fig. 2A). Notably, there is not an alkali anorthosite component to 12013; Na_2O concentrations are < 2.5 wt.% for all samples.

One of the major components of the 12013 breccia is granite. This granitic component has low La and high Ba concentrations (Fig. 2A). Lunar granites are typically enriched in Yb relative to La [3], which is the case for these 12013 granitic samples (Fig. 2B). The granite portion of 12013 deviates from the KREEP line, representing the separation of the K-fraction of KREEP during SLI, as described by [11,12]. Elements that are partitioned into the K-fraction of 12013 include K, Rb, Cs, Ba, Ta, Th, and U.

The complementary REE-rich fraction to the granitic portion is represented in the impact melt component of 12013. This fraction includes the REEs and Sr. This fraction follows the KREEP line (Fig. 2). Compositions that fall along the KREEP line represent mixing of rocks that have varying amounts of KREEP. The impact melt component is high in La and comparatively low in Ba concentrations (Fig. 2A). This component most likely represents the impact melt that comprises the black breccia groundmass.

The third component of 12013 is a mafic lithology. It is likely that a portion of the mafic lithology of 12013 is mare basalt. The mafic component also deviates from the KREEP line, having an enrichment in Yb relative to La (Fig. 2B). In basalt, the deviation is caused by LREE (light rare-earth elements) depletion relative to HREE (heavy rare-earth elements). In addition, FeO concentrations in the mafic portion of 12013 trends towards that of mare basalt (Fig. 2C). If modeled using Apollo 12 basalt compositions, the "mafic component" of 12013 is composed of ~40% granite, ~20% KREEP IMB (impact melt breccia) and ~40% mare basalt.

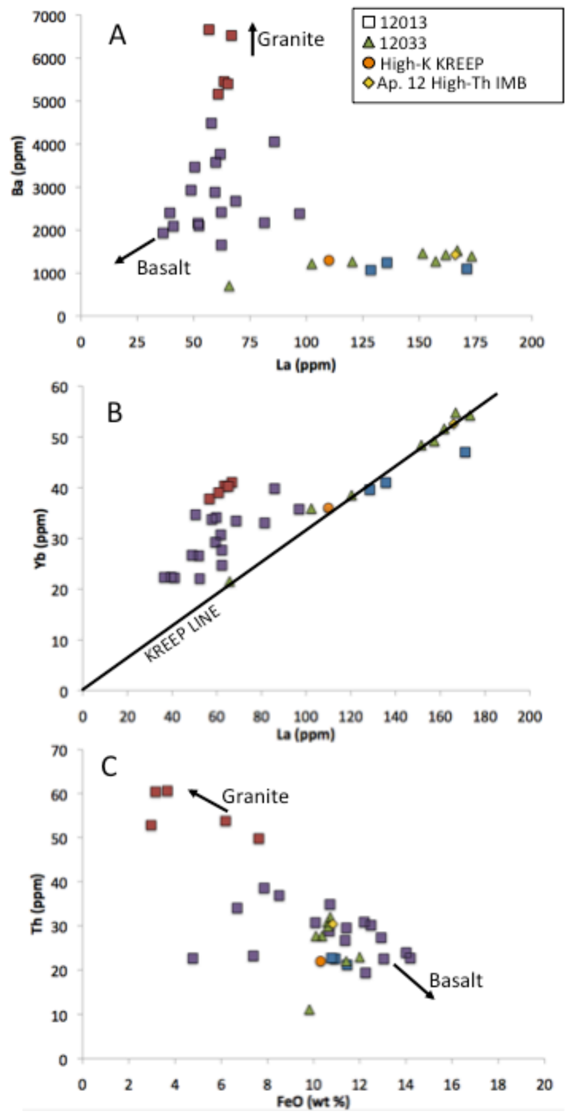

Figure 2. Element plots for 12013 and 12033 samples. 12013 samples are categorized into three colors—red to denote the granitic component; blue, the "REE-fraction"; and purple, the mafic component. Apollo 12 high-Th IMB [10] and high-K KREEP [13] are also included for comparison. A. La-Yb plot, which shows deviation from the KREEP line for the granitic and mafic components of 12013. B. La-Ba plot, which shows the 3-component mixing system of 12013, and the deviation from the KREEP line for the granitic and mafic components. C. FeO-Th plot, which shows the separation of the granitic component with high Th and low FeO, as well as the trend toward basaltic FeO concentrations of the mafic component (purple squares).

The 12033 samples are typically similar to the impact melt end-member data from 12013, either clustering with, or falling along the same trend as the 12013 impact melt component data. However, there are some differences between the two samples. For example, the mafic component of 12013 is higher in Na_2O than 12033. The tightest cluster of 5 samples of 12033 has an average composition similar in most elements to that of Apollo 12 high-Th IMB, computed by [10].

Much of the data for 12013 and 12033 are well-correlated. Highly correlated elements allow us to determine which elements separated in into the K-fraction and REE-fractions of 12013. K_2O is well correlated with Rb (R^2 = 0.94), Cs (0.95), Ba (0.90), Th (0.86) and U (0.90). Sc correlates well with FeO (0.92). Sr is correlated with the REEs Nd (0.75), Sm (0.75), Eu (0.88), and Tb (0.75). With the exceptions of Yb and Lu, the REEs are all well correlated to each other (0.75-1.00). Meteoritic contamination occurs mainly in the IMB (up to 7.4 ppm Ir in 12013 and 8.5 ppm Ir in 12033).

Conclusions: This data set provides key information about the components of the 12013 system. The 12013 system can be broken down into at least three end-member compositions—a granitic component (the K-fraction), a REE-rich impact melt, and a mafic component. A mixing model shows that the mafic component of 12013 is ~40% granite, ~20% KREEP IMB and ~40% mare basalt.

This new data set gives valuable insights into a granitic system on the Moon. Lunar granitic materials represent evolved magmatic fractionates. Understanding the formation of granite and its related lithologies will improve our knowledge of volcanic processes on the Moon.

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