INVESTIGATING THE HISTORY OF ALLAN HILLS (ALHA) 81005: WHAT A METEORITE'S COMPONENTS CAN TELL US ABOUT IT'S PAST.

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Introduction: Lunar meteorites have the potential to advance our understanding of lunar chronology and extraterrestrial geological processes beyond what can be determined from the returned Apollo and Luna samples. This is due to the fact that lunar meteorites are potentially derived from regions across the lunar surface, far from those sampled in-situ by sample recovery missions [1,2,3]. Specifically, meteoritic lunar breccias have the potential to provide wide-ranging constraints on lunar evolution due to their likely complex impact history which has resulted in the amalgamation of a diverse suite of minerals and lithologies into what is now one sample.

In order to evaluate the potential these complex meteorites have to record events throughout the Moons history, this study focusses on evaluating the mineralogy, textural relationships, petrology, and chronology of the anorthositic polymict regolith breccia Allan Hills (ALHA) 81005. Uniquely, this meteorite was the first meteorite to be classified as lunar in nature [4].

From previous work, the clast types identified to date include the main rock types that are found on the Moon today: troctolites, norites, Mg-suite, mare basalt, impact melt breccias, and granulitic breccias [4]. Therefore, ALHA 81005 presents an excellent opportunity to study the diversity of a range of lunar rock types and unravel the processes and associated timing of events which led to not only their formation, but also their incorporation into the breccia as observed today. Although ALHA 81005 was found in the early 1980s, a comprehensive understanding of the age of the meteorite and its clasts also remains lacking. There have been only 3 previous age studies examining ALHA 81005, and these resulted in poorly constrained Lead-Lead (Pb-Pb) ages of 4.5-3.9 Ga, and a poorly constrained Potassium-Argon (K-Ar) gas retention age of 4.3±0.9 Ga. With respect to composition, ALHA 81005 is broadly consistent with the Moon's near-side which implies that the clasts within it are at least older than 4.0 Ga (based on current understanding of lunar geology and evolution).

The primary goal of this work is to therefore examine and classify the clasts of ALHA 81005, evaluate their minerals and textures, and identify appropriate phases for *in-situ* geochronological analysis. Currently, three sections of this meteorite are available to study (-23, -80, -92).

Methods: Polarized light and backscatter-electron (BSE) images of thin sections 23, 80 and 92 have been collected along with spectral data [Figures 1-3]. Polarized light images were collected on a Leica DM2700 P Petrographic Microscope with attached MC190 HD Microscope Camera as well as an Olympus Research System Microscope AX-70 and composited on a Zeiss 710 Confocal Microscope. Preliminary X-ray elemental maps were acquired on a Cameca SX-50 Electron MicroProbe at the University of Notre Dame's Materials Characterization Facility (MCF). This work is continuing in-house using a Zeiss Supra 35 VP FEG-SEM at Miami University's Center for Advanced Microscopy and Imaging (CAMI). At CAMI, the x-ray spectra were collected using a Bruker Quantax 100 Energy Dispersive x-ray microanalysis system. This approach follows similar work presented in previous studies [5, 6], but has been adapted for this instrumentation and software.

Results: Observations of sections 23 and 80 are consistent with their anorthositic classification. Observed during BSE imaging [Figure 2], compositions consistent with anorthite dominate the majority of the background (glassy groundmass) regions in these sections. Other individual mineral phases that have been observed throughout these thin sections include plagioclase, clinopyroxene, olivine, ilmenite, spinel, taenite, troilite, and pigeonite. Due to shock and heat from the impact, several grains are highly fractured.

In Plane Polarized Light (PPL), some areas of within glassy groundmass are also observed to have a flow structure [Figure 3].

Future Work: Identification and classification of the different clast types throughout the 3 sections available for study will form the basis of the next steps of this work. By quantifying clast type and distribution, we hope to gain additional insights into the nature of the lithologies that potentially existed at the impact site. Future work will include detailed HyperMapping of each section via SEM-EDS, complemented by detailed petrographic characterization. This approach will also work to identify U-bearing phases which will be targeted for U-Pb chronological analyses.

References: [1] Snape, J. F., et al. (2016) *EPSL*, 451; 149-158; [2] Michael, G., et al. (2018) *Icarus*, 302; 80- 103; [3] Morbidelli, A., et al. (2018) *Icarus*, 302; 262276; [4] Treiman, A. H & Drake, M. J. (1983) GRL, 10(9); 783-786; [5] Joy, K. H., et al (2011) *GCA*, 75; 2402-2452; [6] Niihara et al., (2013) 44th *LPSC*, #2083.

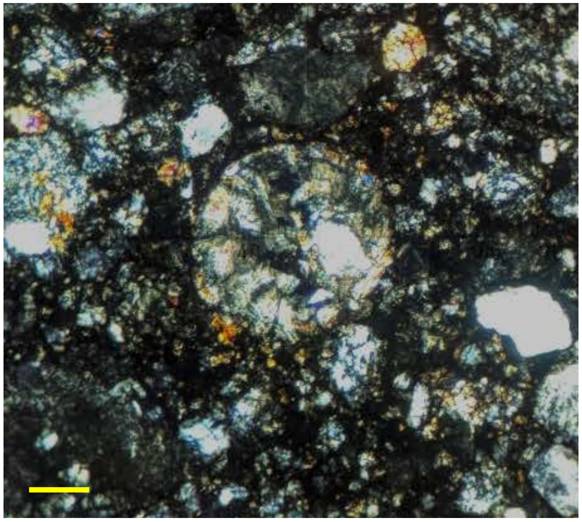

Figure 1: XPL image of section 80. Circular structure in center. These circular features have well-defined outer edges and contain crystals within. Magnification is at 10x. Scale Bar is 20 µm.

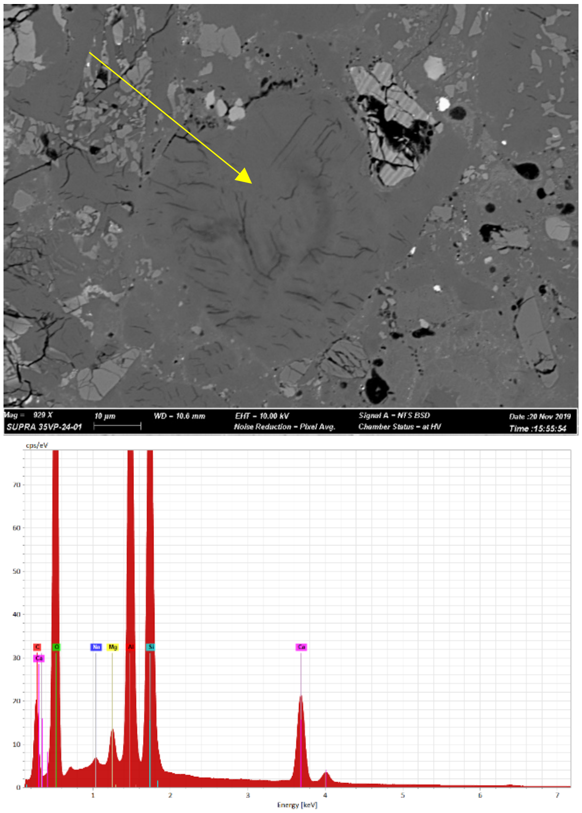

Figure 2: BSE image of an anorthite clast in section 80. Gray area in the center is the clast confirmed by spot analysis on the SEM. Spectra is representative of several spots analyzed.

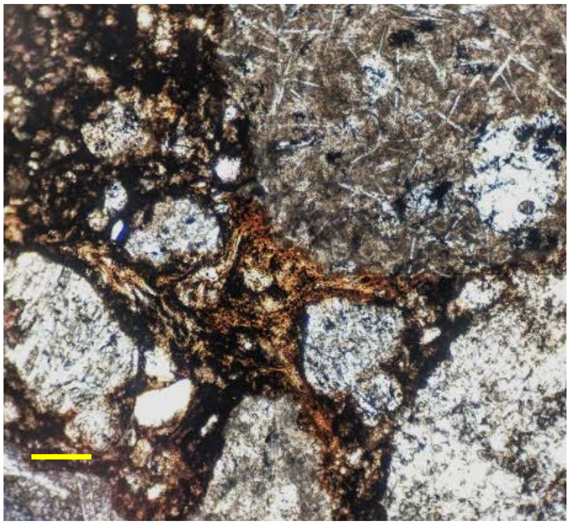

Figure 3: PPL image of section 80. Observed glassy ground mass with flow structure. Magnification is at 10x. Scale Bar is 20 µm.