ANALYSIS OF HIGHLAND MATERIAL IN APOLLO 17 SAMPLE 73263: IMPLICATIONS FOR FUTURE DISCOVERIES

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Introduction: The Taurus-Littrow valley, the landing site for Apollo 17, is located on the south-eastern border of the Mare Serenitatis. The main goal of this Apollo mission was to collect ancient lunar material as well as samples from volcanic deposits thought to be younger than samples retrieved from earlier missions. Station 3 was located in the light mantle landslide deposit approximately 50m east of Lara Crater (**Fig. 1**). The samples collected from this station include rock, regolith, and a double-drive tube [1]. The double-drive tube comprises samples 73002 above 73001, and these have not yet been opened.

The focus of the Apollo Next Generation Sample Analysis (ANGSA) project is to investigate drive tubes 73001 and 73002. They have stayed preserved under unique conditions and have not yet been opened or studied. In preparation for this study, we are examining samples from Apollo 17 Station 3. While more samples will be studied, the initial work is on a breccia fragment (73263,6) containing a highlands clast taken from highlands soil 73263,1 [2]. Here we have utilized electron microprobe data to examine the mineralogy and chemical composition of a highland clast present in thin section 73263,6,11 that was collected from the rim of a 10 meter crater located approximately 20 meters northeast of where these cores were collected [1]. Generally, this sample contained Mg-Suite lithologies [3].

Lunar highland rocks are chemically distinct from the rest of the Moon and allow for the study of ancient magmatic events [4,5]. In particular, ferroan anorthosites (FANs) are essential to understanding the Moon's earliest crust and are believed to originate from plagioclase accumulation via flotation in the lunar magma ocean [6]. Thus, the presence of FANs in the newly opened samples will potentially contribute to better understanding the Moon's primordial crust, potentially helping to resolve the issue of the large age-range defined by the current FAN suite (e.g. [7]).

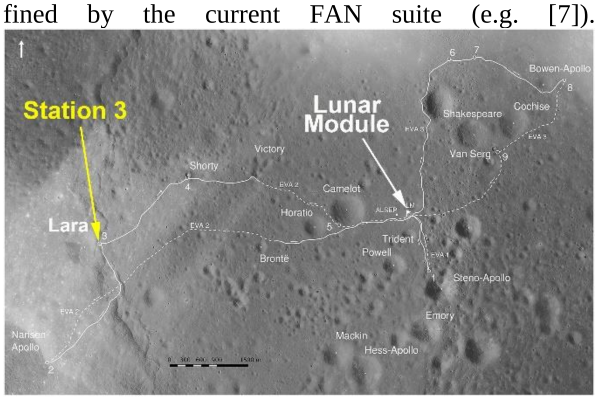

Figure 1: Map showing locations of the Lunar Module and Station 3 in the Taurus-Littrow valley (modified from [8]).

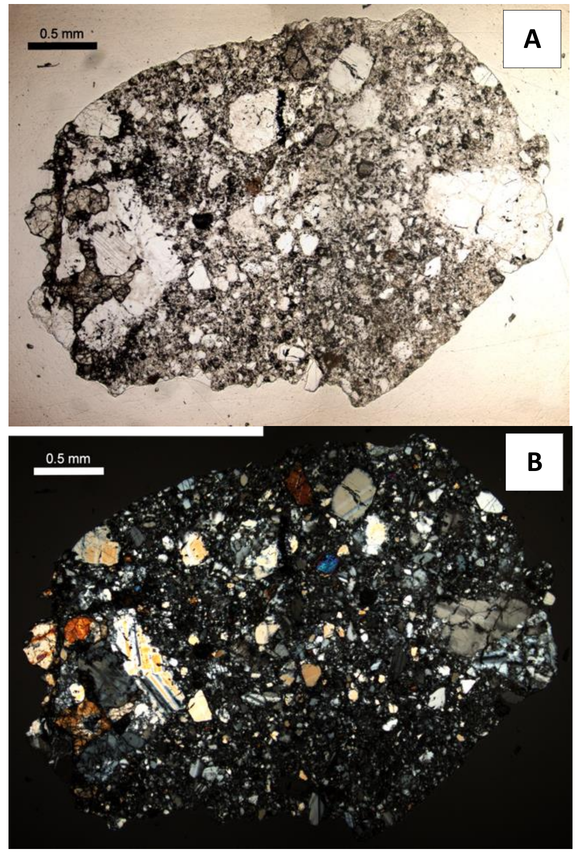

Figure 2: Composite photomicrographs of 73263,6,11 taken in both (A) plane polarized and (B) crossed-polarized light.

Methods: Photomicrographs were collected using a Nikon petrographic microscope with a 4x objective in plane-polarized light (**Fig. 2A**) and cross-polarized light (**Fig. 2B**). The images were then stitched together using *Microsoft Image Composite Editor©* and used to identify the region of interest. Through use of a CAMECA SX 100 electron microprobe at the University of Notre Dame, a map was produced of the sample and point analyses for Mg, Fe, Ca, Ti, Al, K, Si, Mn, Na, and Cr were taken using 15 kV accelerating voltage with a beam current of 25 nA on a carbon-coated thin section. The sample was analyzed for Na and K first in order to minimize the effects of volatilization. Images of collected element maps were exported to *ImageJ ©* to select relevant, representative data points for more in-depth study. 30 points were collected for pyroxene using a beam diameter of 1 µm to collect data and 31 points collected for plagioclase using a beam diameter of 5 µm.

Data were collected on both the host pyroxene and the observed exsolution lamellae as well as plagioclase rims and centers. Data collected from the electron microprobe was then analyzed to identify pyroxenes and their corresponding Mg number (Mg/(Mg+Fe)) along with the anorthite content of the plagioclase to allow a classification of the clast to be determined.

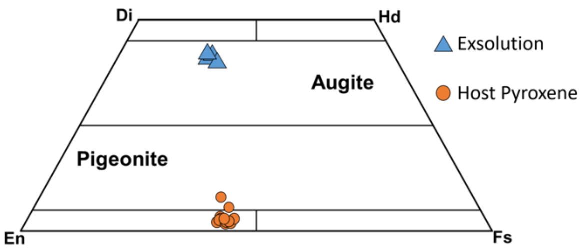

Figure 3: Pyroxene quadrilateral for 73263,6,11 showing the 2 pyroxene populations present in the clast.

Results and Discussion: Analysis shows that there is mixture of high- and low-Ca pyroxene (**Fig. 3**), with the host orthopyroxene exhibiting both wide and fine lamellae as well as blebby exsolution of augite (**Fig. 4**). As seen in basalts collected from Apollo 17, several different "sets" of augite lamellae and blebs located on the orthopyroxene can be indicative of the replacement of several individual pigeonite crystals by one orthopyroxene, or "inversion" of the pigeonite [9,10]. The continued cooling of these orthopyroxene after this reaction then causes the exsolution of augite. The clast appears to have gone through a similar process, as the exsolution observed is similar. Anorthite content, collected from both rims and cores of the plagioclase crystals, ranges from ~93 – 95%. Through comparison of the Mg number of the mafics and the anorthite content, 73263,6,11 is from the FAN suite (**Fig. 5**). FANs are relatively rare from the Serenitatis region sampled by Apollo 17 [11].

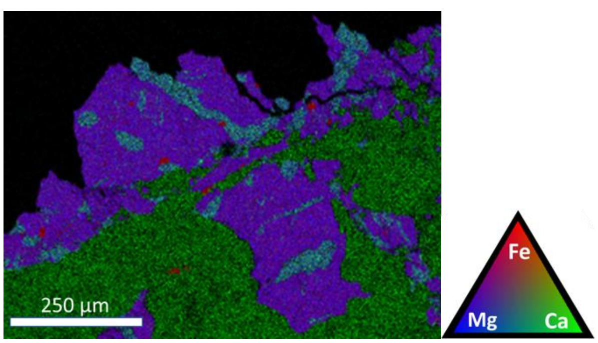

Figure 4: An element map showing a close-up of augite exsolution in the pyroxenes.

Conclusion & Future Work: The majority of the samples from Apollo 17 that have been studied have been mare basalts and Mg-Suite highlands samples [9]. However, 73263,6,11 contains a sample of the FAN suite from Station 3, which are not common in the Apollo 17 sample collection. We hypothesize there could be more FANs to be found in the unopened Apollo 17 cores and possibly other types of samples previously unknown from this site. Future studies on this sample will include studying the pyroxene exsolution features as well as crystallographic orientation to determine the cooling rates and possibly infer burial depth [7]. Additional studies will include a re-examination of other Station 3 samples to potentially identify similar patterns. Samples that have been identified for potential further study: 73155,28 (gabbro clast), 73215, 73216, 73217, 73218, 73235, 73255, and 73275 (breccias/impact melts containing various high-lands clasts).

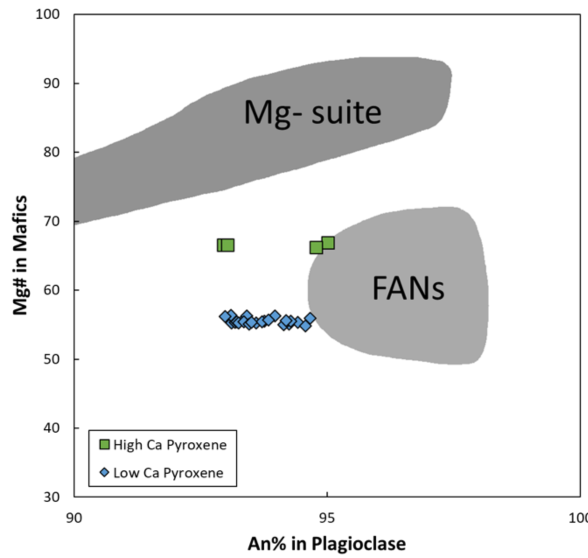

Figure 5: The highland clast found in 73263,6,11 plotted on a graph of Plagiolcase An content vs. Mg# of the mafics (pyroxenes) in the sample. This indicates the sample is a ferroan anorthosite. Adapted from [12].

References: [1] Wolfe, E.W. et. al. (1981) *USGS Professional Paper*, 1080. [2] Bence A.E. et al. (1974) *PLSC 5th*, 785-827. [3] McCallum I.S. & Schwartz (2001) *JGR 106*, 27,969-27,983. [4] Taylor, S.R. 91972) *The Moon*, 7, 181-195. [5] McCallum I.S. & O'Brien, H.E. (1996) *Am. Min. 81*, 1166-1175. [6] Floss, C. et. al. (1998) *GCA 62*, 1255-1283. [7] Borg L. et al. (2019) *EPSL 523* (in press). [8] Hasse, I. et. al. (2018) *ESS 6*, 59-95. [9] Huebner, S.J. et. al. (1975) *PLSC 6*, 529-546. [10] Taylor, O. B. et. al. (1991) *PLPS 21*, 63-87 [11] Schmitt H. H. et al. (2017) *Icarus 298*, 2-33. [12] Gross. et. al. (2014) *EPSL* 388, 318-328.