

Insights to the Petrogenesis of Apollo 12 Basalts from Crystal Size Distributions and Mineral Geochemistry.

K. O'Sullivan¹ and C.R. Neal¹, ¹Dept. of Civil Eng. & Geo. Sci., University of Notre Dame, Notre Dame, IN 46556, USA (kosulli4@nd.edu) (neal.1@nd.edu).

Introduction:

Crystal Size Distributions (CSDs) coupled with elemental data across individual crystals can provide detailed information on magma evolutionary processes. CSDs along with major and trace element data are presented here for plagioclase crystals in lunar samples 12031,45 and 12038,245. A CSD is a statistical analysis of the number, size, and shape of crystals in a particular rock sample [eg. 1-3]. CSDs can help determine initial nucleation density, nucleation rate, growth rate, and whether the system was closed or open [1]. CSDs are plotted on a log-normal scale with number of bins (equivalent sieves used in sedimentology) versus the log of the crystal size (Fig. 1). The shape of the CSD depends on a number of factors: equilibrium state, presence or absence of crystals in the melt before eruption, change in cooling rate, etc. Magma erupted onto the surface will yield a linear CSD if in a completely liquid state and cooled at a constant rate [1]. If there is settling of crystals in the magma chamber the CSD will be deflected concave down, or if there is an influx of larger crystals into the chamber the CSD will be deflected concave up (Fig. 1). Curved CSDs generally indicate a complex crystallization history [4]. For that reason, we are supplementing the CSD data with major and trace element data, specifically rare earth element data (REE). Spatial resolution of REEs can be achieved with LA-ICP-MS. If crystallized early, cores of plagioclase will have compositions similar to the parental magma,

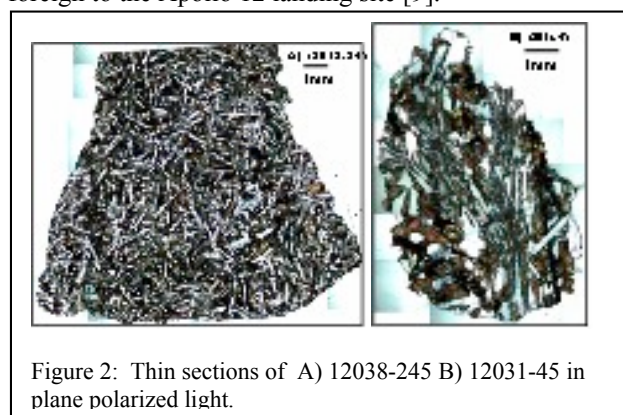
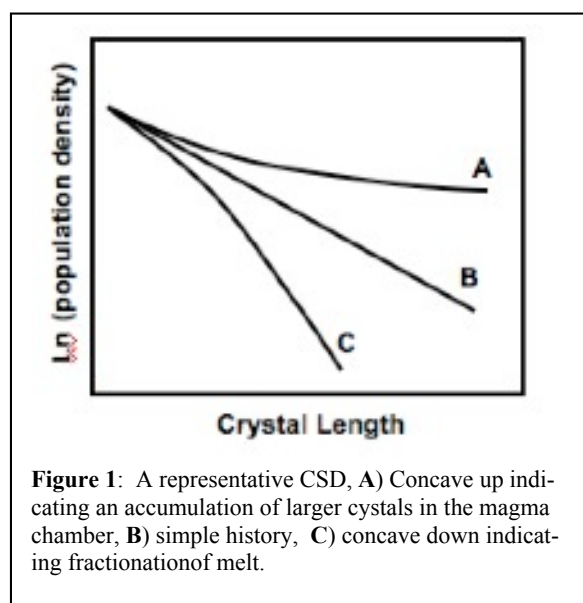
while the rims will contain compositions of the later stage magma. Certain mare basalt types have been shown to have crystallized plagioclase early in their cooling histories [5,6; Table 1].

Plagioclase:

Plagioclase is a useful mineral to analyze using a combined CSD-geochemical method due to fact that it can remain on the liquidus over a long period of magma crystallization. Also, minerals that crystallize before plagioclase (commonly olivine \pm Cr-spinel) do not appreciably fractionate the incompatible trace elements, so the original parental melt composition can still be derived [7].

Apollo 12 Basalts:

For this study, two aluminous Apollo 12 basalts have been analyzed. 12038 is the only member of the Feldspathic suite [8] and has plagioclase as a relatively early crystallizing phase [5,6]. It has an equigranular texture and medium grain size (Fig. 2a), and the CSD indicates at least two stages of plagioclase crystallization. The earlier stage yielded twinned crystals, while the later stage yielded anhedral crystals, some of which poikilitically surround older crystals [9]. Sample 12031 is an aluminous pigeonite basalt [8] that, in contrast to 12038, has plagioclase as a late crystallizing phase [5,6]. It coarse crystalline rock with older anhedral crystals (Fig. 2b). It has been suggested that 12038 is foreign to the Apollo 12 landing site [9].



Methods:

CSD analysis: CSDs were constructed from thin sections 12031,45 and 12038,245. Crystals were traced in Photoshop from a high-resolution photograph of each thin section. Traces were then analyzed using Image Tool to get the roundness, minimum length, and

maximum length of each individual crystal, then processed in CSDslice to account for the random intersection of a thin section, then ran through CSDcorrections to yield the plot of the CSD [10].

Elemental Analysis: Major element (via electron microprobe) and trace element (using Laser Ablation ICP-MS) are currently underway for these samples, but the data are not available at the time of writing this abstract. They will be presented at LPSC-39.

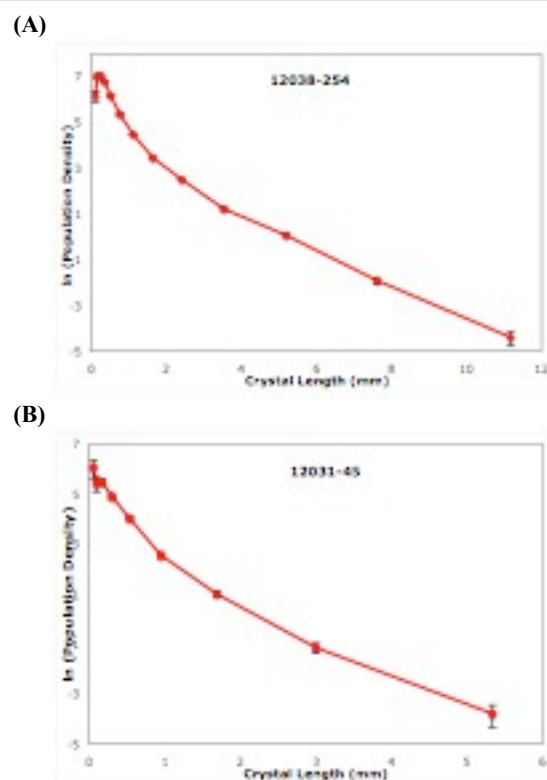


Fig. 3: CSDs for Apollo 12 aluminous basalts. **(A)** 12038,254, and **(B):** 12031,45.

Results:

Although plagioclase appears on the liquidus at different times for the two Apollo 12 basalts, they have surprisingly similar plagioclase CSDs (Fig 3a,b).

12038 has a steeper initial slope (representing smaller crystals) followed by a shallower more linear slope (representing larger crystals). 12031 has a concave up pattern, much like that of example A in Fig.1.

Discussion:

The CSDs for 12031 and 12038 are slightly concave up, indicating accumulation within the magma chamber before eruption, and have a distinct gradient change around 1 mm for 12031 and around 2 mm for 12038.

Apollo 12 basalt 12038 may have two distinct periods of crystallization, due to the two distinct slopes in

the CSD. This may be due to an influx of new magma resulting in the resorption of smaller crystals, or the mixing of two crystal populations. Either interpretation indicates an open system at one point during the magma chamber history.

The CSD for Apollo 12 basalt 12031 can be interpreted to have a period of accumulation within the magma chamber to accumulate larger phenocrysts with a period of faster cooling, again with an open system during some point in history.

Completion of the elemental data acquisition from crystals targeted by the CSD determinations will allow a quantitative evaluation of the models suggested by the CSDs. This evaluation will be presented at LPSC.

References: [1] Marsh B. (1988) *Contrib. Mineral. Petrol.* **99**, 277-291. [2] Marsh B. (1998) *J. Petrol.* **39**, 553-599; [3] Cashman K. & Marsh B. (1988) *Contrib. Mineral. Petrol.* **99**, 292-305. [4] Amenta, R. (2007) *American Mineralogist*, **92**, 1936-1945; Higgins M. (1996) *J. Volcan. Geotherm. Res.* **70**, 37-48. [5] Papike J.J. et al. (1998) *Planetary Materials* Chapter 5, 234 pp. *Rev. Mineral.* **36**. [6] Papike J.J., et al. (1976) *Rev. Geophys. Space Phys.*, **14**, 475-540. [7] Bindeman et al. (1999) *J. Pet.* **40**, 807-830. [8] Neal C.R. et al. (1994) *Meteoritics* **29**, 334-348. [9] Beaty, D. (1979) *Proc. Lunar. Planet. Sci. Conf*, **10**, 115-139. [10] Morgan D. & Jerram D. (2006) *J. Volc. Geotherm. Res.* **154**, 1-7.