PETROGRAPHY IS STILL RELEVANT! EXAMINATION OF LUNAR MELT ROCKS TO DETERMINE FORMATION AND EVOLUTION. S. E. Roberts[1] and C. R. Neal[1], [1]Dept. of Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, USA (sarah.e.roberts.122@nd.edu; neal.1@nd.edu).

Introduction: Petrographic analysis of rock thin sections is becoming a secondary mode of scientific investigation given the increasingly sophisticated nature of analytical machinery that is being used in the investigation of geological materials. Only after destructive analysis to obtain highly siderophile element (HSE) data (e.g., [1]) or time-consuming experiments can impact melts actually be identified (e.g., [2]).

Application of quantitative textural analysis [3-7] when applied to the Moon is giving new insights into igneous petrogenesis (e.g., [8]). Crystal size distribituions (CSDs) are represented in diagrams of natural logarithm of the population density against crystal size. These yield a negative correlation, the slope of which can provide information on the thermal history and residence times of the crystals. Application of the CSD method to different mineral phases is showing promise in distinguishing between impact melts and pristine mare basalts (i.e., pristine melts of the lunar interior – hereafter "pristine melts") [9,10]. Here we test and refine the quantitative petrographic analysis methods of olivine and plagioclase. Fagan et al. [10] reported textural analyses of impact-generated olivine vitrophyre samples that appeared to be distinct from crystalline pristine melts. Two known pristine A-17 olivine vitrophyres (71048 and 71157; Fig. 1) and two glass- and plagioclase-rich A-14 high-Al basalts (14321,1260 and ,1473; Fig. 2) are analyzed to test these methods.

Methods: Crystal traces made in Adobe Photoshop were exported and analyzed for long and short axis dimensions and area using an image processing program (*ImageJ*, available at http://rsbweb.nih.gov/ ij/). 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) [6]. In order to compare CSDs of the same mineral species from different basalts, only a portion of the CSD is used. For Plagioclase, the lengths ≤ 1.5 mm are used. If the errors on the data points for the larger crystal sizes exceed 15%, they are not For Olivine, samples sizes ≤0.4 mm are used. For both phases, if the CSD shows a decrease in slope (or even a downturn) at the smaller crystal sizes, these data points are omitted because they represent the limit of detection of the CSD method (i.e., not all of the crystals in these small size bins were collected during the tracing of the section). Once the CSD region has been identified, the slope and y-axis intercept are calculated. These data are then plotted against each other.

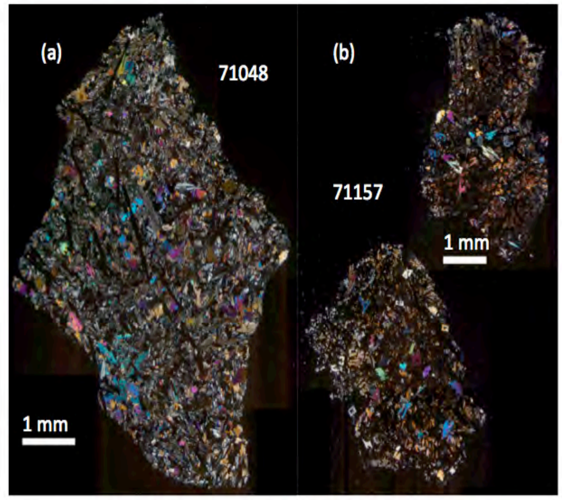

Figure 1: (a) 71048 and (b) 71157 in xp.

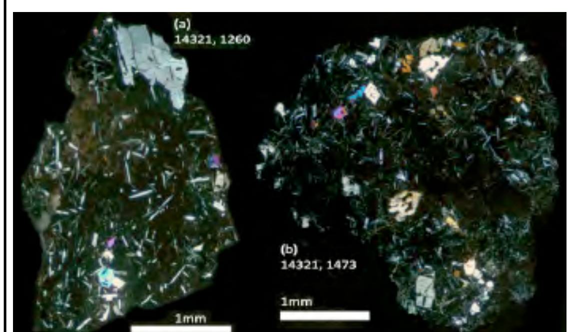

Figure 2: (a) 14321,1260, (b) 14321,1473 in xp.

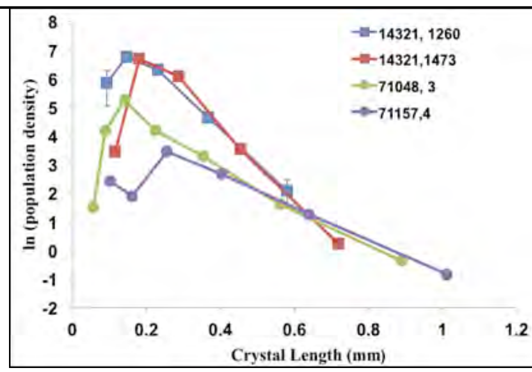

Figure 3: CSDs of the 4 vitrophyres, plagioclase is represented by squares and olivine by circles. Error bars represent the minimum and maximum population density per that crystal bin size.

Results: The CSDs for the 4 samples are presented in Figure 3. Each profile experiences a downturn in the lowest crystal sizes. This represents the limits of detection for the method (i.e., not all of the small crystal sizes to be adequately represented on the crystal traces making these sizes under-represented in the final CSD). The data from Figure 3 have been plotted with plagioclase and olivine data derived for mare basalts and impact melts by the Notre Dame group over the past 4 years. These results are presented in Figure 4.

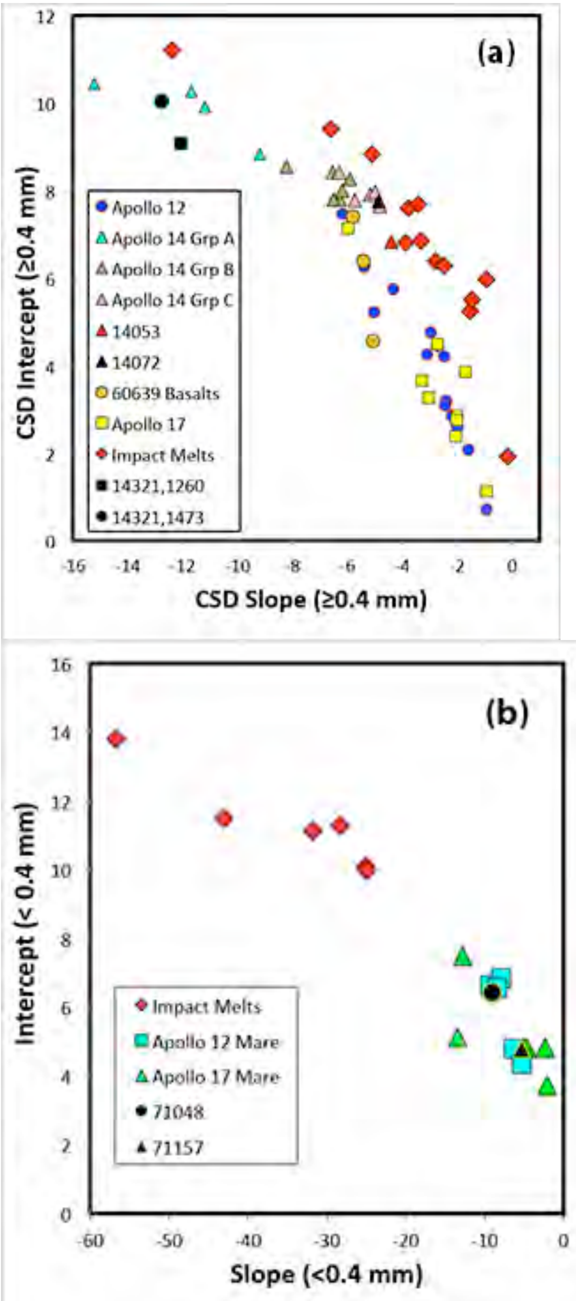

Figure 4: Slope vs. Intercept CSD plots for (a) Plagioclase; (b) Olivine.

Discussion: Using the new data reported here, we have undertaken an evaluation of petrographic methods for distinguishing impact and pristine melts [9,10].

A CSD profile when presented as in Fig. 3, shows a negative correlation with higher abundances of the smaller crystal sizes. In order to compare the CSDs from different samples only certain size ranges are considered: ≥0.4 mm for Plagioclase (Fig. 4a) and ≤0.4 mm for Olivine (Fig. 4b). If errors on the data points at either end of these size ranges exceeds ~10%, the data are excluded. For the smaller crystal sizes, if the CSD exhibits marked downturn or even a positive correlation, the data points are excluded. A slope and intercept are then calculated and plotted against each other.

Plagioclase (Fig. 4a): Plagioclase CSDs from impact melts tend to have shallower slopes coupled with higher intercepts for a given slope compared to pristine melts (mare basalts). This indicates that for plagioclase, pristine mare basalts have lower nucleation rates than impact melts (i.e., impact melts plot above and to the right of pristine mare basalts in Fig. 4a). The two new samples were designated as vitrophyric Group A Apollo 14 high-Al basalts [12-14]. Both samples plot with the other Group A basalts.

Olivine (Fig 4b): Unlike plagioclase, olivine CSDs from impact melts exhibit steeper slopes but still have higher nucleation densities than those from pristine melts. The distinction between impact melts and mare basalts is very evident in Fig. 4b, but this may be a sampling issue as there are not so many impact melts and mare basalts that have had olivine CSDs constructed (as yet). The new A-17 olivine CSDs plot with the pristine melts (Fig. 4b).

Implications. Petrography can be used to distinguish lunar impact melts from pristine mare basalts. Use of plagioclase and olivine CSDs derived from a thin section will be critical for identifying impact melts from any sample return from SPA (or other large impact basins) thus preserving precious sample for other investigations. It also allows melt samples in the current lunar sample collection that are too small for HSE analysis to be classified as either impact or pristine. This in turn could allow lunar impact chronology to be better constrained using the exisiting collection on the basis of age dating small samples that can now be identified as impact melts.

References: [1] Warren P. (1993) *Am. Miner. 78*, 360-376. [2] Lofgren G. (1977) *PLSC 8*, 2079-2095. [3] Cashman K. & Marsh B. (1988) *CMP 99*, 292-305. [4] Marsh B. (1988) *CMP* 99, 277-291. [5] Marsh B. (1998) *J. Petrol. 39*, 533-599. [6] Higgins M.D. (2000) *Am. Mineral. 85*, 1105-1116. [7] Higgins M.D. (2010) *Internat. Geol. Rev. 53*, 354-376. [8] Hui H. et al. (2001) *GCA 75*, 6439-6460. [9] Neal, C.R. *et al.* (2010) *LPSC 42*, #2668 (abs). [10] Fagan, A.L. *et al.* (2013) *GCA* (in press). [11] Morgan D. J. & Jerram D. A. (2006) *JVGR 154*, 1-7. [12] Shervais et al. (1985) *PLPSC 15*, C375-C395. [13] Neal et al. (1988) *PLPSC 18*, 139-153. [14] Neal and Kramer (2006) *Am. Mineral. 91*, 1521-1535.