DIFFERENTIATING BETWEEN PRISTINE MARE BASALTS AND IMPACT MELTS USING QUANTITATIVE PETROGRAPHY.

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Introduction: Lunar impact melts and pristine mare basalts have similar textures yet very different origins. Distinguishing between them has proven difficult in the past. For example, sample 14310 was originally classified as a high-alumina mare basalt [e.g., 1-3] yet subsequent studies showed its impact origin [e.g., 4,5]. While siderophile element abundances are a good indicator of a non-pristine origin of impact melt rocks (e.g., [6]), not all returned samples are large enough to allow accurate siderophile element analyses to be conducted (e.g., breccia clasts). In the experimental studies from the 1970s noted above for 14310 [4,5], it was the textures that demonstrated a potential impact origin for this melt rock. The presence of more crystallization nuclei has been hypothesized to be responsible for the textural differences. In order to test this, we present a quantitative study of lunar melt rock textures via crystal size distributions (CSDs; e.g., [6-8]) to demonstrate distinct differences between impact melts and pristine mare basalts. This work builds upon the work of [9,10] supplementing it with current work by Fagan et al. [11]. We use plagioclase and olivine CSDs to show distinct differences between pristine mare basalts and high-Mg and aluminous impact melts taken from the Apollo 14 site. CSDs of plagioclase and olivine from the Apollo 14 high-alumina basalts were examined in comparison with plagioclase CSDs from impact melts 14310, 14073 and 14276 and with olivine from the Apollo 14 olivine vitrophyres (e.g., [12,13]).

CSD Analysis: CSDs measure the number of crystals of a characteristic size per unit volume of rock (e.g., [6-8]). They are normally displayed on a log-normal plot of population density (number of crystals per unit volume rock) versus crystal size (L) [8]. The slope of a CSD is -1/G (growth rate) multiplied by τ (residence time). Crystal nucleation rate will generally increase as an initially wholly molten flow cools [14]. If nucleation and growth continue uninterrupted, the final rock will likely yield a linear or near linear distribution of crystal sizes ([6,15]). However, if the magma arrives at the surface carrying macroscopic crystals, the final rock will likely yield a non-linear, possibly concave up CSD, if the phenocrysts settled appreciably [15]. Crystals carried in the initial magma may vary in size and can easily be interpreted as phenocrysts crystallized from the present host magma [16,17]. Non-linear CSDs indicate dynamic and/or kinetic processes affected crystallization [8,14]. Curved CSDs may reflect the different nucleation and growth conditions of distinct crystal populations in the rock (e.g., [8,18,19]). CSDs can also be used to estimate crystal residence times in igneous systems (e.g., [20]) and physical processes that affected the magma like phenocryst settling or textural coarsening of cumulate materials (e.g., [19]).

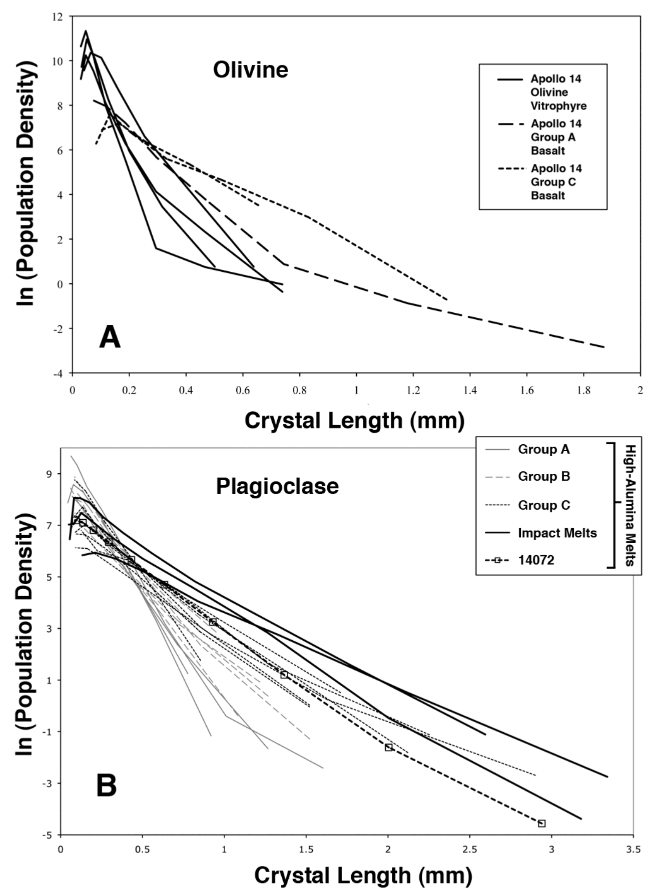

Figure 1. CSDs of Apollo 14 high-alumina basalts and impact melts. A: Olivine CSDs from Olivine Vitrophyres and Group A and Group C high-alumina basalts. B: Plagioclase CSDs from Group A, B, C, and 14072 high-alumina basalts and aluminous impact melts 14073, 14275, and 14310.

Thin sections were photographed under 5x magnification and plagioclase and olivine crystals were traced in *Adobe Photoshop*. Crystal outlines were then imported into *ImageTool* [21] to obtain the length, width, and roundness of each crystal. Length and width measurements were then imported into *CSDslice* [22] to get the most probable crystal shape. Crystal lengths and widths along with the most probable crystal shape were then imported into *CSDcorrections* [21] to yield the CSD plotted as the natural log of the population density versus crystal length. Non-linear CSDs indicate a complex crystallization history

[23], which is why we supplement the CSD data with major and trace element analysis.

Results: CSDs of olivine and plagioclase are shown in Figure 1. Olivine CSDs (Fig. 1A) are still in the process of being collected from the Apollo 14 high-alumina basalts, but appear to be showing that each group has distinct CSD profiles, as seen with the plagioclase CSDs in Figure 1B. The olivine CSDs for the impact melts are steeper than those for the high-alumina basalts, whereas the plagioclase CSDs for the impact melts are more gentle that the basalts. In addition, the olivine CSDs for the impact melts have a concave upward/"kinked" appearance whereas those for plagioclase are generally linear.

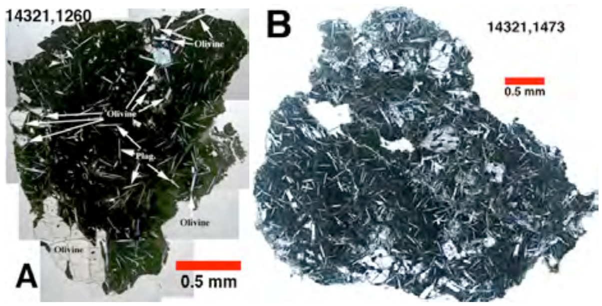

Figure 2: Textural comparison between (A) the impact melt 14321,1260 (Olivine Vitrophyre) and (B) Apollo 14 high-alumina mare basalt 14321,1473.

Figure 3: Textural comparison between (A) aluminous impact melt 14276,54 and (B) Apollo 14 high-alumina basalts 14321,1473.

Discussion: Results indicate different crystallization conditions for the impact melts compared to the mare basalts. Figures 2 and 3 show comparisons between the Apollo 14 olivine vitrophyres (impact origin; Fig 2A) and an Apollo 14 high-alumina basalt vitrophyre (Fig 2B), as well as between aluminous impact melt 14276 (Fig. 3A) and an Apollo 14 high-alumina mare basalt (Fig. 3C). Visually, the impact melts and mare basalts look similar. However, the CSDs shown in Figure 1 exhibit distinct profiles for the impact melts for both olivine and plagioclase.

The mare basalt shown in Fig, 2B erupted as a mixture of crystals plus melt and was then quenched. Olivine vitrophyres were generated on the surface by an impact into a heterogeneous target rock [11], and the presence of abundant crystallization nuclei [4,5] promoted crystallization at a lot of sites. This explains the steeper CSDs for the olivine from the olivine vitrophyres compared to olivine in the mare basalts and is consistent with more rapid crystallization for the former. However, when plagioclase is considered the situation is reversed. This suggests that the aluminous impact melts crystallized longer than the olivine vitrophyres, which is supported by the lack of glass in the former (Fig. 3A). This allowed textural coarsening of the plagioclase in the impact melts, such that the larger crystals continued to grow at the expense of the smaller crystals as the impact melts cooled. This produced the much shallower plagioclase CSD profiles and apparent longer residence times. Work is ongoing to better test these initial results that CSDs of olivine and plagioclase can be used to distinguish between pristine mare basalts and impact-generated melts.

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