TESTING THE ORIGINS OF BASALT FRAGMENTS FROM APOLLO 16. P. H. Donohue*[1], R. E. Stevens[2], C. R. Neal[1], and R. A. Zeigler[3], [1]Civil & Environmental Engineering & Earth Sciences, University of Notre Dame, Notre Dame, IN (*pdonohu1@nd.edu) [2]University of Leicester, Leicester, UK [3]NASA Johnson Space Center, Houston, TX.

Introduction: Several 2-4 mm regolith fragments of basalt from the Apollo 16 site were recently described by [1]. These included a high-Ti vitrophyric basalts (60603,10-16) and one very-low-titanium (VLT) crystalline basalt (65703,9-13). As Apollo 16 was the only highlands sample return mission distant from the maria, identification of basaltic samples at the site indicates input from remote sites via impact processes [1]. However, distinguishing between impact melt and pristine basalt can be notoriously difficult and requires significant sample material [2-6]. The crystal stratigraphy method utilizes essentially non-destructive methods to make these distinctions [7,8]. Crystal stratigraphy combines quantitative petrography in the form of crystal size distributions (CSDs) coupled with mineral geochemistry to reveal the petrogenetic history of samples. The classic CSD plot of crystal size versus population density can reveal insights on growth/cooling rates, residence times, and magma history which in turn can be used to evaluate basaltic vs impact melt origin [7-9].

Electron microprobe (EMP) and laser ablation (LA)-ICP-MS analyses of mineral phases complement textural investigations. Trace element variations document subtle changes occurring during the formation of the samples, and are key in the interpretation and preservation of this rare lunar sample collection.

Samples and Methods: This study focuses on two samples: 60603,10-16 and 65703,9-13. Fragment 60603,10-16 is a vitrophyric basalt, with numerous phenocrysts of olivine (subhedral grains up to ~60 µm across), ilmenite laths (≤200µm in length) and equant spinel (<0.25µm) in a groundmass of glass, olivine, and trace Fe-metal [1]. Fragment 65703,9-13 is a crystalline basalt with a subophitic texture of plagioclase (modally 45%, laths up to 0.3mm in length) and subequal amounts of olivine and pyroxene (mode of ~44%), with trace amounts of fayalite, Cr-rich spinel, troilite, and ilmenite [1].

Crystal traces were made in Adobe® *Photoshop®* and exported and analyzed for long and short axis dimensions and area using an image processing program (*ImageJ* [10]). Each crystal population (minimum of 150 crystals) was compared with the CSDSlice (v4) Excel© database to determine the best-fit 3D habit [11]. These parameters were used in calculating CSDs (*CSDCorrections* v1.4.1) [12].

Major and minor element analyses were performed on a JEOL JXA-8200 electron microprobe at Washington University St. Louis. A subset of these crystals will be analyzed for trace element abundances using a UP213 Nd:YAG New Wave laser ablation (LA) system coupled with a Thermo Finnegan Element2 inductively coupled plasma mass spectrometer (ICP-MS) at the University of Notre Dame. EMP results will be used for internal standards in LA-ICP-MS analysis, and results will be presented at LPSC.

Results: Olivine and ilmenite CSDs were generated for 60603,10-16, and plagioclase and olivine CSDs were made for 65703,9-13 (Fig. 1). All four CSDs are linear to sub-linear with distinct downturns at smaller crystal sizes (<0.15mm). The model fit for plagioclase crystal habit in 65703,9-13 is poor (R^2<0.8). The small sample size and the fact that olivine is being resorbed in 65703,9-13 resulted in imprecision in olivine CSD calculations, and interpretation of this CSD should be undertaken with caution.

The use of slope-intercept relationships has shown promise in distinguishing pristine basalts from impact melts using plagioclase [13] and olivine CSDs [14]. For comparison, we have compiled olivine CSD data for 8 A17 high-Ti basalts, 4 A14 olivine vitrophyres (OVs), 1 A14 Group B basalt, 2 A12 OVs, and 1 A12 olivine basalt. The plagioclase dataset consists of 9 A17 high-Ti basalts, 15 A12 ilmenite basalts, 18 A14 basalts (4 Group A, 6 Group B, 8 Group C), 3 A14 Impact Melts (IMs), and 13 A16 IMs. Because of the variety of CSD profiles among the samples, the focus of this study is on overlapping size ranges of plagioclase (≥0.4 mm) and olivine (≤0.4 mm). The ilmenite CSD of 60603,10-16 is discussed in [15].

Discussion: The linear CSDs of investigated phases indicate uninterrupted cooling during crystallization.

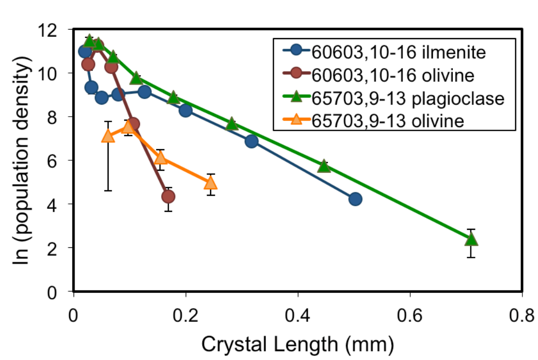

Fig. 1. CSDs for 60603,10-16 (ilmenite and olivine) and 65704,9-13 (plagioclase and olivine).

Homogeneity of major phases coupled with small size is consistent within an environment of constant growth rate.

Plagioclase CSDs from impact melts tend to have higher intercepts for a given slope compared to mare basalts [13]. In order to compare CSD profiles we use the methods described in [16] by using the lengths of crystals ≥0.4 mm (see [16] for details). In general, impact melts have shallower slopes and higher nucleation rates (i.e., they plot above and to the right) relative to mare basalts. Sample 65703,9-13 has a similar slope to but higher nucleation density than Apollo 14 Group A

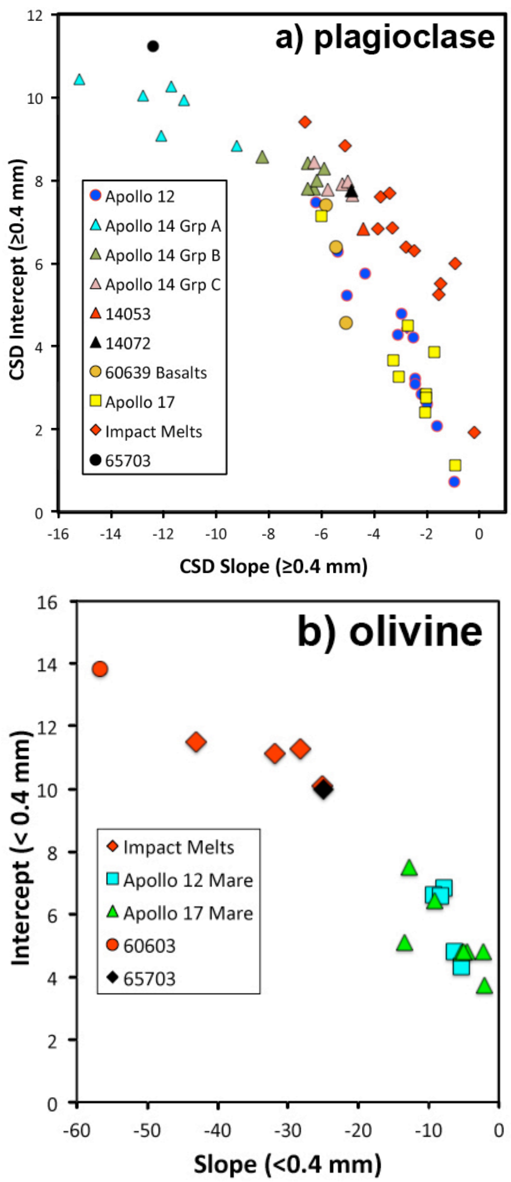

Fig. 2. Plots of CSD slope *vs.* intercept (nucleation density) for a) plagioclase, and b) olivine. Adapted from [13].

basalts (Fig. 2a), although the effect of the low R^2 value on this datum remains to be evaluated. In comparison to impact melts, the relatively steeper slope of 65703,9-13 reflects the fact that this sample is finer grained than those impact melts we have studied to date. Additional textural studies of plagioclase in impact melts are needed to see if there is a continuum of CSD data between 65703,9-13 and the main group of impact melts in Fig. 2a.

Olivine CSDs of impact melts exhibit steeper slopes and higher nucleation densities than olivine in pristine basalts (Fig 2b). The olivine CSD of 60603,10-16 extends the field of impact melts toward steeper slopes and higher nucleation densities. 65703,9-13 plots within the impact melt field, though as noted above the effects of olivine resorption require further consideration.

Whole-rock data show these samples have low siderophile element abundances suggesting they are pristine basalts [1]. However our textural work suggests these may be impact melts. LA-ICP-MS trace element analyses of minerals in 60603,10-16, and 65703,9-13 are underway to see if the evolution of these samples can definitively ascribed a pristine or impact origin for these samples.

Acknowledgements: This research was supported by NASA grant NNX09AB92G to CRN.

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