A RENEWED SEARCH FOR ELUSIVE LUNAR GRANOPHYRES.

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Introduction: Recent remote sensing studies [e.g., 1-3] indicate that several un-sampled regions of the Moon have significantly higher concentrations of silicic material (also high in [K], [U], and [Th]) than sampled regions. Within these areas are morphological features that are best explained by the existence of chemically evolved volcanic rocks. Observations of silicic domes [e.g., 1-5] suggest that sizable networks of silicic melt were present during crust-formation. Because of these recent findings there is a renewed interest in the petrogenesis of lunar, felsic igneous rocks. Specific questions are: (1) when were these magmas generated?, and (2) what was the source material?

The two main hypotheses for generating silicic melts on Earth are fractional crystallization or partial melting of preexisting crust. On the Moon silicic melts are thought to have been generated during extreme fractional crystallization involving end-stage silicate liquid immiscibility (SLI) [e.g. 6, 7]. However, SLI cannot account for the production of significant volumes of silicic melt and its wide distribution, as reported by the remote global surveys [1, 2, 3]. In addition, experimental and natural products of SLI show that U and Th, which are abundant in the lunar granites and seen in the remote sensing data of the domes, are preferentially partitioned into the depolymerized ferrobasaltic magma and not the silicic portion [8, 9]. If SLI is not the mechanism that generated silicic magmas on the Moon then alternative processes such as fractional crystallization (only crystal-liquid separation) or partial melting should be considered as viable possibilities to be tested.

Fractional crystallization of a basaltic source without SLI is an inefficient process for generating silicic melts. This is because the distilling process must proceed to completion, which is physically difficult in terms of the degree of crystallization. For example, on the Moon a basaltic magma with K_2O/CaO of ~0.03 must fractionate to that of a granite (e.g., ~7 like the granite clasts contained in Apollo breccias 14321 and 14303). Chemical modeling [10] suggests it is unlikely that fractional crystallization alone can produce K/Ca ratios greater than 0.2. Likewise, segregation and extraction of highly-polymerized viscous melt from a highly crystalline mush is nearly impossible without strong external forces [11] (e.g., gravitational and/or secondary impacts).

Because it is difficult to produce such chemically “evolved” melts solely by fractional crystallization, partial melting of preexisting crust may also have been important and possibly the primary mechanism which produced the silicic magmas on the Moon. Terrestrial studies (e.g., [12]) demonstrate that partial melting of gabbroic rock under mildly hydrated conditions can produce granitic compositions and it has been suggested by [1] that partial melting by basaltic underplating is the mechanism by which silicic melts were produced on the Moon. Isotopic and elemental data from evolved clasts can help decipher what source rocks were partially melted and when the melting occurred.

Scanning Lunar Meteorites: Large-area (~10 cm^2) back-scattered electron image mosaics were generated at the University of Washington for 7 lunar meteorites (Dhofar-1442, NWA-3136, -4472, -4884, -6721, -7274, and Shisr-161) in order to look for small clasts of granophyre. Among those studied, we found granophyre clasts in Dhofar 1442, although it is possible that extremely small fragments (<100 μm^2) were missed in the other meteorites. It is not surprising to find granophyre clasts in Dhofar 1442, as they have been documented previously [13, 14]. Dhofar 1442 is a clast-rich regolith breccia with high concentrations of incompatible elements [13]. Analysis of chemical data led [14] to hypothesize that the meteorite came from the Procellarum KREEP Terrane (PKT). However, because incompatible element-rich areas appear to be widespread on the Moon it is not certain that Dhofar 1442 came from the PKT.

Elemental phase maps obtained with the FE-SEM at NASA-JSC for Dhofar 1442 (Fig. 1) indicate that K is in high concentrations in the granophyre fragments (~ 1 area% of the meteorite) and felsic impact glasses. However, it is easy to distinguish the two, as the impact glass is higher in SiO_2 (~75 wt.%) and does not contain the silica-feldspar intergrowths. Alkali feldspars in the granophyre fragments are ~ Or 90 with a celsian component that ranges from 1 to 3 (Fig. 1C). When plagioclase is also found in the granophyre fragments it is ~ An60. In some cases pyroxene occurs in the granophyre fragments (Fig. 1B).

Next Step: Granophyre fragments will be micro-drilled out of Dhofar 1442 for K-Ca, Rb-Sr, and Lu-Hf isotope measurements. As in [15], these data will be used to define the bulk compositions of the source(s) of evolved materials that make up the lunar crust. The search for source(s) will be further refined by comparison of radiogenic isotope compositions (inferred initial $^{40}Ca/^{44}Ca$, $^{87}Sr/^{86}Sr$, and $^{176}Hf/^{177}Hf$ isotopic compositions and isochron ages) in these clasts to the compositions and ages of known lunar rock types.

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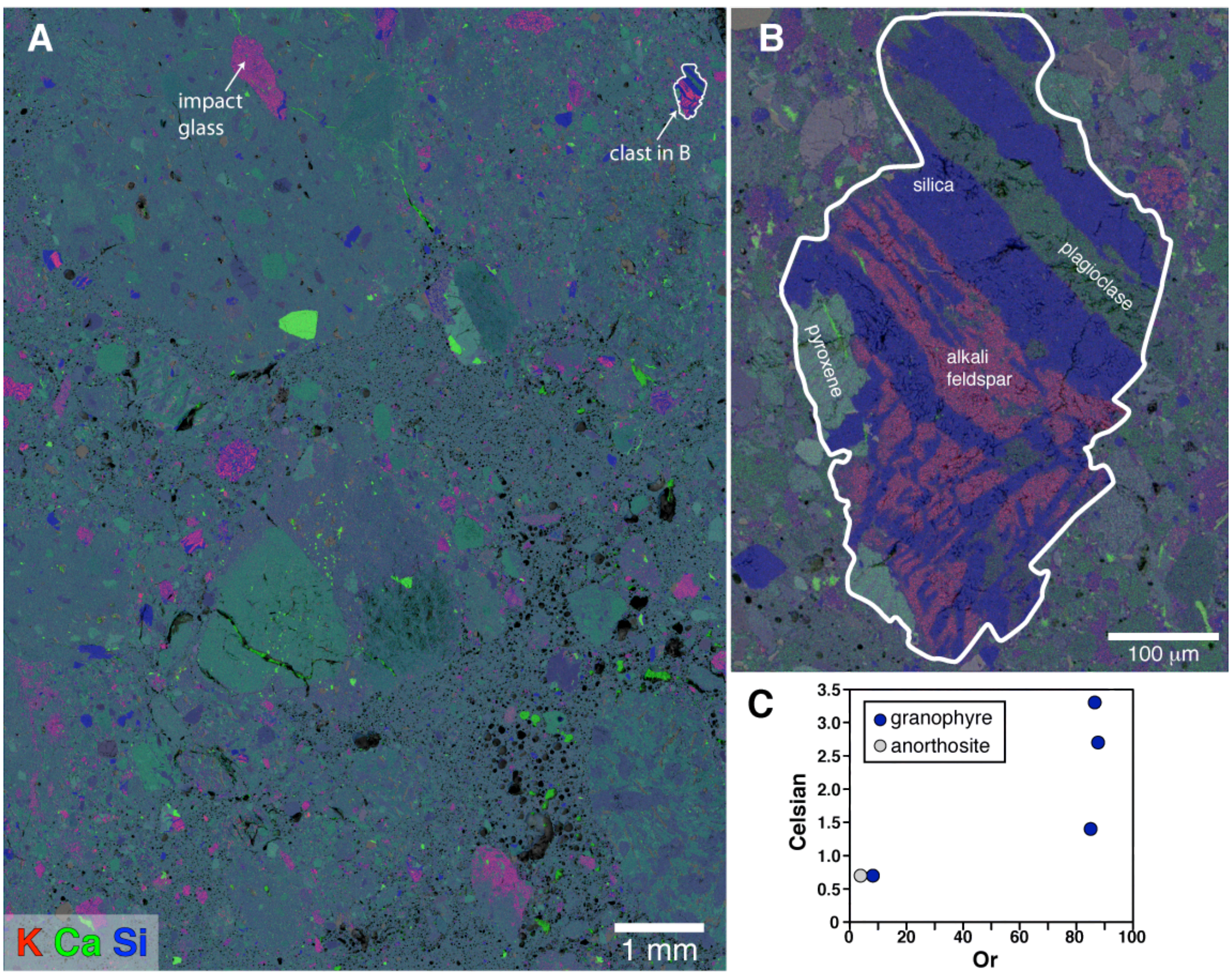

Fig. 1A Mosaic of X-ray maps from a section of Dhofar 1442 (K-red, Ca-green, Si-blue) on top of back-scattered electron images [X-ray maps and chemical data obtained on the JEOL FE-SEM at NASA-JSC]. Pink areas are either impact glass (high-silica rhyolite composition) or clasts of granophyre. Granophyre clasts comprise ~ 1% of the analyzed area. **1B** Close-up of the granophyre clast in the NE corner of 1A. Clast is composed of silica, alkali feldspar, plagioclase and pyroxene with exsolution lamellae. **1C** Feldspar data from granophyre clasts and one anorthosite clast. Limited dataset suggests that alkali feldspars in the granophyre clasts have more celsian (Ba-feldspar) than plagioclases. The plagioclase in the granophyre is ~ An_{60}.