THE EVOLVED MINERAL FRAGMENT POPULATION IN APOLLO 17 MAFIC IMPACT MELT BRECCIAS

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Introduction: Poikilitic and aphanitic impact melts from the Apollo 17 landing site are presumed by most investigators (e.g., [1]) to have been produced by the impact that formed the Serenitatis basin (although an Imbrium origin has been proposed by [2] and [3]). Ryder et al. [4] determined by electron microprobe the major and minor element concentrations in hundreds of mineral clasts in fine-grained Serenitatis melts to characterize the crustal rocks in the target area, an approach used successfully on a terrestrial analog [5].

To extend the previous work by [4], we have collected extensive trace element geochemistry data using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) as part of a petrologic study of Apollo lunar samples 72435, 76315, 76295, 76035 in order to extensively characterize the source rocks making up the clast population.

In [6], we determined that the clasts analyzed as a part of this effort are predominantly composed of materials from known pristine lunar rock types, including ferroan anorthosites, and that many of these mineral fragments have compositions outside of the ranges previously determined for pristine lunar igneous endmembers.

In this present work, we discuss in further detail a subset of the orthopyroxene and plagioclase mineral fragments that are extremely enriched in incompatible elements, and represent examples of evolved lunar materials present in the Serenitatis crustal section during the Serenitatis basin-forming event.

Methods: Polished sections 100 μm thick of Apollo lunar samples 72435, 76035, 76315, and 76295 were studied using optical microscopy, X-Ray elemental mapping, electron probe microanalysis, and LA-ICPMS. Each of the thin sections were mapped in P, Ni, Na, K, Ca, Ti, Si, Mg, Fe, and Al K-α at a resolution of 10 μm/pixel using the five wavelength dispersive spectrometers (WDS) of the University of Hawaii's Cameca SX-50 electron microprobe. These data were reduced using the techniques of [7]. The resulting mineral maps were used to inventory different mineral types and to provide targeting information for both the quantitative microprobe analyses and the ICP-MS laser points. The major element compositions of the analyzed mineral fragments were determined using the University of Hawaii's Cameca SX-50 electron microprobe. Analyses were conducted at the center of mineral fragments at least 50 μm from grain boundaries to minimize the secondary florescence effects from adjacent grains.

Trace elements were measured by LA-ICPMS using the Australian National University's custom-built system ([8-10]) A conventional suite of petrogenetic trace elements was measured using a 70 μm-diameter laser beam and a laser repetition rate of 4 Hz. The CaO content of each fragment as determined by electron microprobe was used for internal normalization of the lithophile element analyses. Replicate analyses of the NIST 612 glass were used for the external calibration of relative element sensitivity using the concentration values given by [11] and demonstrate an external precision of 1-6% (1-σ relative standard deviation). The microprobe and LA-ICPMS results for individual mineral clasts combine to form a comprehensive suite of major, minor, and trace element data for all analyzed mineral fragments.

Results: The initial survey of this mineral fragment population discussed in [6] revealed a great deal of compositional heterogeneity among the analyzed mineral fragment population. To more fully understand the petrogenesis of these mineral fragments, appropriate mineral/melt distribution coefficients from previous studies [12-16] were selected and used to invert the original compositions into estimates of equilibrium parent melt REE abundances. We note that due to general uncertainty concerning distribution coefficients, the results being discussed here are estimates and only indicate general trends.

This modeling revealed that there is a subset of orthopyroxene and plagioclase mineral fragments in the analyzed samples that are extremely enriched in incompatible elements, and have modeled parent melt REE abundances higher than the KREEP component of [17].

Orthopyroxene: 6 of the 17 orthopyroxene mineral fragments analyzed during the course of this study have model parent magma REE abundances higher than the KREEP component of [17], as shown in Figure 1. 5 of these fragments are from the section of 76295; 1 was analyzed on section 76035. The orthopyroxene compositions range from $En_{66-82}Fs_{16-30}Wo_{2-10}$.

Plagioclase: 28 of the 79 analyzed plagioclase mineral fragments (An_{89-98}) have model parent magma REE abundances higher than the KREEP component of [17], as shown in Figure 1. 18 of these fragments are from the section of 76295; 6 are from the section of 72435, and 4 are from the section of 76035.

Geochemical Parameters: Incompatible elements such as La, Zr, Th, and the K/Th ratio can be useful in characterizing the petrogenesis of highly evolved lunar materials. The concentration of these elements in equilibrium melts parental to these evolved mineral fragments were also calculated. The results are shown in Figures 2-4, which show the calculated parental melt concentrations of these elements compared to bulk lunar sample compositions and remote sensing data. In general, the modeled parent magmas for these orthopyroxene and plagioclase mineral fragments display similarities to results obtained from other evolved lunar rock types. The calculated K/Th ratios for the plagioclase fragment parent melts (Figure 2) in particular display similarities to lunar granites/felsites and quartz monzodiorites. However, the La (Figure 3) and Zr (Figure 4) concentrations in the calculated parent melts define trends separate from previously recorded lunar materials.

Conclusions: A population of evolved lunar materials, was present in the Serenitatis crustal section at the time of the Serenitatis basin-forming event. Melts in equilibrium with these mineral fragments are generally similar to other evolved lunar materials, but are substantially more enriched in incompatible elements.

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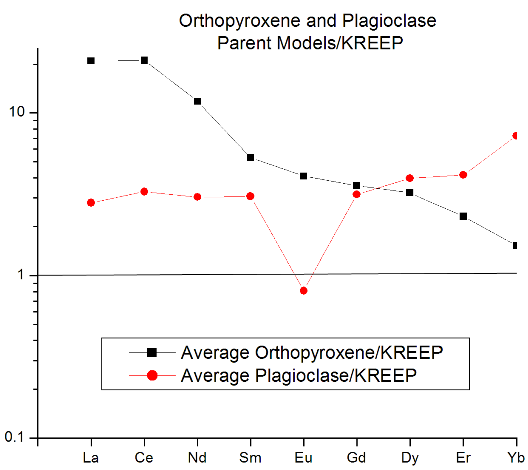

Figure 1: KREEP-normalized REE abundances of the average modeled parent magma of the evolved orthopyroxene and plagioclase fragment population.

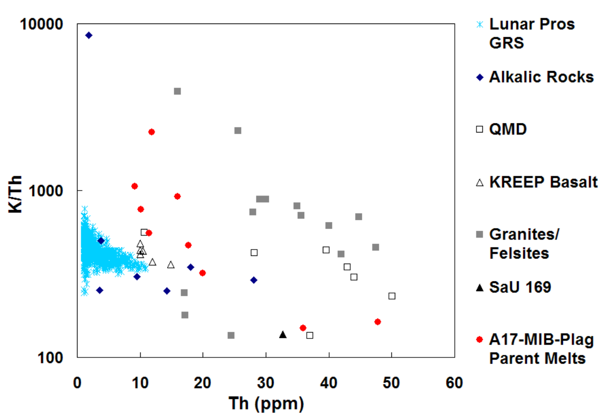

Figure 2: Plot of K/Th vs. Th concentration for evolved plagioclase and pyroxene mineral fragments (this study) and evolved lunar materials. Lunar Prospector data for points with Th > 1 ppm is shown. Sample data from compilation by [18].

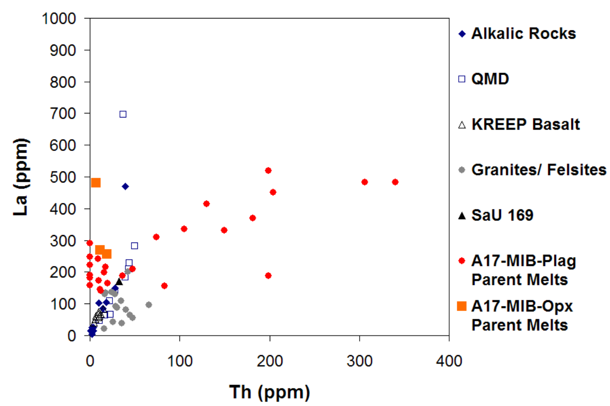

Figure 3: La vs. Th concentration for evolved plagioclase and pyroxene mineral fragments (this study) and evolved lunar materials (as compiled by [18]).

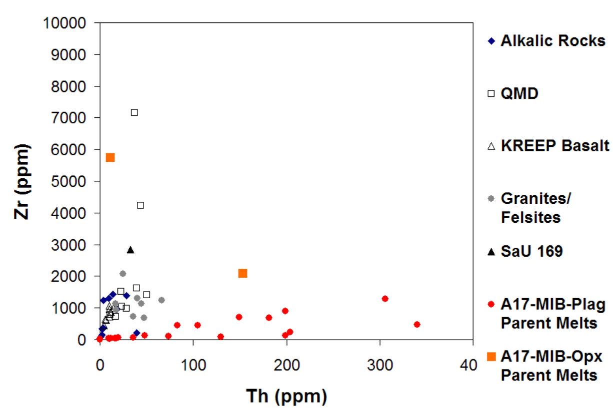

Figure 4: Zr vs. Th for evolved plagioclase and pyroxene mineral fragments (this study) and evolved lunar materials (as compiled by [18]).