INSIGHTS INTO VOLCANISM ON THE MOON FROM QUANTITATIVE TEXTURAL ANALYSIS OF MARE BASALTS. Bridget G. Guiza[1,2] and James M.D. Day[1] [1]Scripps Isotope Geochemistry Laboratory, Scripps Institution of Oceanography, La Jolla, CA 92093-0244; [2]Environmental Systems Program, University of California, San Diego, CA 92037 (e-mail contacts: bguiza@ucsd.edu and jmdday@ucsd.edu)

Introduction: Mare basalts represent derivative mantle melts and so offer key insights into the evolution of the Moon. The majority of mare basalts available for study are considered to have been erupted and emplaced on the lunar surface as lava flows no later than 3 Ga [1]. Processes involved in mare basalt petrogenesis are crucial to understanding their geochemical signatures (e.g., [2-4]), yet our basic understanding of emplacement mechanisms is restricted by limited *insitu* field observations of mare basalt lava flows and on magma crystallization kinetics [5]. Here, crystal size distribution (CSD) and size distribution pattern (SDP) data are used to explore the coupled textural and geochemical evolution of mare basalts in an effort to better understand the volcanic evolution of the Moon.

Methods and samples: Methods for quantitative textural analysis of mare basalts have been described previously in [5]. Thin sections of four Apollo 11 basalts (10003, 49; 10017, 63; 10045, 46; 10057, 61), three Apollo 12 basalts (12021, 132; 12052, 89; 12063, 18), and one Apollo 14, 14053, 187 have been examined under a Nikon Eclipse LV 100 POL transmitted/reflected light microscope. Thin sections were imaged under five times magnification using plane polarized light and stitched, followed by assessment of distortion, which was negligible. Pyroxene, plagioclase, and oxide crystals were traced using a digital overlay to the high-resolution image, with cross-checks for crystal outlines using ten times magnification on the microscope (Figure 1).

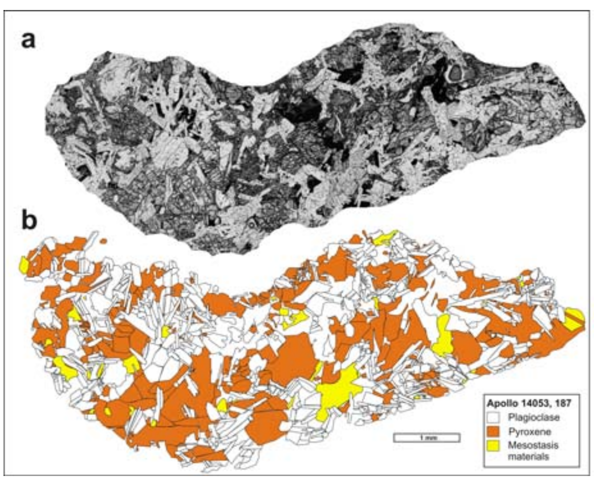

Figure 1: *(a) High-resolution grey-scale plane polarized light image of 14053, 187 and (b) digitized tracing of silicate phases within the sample.*

We have performed digitization of images for plagioclase in 14053 and pyroxenes in 12052, with ongoing analysis of phases from other samples. Images were processed using *Image J,* and 3-D crystal dimensions were predicted using [6]. Stereological corrections were made using *CSD corrections* software [7]. R-values were calculated using the technique of [8].

Results for 12052, 89: 12052 is a porphyritic pigeonite basalt with euhedral skeletal pyroxenes (58-68 modal %) composed of low-Ca cores and high-Ca rims. We obtained a strongly kinked CSD, consistent with emplacement of a crystal-cargo (low-Ca cores) followed by rapid crystallization of high-Ca rims (Figure 2). This mode-of-origin contrasts strongly with mare basalt meteorites with geochemical affinities to Apollo 12 basalts and that exhibit single-stage nucleation and growth [5], but is consistent with open-system crystallization for Apollo 12 mare basalts [9].

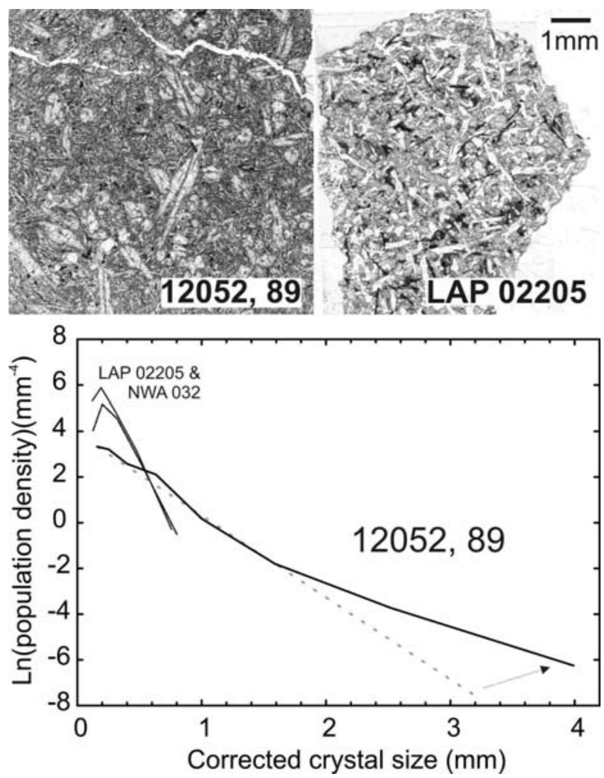

Figure 2: *CSD diagram for 343 pyroxene grains from 12052 versus pyroxenes from mare basalt meteorites LAP 02205 (n = 563) and NWA 032 (n = 302) [5]. Also shown are scaled plane polarized light images for 12052 and LAP 02205. Dashed lines shows straight best-fit line through <1.6 mm crystal-sizes for 12052.*

Results for 14053, 187: 14053 is an Al-rich ophitic basalt with ~30 vol% plagioclase in the sample that we studied. The texture of 14053, 187 hints at some mineral fabric, with separation of pyroxene and plagioclase (Figure 1), although this is not apparent in other studied sections of 14053. We obtain a broadly linear CSD for 14053 plagioclase, consistent with single-stage nucleation and growth, with strong similarities to LaPaz mare basalt meteorite plagioclase (Figure 3).

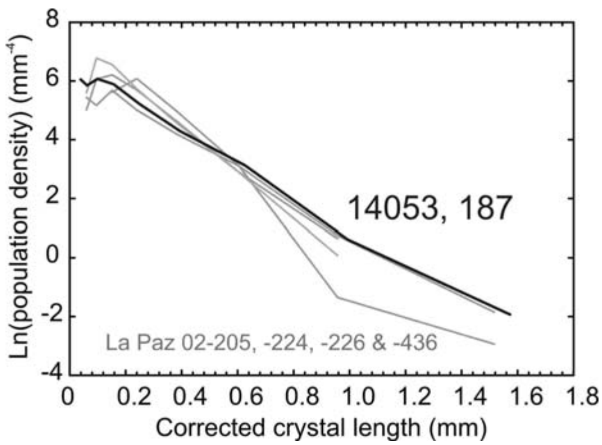

Figure 3: *CSD diagram for 821 plagioclase grains from 14053, 187 versus plagioclase data (from [5]) for mare basalt meteorites LAP 02205 (n = 542), 02224 (n = 563), 02226 (n = 868) and 02436 (n = 343).*

Discussion: Quantitative textural analyses of lunar mare basalts have previously revealed that, despite different textures, Northwest Africa 032 and the LaPaz mare basalts have similar calculated cooling rates for phenocrysts [5]. Combined with geochemical evidence for compositional pairing, this has led to a model for emplacement of a putative lava flow on the Moon to explain the relationship between a diversity of mare basalt meteorites [5]. The new CSD data for 12052 are consistent with a more complex crystallization behaviour for Apollo 12 basalts (e.g., [9]), and strong correspondence between textural evolution of lunar basaltic rocks and their mineral chemistry. Quantitative textural analysis and mineral chemistry therefore offers a refined tool for establishing geochemical evolution of mare basalts associated with their emplacement on the lunar surface [5].

It has been suggested that quantitative textural analysis may offer an additional tool - in conjunction with geochemical and petrographic indicators [10] - for distinguishing between pristine mare basalts and impact-generated melts [9]. This method relies on impact-melts generating a flatter gradient on CSD diagrams than pristine basalts, presumably associated with cooling and nucleation rates. 14053 has been considered a possible impact-generated basalt based on disturbed Sm-Nd isotope systematics and a well-defined 3.9 Ga Rb-Sr isochron age [11].

Aside from finding no evidence to suggest that plagioclase in 14053 crystallized any differently from plagioclase in ‘pristine’ mare basalts (e.g., Figure 3); using CSD to establish impact-melt versus pristine mare basalts requires further assessment. This is due to the fact that textures in rocks derived from high-temperature melts result from the dynamics of crystal nucleation and growth, which in turn reflects the cooling regime. The volume of the melt sheet and degree of under- or over-cooling will have the most profound effect on textures, as also seen in CSD studies of terrestrial igneous systems (e.g., [12]).

The most robust method for establishing pristinity of lunar rocks remains through analysis of Os isotopes and highly siderophile element (HSE) abundances. The HSE are at very low abundances in pristine lunar rocks and so are extremely sensitive to even minor contributions from HSE-rich impactor compositions (e.g., [13]). Warren et al. [14] assessed whether Apollo 14 high-Al mare basalts were impact-melt products using siderophile elements, establishing low HSE abundances in most samples, and 14053 in particular (6.6 ppt Re; 17 ppt Ir [15]). Establishing $^{187}Os/^{188}Os$ ratios and HSE abundances for 14053, as well as other Apollo 14 high-Al mare basalts will likely offer the most stringent tests of pristinity for these important samples.

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