CRYSTAL STRATIGRAPHY OF OLIVINE CUMULATE 71597: TRACING THE CRYSTALLIZATION HISTORY OF A HIGH-Ti BASALT LAVA FLOW.
P. H. Donohue* and C. R. Neal, Department of Civil Engineering & Geological Sciences, University of Notre Dame, Notre Dame, IN (*pdonohu1@nd.edu).

Introduction: Coarse-grained mare basalt 71597 is a rake sample (12.35 g.) from Station 1 of the Apollo 17 mission. Detailed petrographic and mineralogical work by [1] indicated the sample experienced significant olivine accumulation (24-27%) and possibly minor ilmenite accumulation (0-2%) during crystallization in an Apollo 17 high-titanium-type flow. Evidence for this conclusion is:

a) 71597 contains high MgO content (15.8 wt.%) and the highest modal olivine abundance (19.3%) of any high-Ti basalt [1,2].
b) A bimodal distribution of olivine Fo-content was observed between large, skeletal olivine cores (Fo_{73-75}) and small olivine grains (Fo_{63-69}).
c) Olivine in coarse-grained basalts are generally <1mm, whereas the majority of those in 71597 are >2mm and often skeletal.
d) Whole-rock REE abundances are lower than but sub-parallel to REE profiles of typical Apollo 17 high-Ti basalts, indicative of dilution by REE-poor olivine (+/- ilmenite).

The purpose of this study is to investigate the petrogenesis of 71597 for the first time using a crystal stratigraphy approach [crystal size distributions (CSDs) combined with mineral major and trace element analyses]. The CSD method is a way to quantify textures and constrain the solidification and growth history of a given mineral crystal population [3,4]. This technique is a powerful complement to *in-situ* mineral geochemical analysis, wherein we measure major and trace element abundance variation between crystal cores and rims and among different crystal populations identified in the CSD analysis.

Samples and Methods: For this study we investigated two thin sections of basalt 71597 (,12 and ,13). To facilitate CSD analysis, photomicrograph mosaics of each thin section were created in *Adobe Photoshop*© for plane polarized, cross polarized and reflected light views at 5x magnification. Ilmenite and olivine crystal outlines were traced by hand and analyzed with the image-processing program *ImageJ* to measure crystal properties (length, width and area). As thin sections only give a 2D view of a 3D crystal, we compared the aspect ratios (length and width) of the population of each phase to a database of random intersections of various crystal forms (*CSDSlice ver. 4*) to obtain the most-likely 3D crystal habit [5]. CSDs for each phase are then generated with the *CSDCorrections* program (ver. 3.1.9) using crystal length, width and area, crystal habit and roundness, and sample area parameters [6].

Petrographic analysis of 71597,12 revealed three ~10μm regions of mesostasis, all of which border an ilmenite mantle on armalcolite (Fig. 1). The mesostasis appears to be intergrown metal and glass.

Major and minor element characterization of olivine (n=18), ilmenite (14), armalcolite (2), melt inclusions (6), and mesostasis (3) were performed on a Cameca SX50 electron microprobe at the University of Chicago. Spot sizes of 1-30 μm were used (depending on phase and crystal size) with a 15 kV accelerating voltage and 30 nA beam current. As larger, skeletal crystals are thought to have formed earlier [1], we ana-

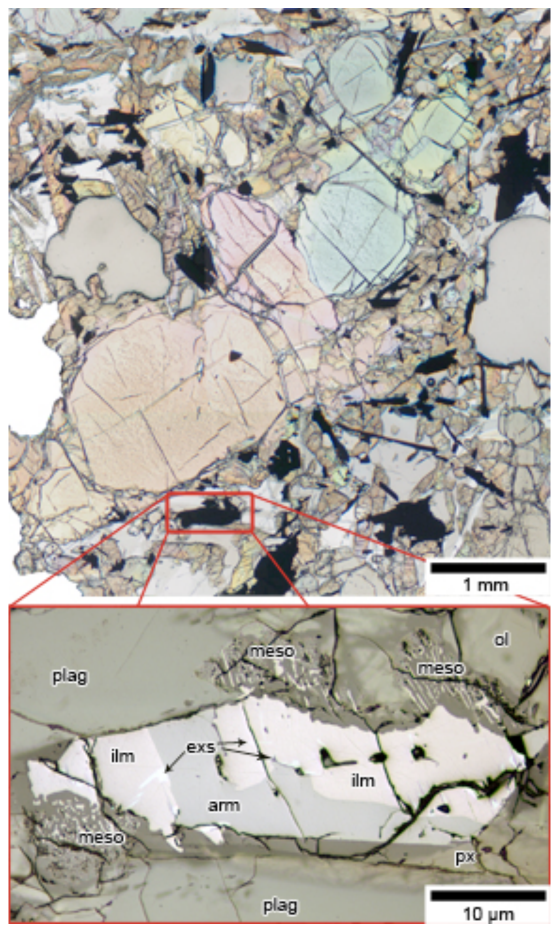

Fig. 1: Transmitted light photomicrograph showing large clustered olivines. Highlighted region at bottom showing reflected light image of armalcolite (arm) partially mantled by ilmenite (ilm) with some rutile exsolution (exs) features, and surrounded by plagioclase (plag), olivine (ol), pyroxene (px), and patches of mesostasis (meso).

lyzed a variety of crystal sizes. *In-situ* trace element analyses of major phases are being obtained at the time of writing via laser ablation (LA)-ICP-MS (New Wave 213 nm laser system in conjunction with a Thermo-Finnigan Element 2 magnetic sector ICP-MS) at the University of Notre Dame.

Results: Ilmenite CSDs (Fig. 2a) of both thin sections and exhibit nearly identical concave up profiles. They have a similar distribution to some coarse-grained, plagioclase-poikilitic (textural Type 1B after [7]) Apollo 17 basalts. The CSD for olivine in 71597,12 (Fig. 2b) is kinked at 0.45 mm. The slope of the smaller crystal size population is similar to olivine CSDs from fine-grained, olivine-porphyritic (textural Type 1A after [7]) Apollo 17 basalts. 71597,13 appears to have a similar size distribution but we could not generate a reliable CSD for this sample as only 43 olivine crystals could be traced, whereas [5] recommend at least 75 crystals. This resulted in a poor statistical fit (R^2=0.5) to model 3D crystal habits estimated by CSDSlice (recommended R^2>0.8) [5].

Cores of large olivines have high forsterite abundance (Fo_{72-75}) and generally decrease toward the rims except where buffered by other large olivines (Fig. 3a). This supports the observation by [1] that some large olivines formed in clusters, and suggests this clustering ocurred early during crystallization. The rims of some large olivines are similar in composition to the small, euhedral olivines (Fo_{65-67}). Ilmenite grains are relatively unzoned and major element variation is primarily between grains (Fig. 3b)

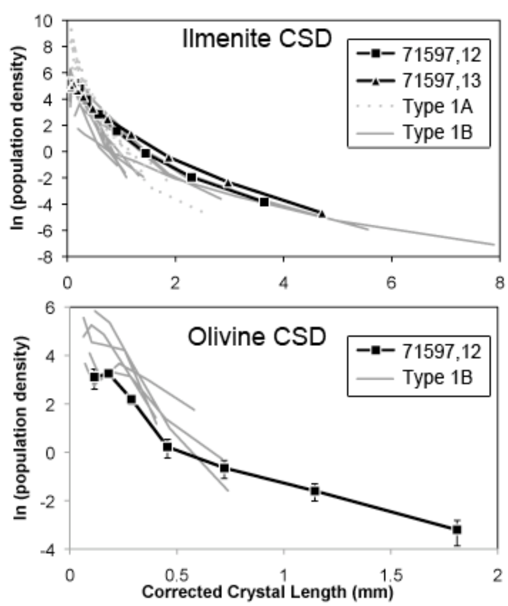

Fig. 2: Crystal size distributions of (a) ilmenite for 71597,12 and 71597,13 and (b) olivine in 71597,12. For comparison we plot CSDs for several Apollo 17 Type 1A basalts (fine grained, olivine porphyritic) and Type 1B basalts (coarse-grained, plagioclase poikilitic). Error bars for 71597 shown where larger than symbol.

Discussion: Curved and kinked CSDs may indicate magma mixing, crystal settling, changes in cooling rate or equilibrium state (e.g., assimilation processes), or other open-system processes [3,8]. Crystal settling deflects CSDs concave down, while crystal influx through magma mixing deflects CSDs concave up [7]. The kink in the olivine CSD is consistent with mixing of crystal populations. Textural coarsening may also cause a curved CSD or “soften” a kinked CSD profile.

The CSDs suggest that 71597 represents a sample that experienced only olivine accumulation, as the ilmenite CSD profiles suggest textural coarsening rather than ilmenite accumulation. This will be tested with crystallization modeling using trace elements and the results presented at LPSC 43.

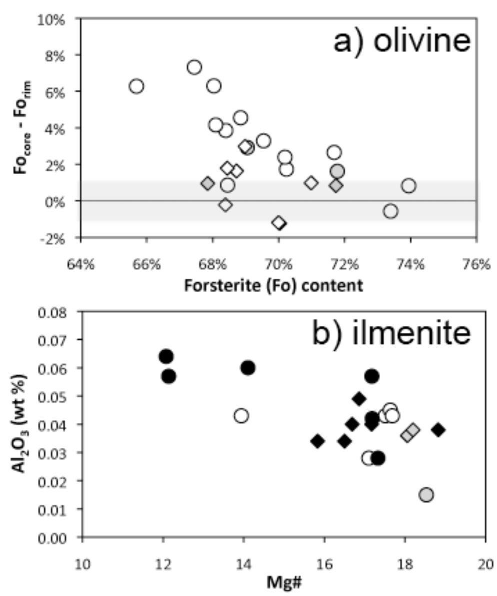

Fig. 3: Major element variation diagrams showing a) difference in core-to-rim forsterite abundance for olivine rims (open symbols) and midpoints (grey symbols) in 71597,12 (circles) and 71597,13 (diamonds), showing normal crystallization trends; and b) ilmenite Mg# and Al_2O_3 variation between crystals. Black symbols are cores, others as in (a).

References: [1] Warner R. D. *et al.* (1977) *Proc. Lunar Sci. Conf. 8th*, 1429-1442. [2] Neal C. R. *et al.* (1990) *Geochim. Cosmochim. Acta 54*, 1817-1833. [3] Marsh B. (1988) *Contrib. Mineral. Petrol.* 99, 277-291. [4] Cashman K. & Marsh B. (1988) *Contrib. Mineral. Petrol.* 99, 292-305. [5] Morgan D. J. and Jerram D. A. (2006) *J. Volc. Geotherm. Res.* 154, 1-7. [6] Higgins M. D. (2000) *Am. Min.* 85, 1105-1116. [7] Brown G. M. *et al.* (1975) *Proc. Lunar Sci. Conf.* 6th, 1-13. [8] Marsh B. (1998) *J. Petrol.* 39, 533-599.