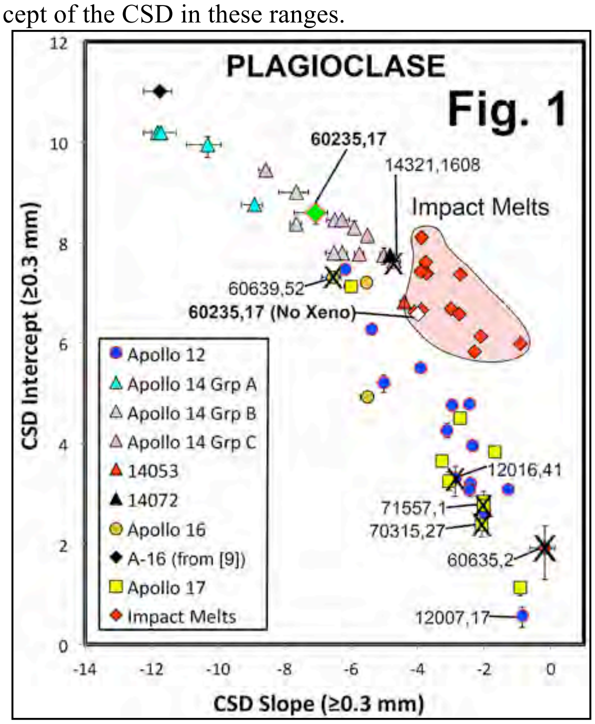
QUANTITATIVE PETROGRAPHY OF LUNAR BASALTS: INSIGHTS TO ORIGIN AND FLOW REGIME. C. R. Neal[1], P. H. Donohue[1], A. L. Fagan[1,2], and K. M. O'Sullivan[1], [1]Dept. Civil & Env Eng. & Earth Sciences, 156 Ftitzpatrick Hall, University of Notre Dame, Notre Dame, IN 46556 USA [neal.1@nd.edu]. [2]Dept. of Geosciences & Natural Resources, 331 Stillwell Building, Western Carolina University, Cullowhee, NC 28723.

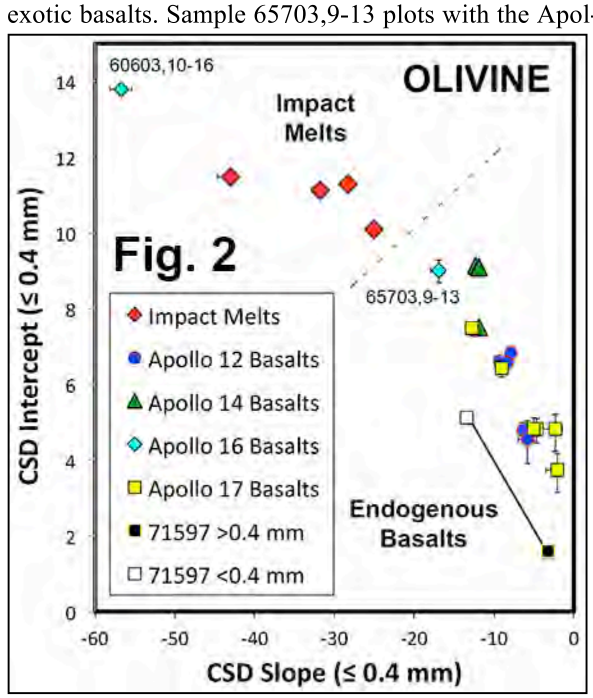
Introduction: Over the last 6 years, the lunar research group at Notre Dame has quantified the textures of lunar basalts (both endogenous mare basalt and impact melt) following the Crystal Size Distribution (CSD) statistical method (e.g., [1-6]). A CSD database has been built for plagioclase from 57 samples and for olivine from 20 samples, which is used to explore petrogenesis [7].

Impact Melt or Endogenous Mare Basalt? We have developed a scheme using olivine and/or plagioclase CSDs [7,8] that allows the distinction of basaltic impact melts from endogenous mare basalts, which at times is difficult to do with qualitative petrography alone. Using both olivine and plagioclase, CSD slopes and y-axis intercepts from a portion of the CSDs are used. The samples in the CSD database contain a range of crystal sizes. In the comparative scheme presented here, only the portion of each CSD present in all samples is used. For olivine, this is the portion of the CSD that is ≥0.4 mm and that has a negative slope, omitting any change in gradient that can occur in small crystal sizes. The calculated intercept of this slope is equivalent to the nucleation density. For plagioclase, similar criteria are followed, with the exception that the corrected crystal size range is ≥0.3 mm. For both olivine and plagioclase, only consecutive data points with errors ≤15% are used to determine the slope and intercept of the CSD in these ranges.



Plagioclase CSDs: Plagioclase is volumetrically more abundant than olivine in mare basalts and impact melts, which means fewer statistically relevant olivine CSDs can be constructed. When we plot the CSD slope vs. the CSD intercept for plagioclase crystals, the basaltic impact melts form a distinct field (shaded in red, **Fig. 1**) and are less steep than mare basalts (see [8]). It has been recommended that at least 75 crystals are required to define an accurate CSD profile for tabular crystals, whereas a minimum of 250 crystals should be required for acicular shapes [9]. Plagioclase often exhibits an acicular habit, and there are 10 samples in our database with plagioclase CSDs defined using <250 crystals. We have evaluated these CSDs qualitatively using the smoothness of the profile, and quantitatively using the errors in population density – if they are ≤10% for at least three consecutive data points, the profile can be used for further analysis. Samples must pass both criteria to be used in our classification scheme. Among these 10 samples, 6 are not used any further in this study (crossed out in **Fig. 1**).

Olivine CSDs: The olivine CSDs for impact melts and endogenous mare basalts behave in the opposite sense to plagioclase CSDs: impact melt olivine CSDs are steeper than those for mare basalts (**Fig. 2**; also see [8]) and plot in distinct fields. In **Fig. 2**, we emphasize two Apollo 16 basalts reported by Zeigler et al. [10] to illustrate that this scheme can also be used to classify exotic basalts. Sample 65703,9-13 plots with the Apol-



lo 14 Group A high-Al mare basalts (as with plagioclase in **Fig. 1**), whereas 60603,10–16 extends the impact melt field to steeper negative slopes and higher **y**-axis intercepts (**Fig. 2**).

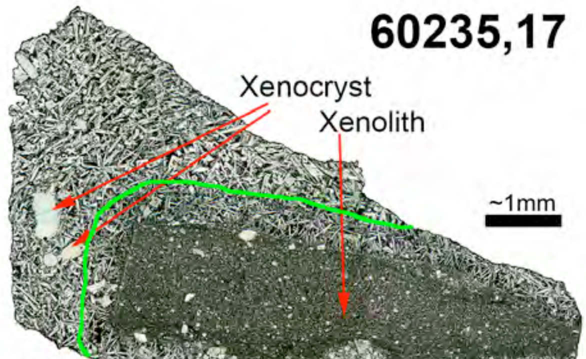
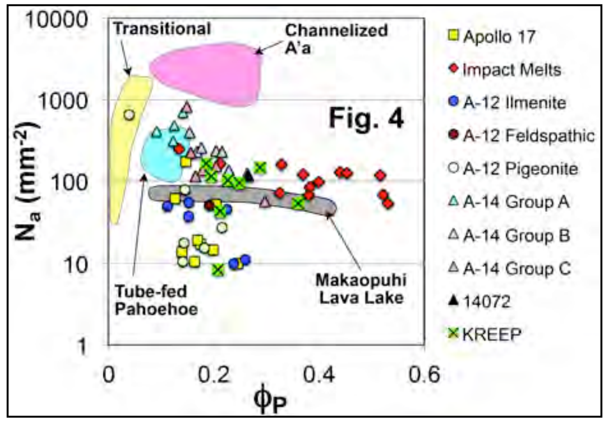


Fig. 3

Xenoliths: Some complications arise using this method from the inclusion of xenoliths (see “60235,17” and “60235,17 (No Xeno),” **Fig. 1**). Such inclusions impart different cooling rates at the centimeter scale, which can have a significant affect on the slope of a CSD. In order to investigate this potential impediment with the quantitative petrography method described here, sample 60235,17 was examined in detail (**Fig. 3**). CSDs were constructed for all plagioclases in the melt portion of the thin section, represented by 60235,17 (green diamond), **Figure 1**. This CSD plots within the Apollo 14 high-Al basalt field. A second plagioclase CSD was constructed by omitting the plagioclases in a ~0.5 mm zone around the xenolith as the grain size diminishes slightly presumably due to the cooling effect of the xenolith (outlined in green in **Fig. 3**). This CSD is also plotted on **Fig. 1** as 60235,17 (No Xeno) (white diamond) and falls within the impact melt field. The clear distinction between these two points demonstrates that impact melt cooling rates (and the slope of the plagioclase CSD profile) is influenced by the presence of xenoliths.

Type of Lava Flow – Pahoehoe or A’a? Plagioclase CSD data can also be used to examine the type of terrestrial lava flow from whence the samples were derived. Hawaiian lava flows transition from pahoehoe to a’a once a rheological transition had been reached [11]. Initial melting temperature controls the number of plagioclase nuclei with a’a lavas resulting from slightly lower melting temperatures than pahoehoe, leading to a larger number of plagioclase crystallization nuclei that produced higher yield strengths [12]. Plagioclase crystallinity can be used to describe the difference between pahoehoe and a’a flows when the number of plagioclase crystals per mm^2 ($\mathbf{N_a}$) is plotted against plagioclase volume fraction crystallized (ϕ_P) [13] (**Fig. 4**). We use this scheme to examine the samples in our study (**Fig. 4**). None of the lunar samples fall in the channelized a’a field, and only one A-12 pigeonite basalt (12019,5) falls within the transitional field. The remaining basalts, including the impact



melts, straddle theTube-fed Pahoehoe and Makaopuhi Lava Lake fields. This implies that the lunar basalts, including the impact melts, are from pahoehoe lavas, either as flows or ponds. LROC images of impact melt flows show the pahoehoe lobe structure (**Fig. 5**). This study demonstrates that CSDs from mare basalts can be used to define the type of lava from whence the samples were derived.

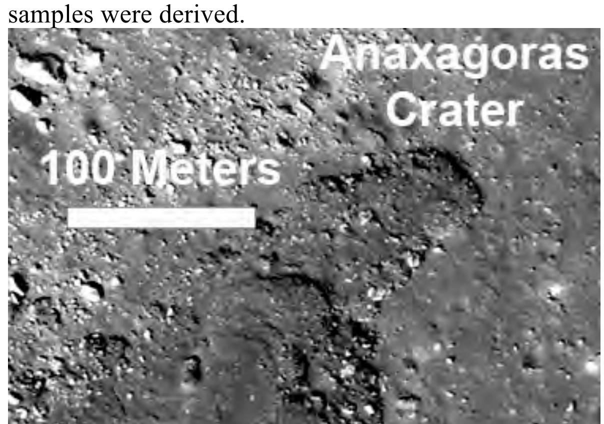


Fig. 5

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