Investigating the History of Allan Hills (ALHA) 81005: What a Meteorite's Components Can Tell Us About It's Past

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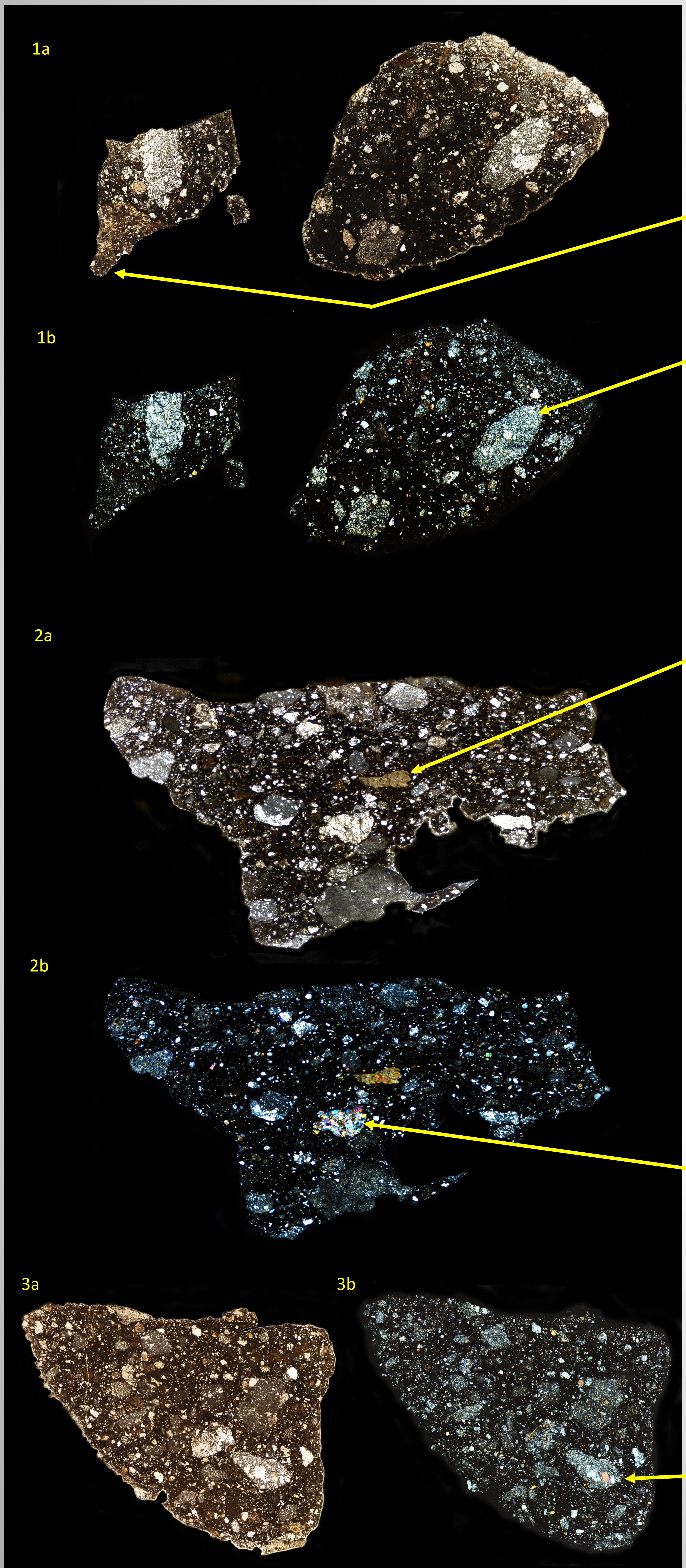
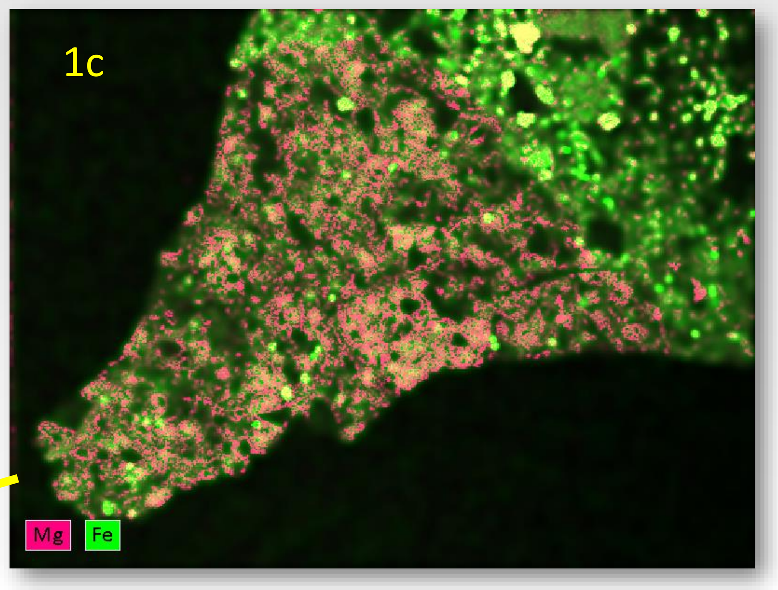
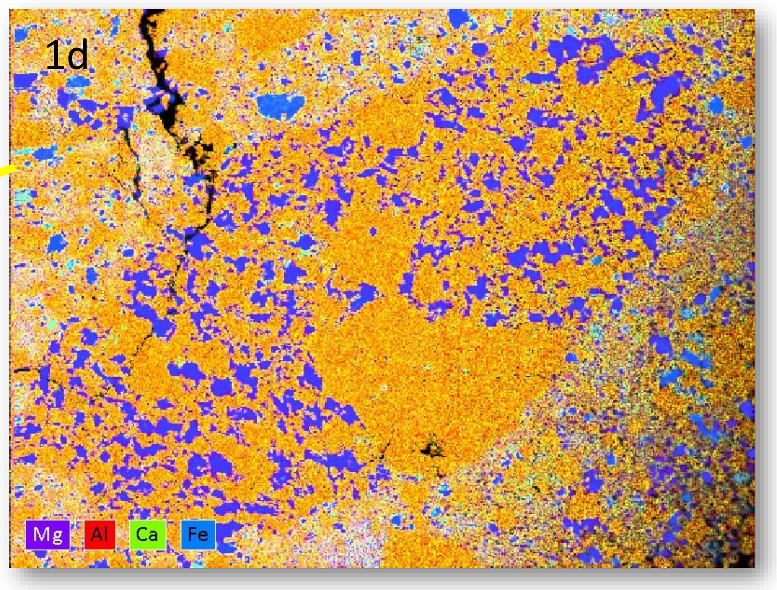
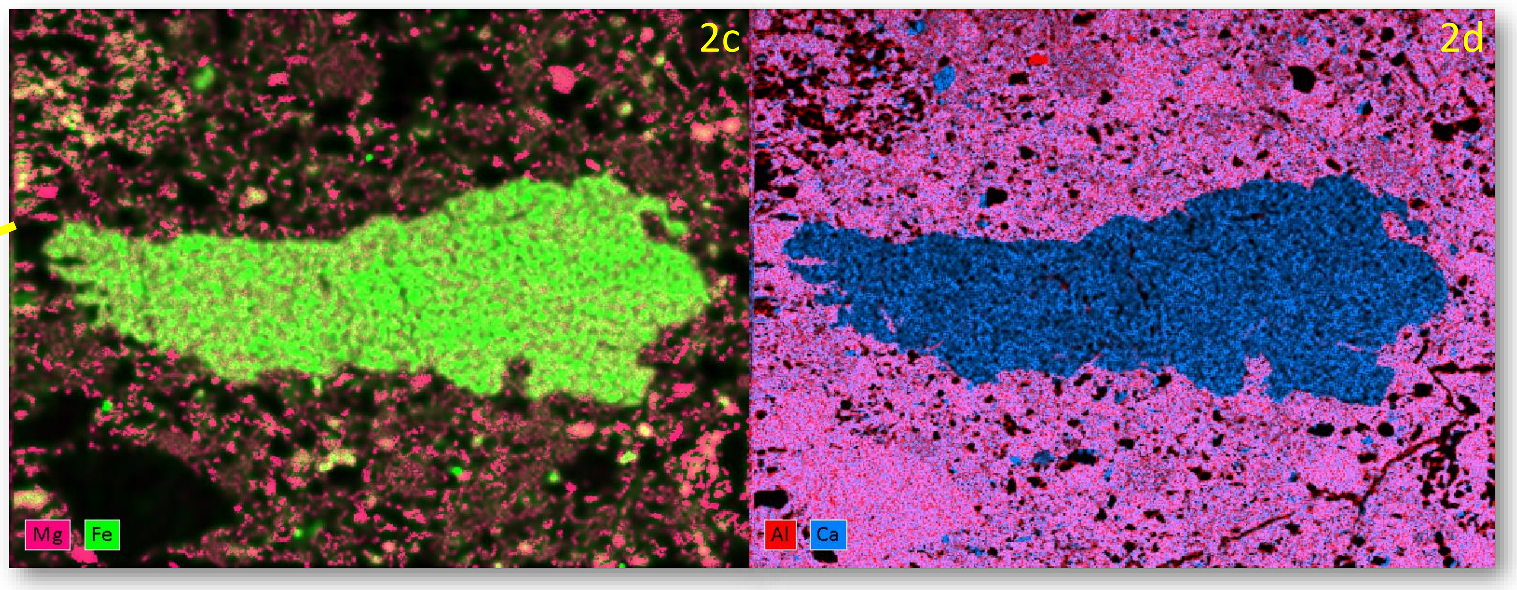


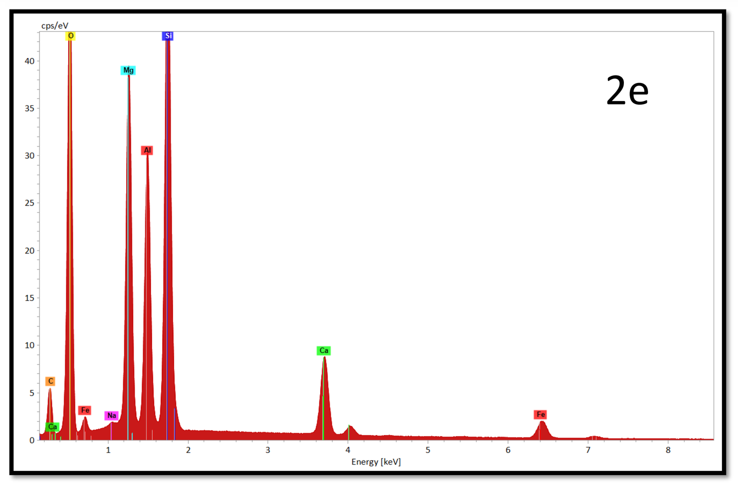


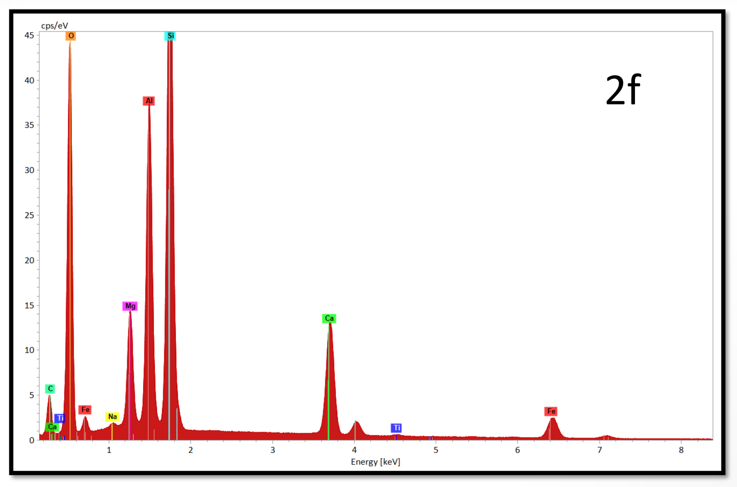


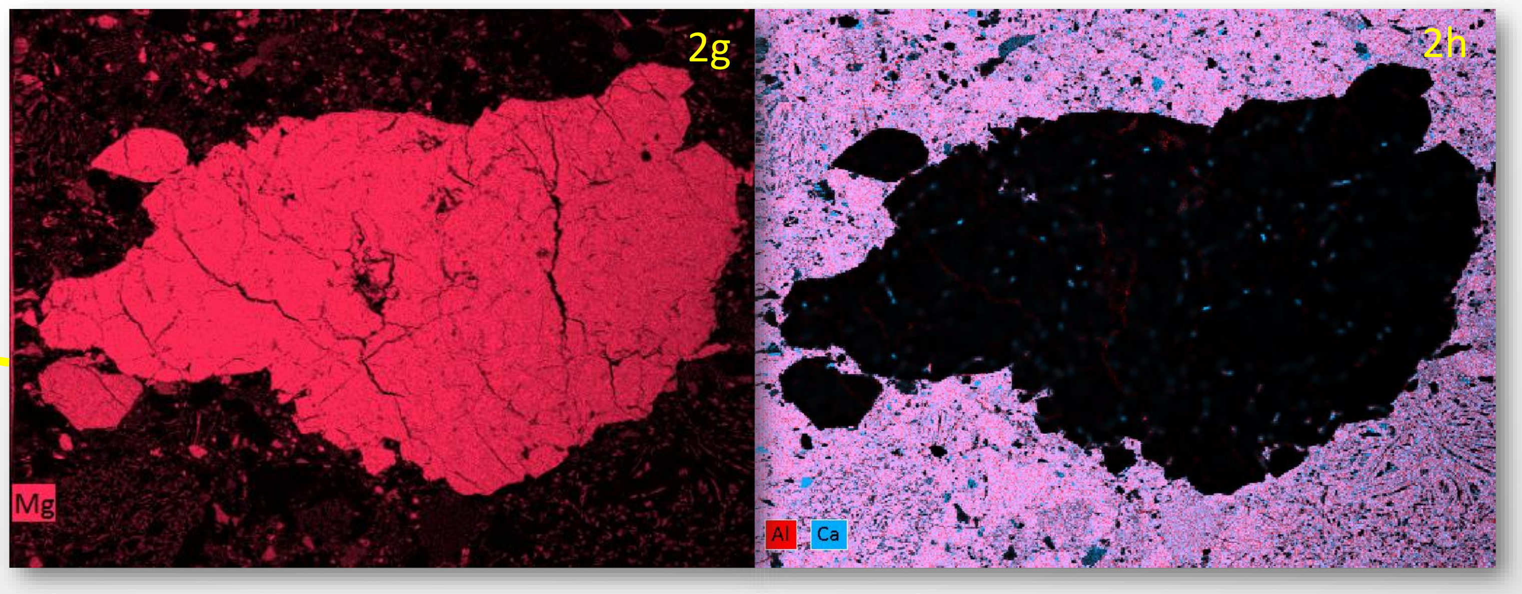
Introduction: Considering lunar meteorites can originate from across the whole lunar surface, they have the potential to advance our understanding of chronology and extraterrestrial geological processes beyond what can be determined from the returned Apollo and Luna samples. The complex nature of meteoritic lunar breccias provide constraints on the evolution of the Moon due to their complex impact histories. These meteorites are amalgamations of diverse minerals and lithologies sampling different periods of time and potentially a variety of localities. Focusing on mineralogy, textural relationships, petrology and chronology of anorthositic polymict regolith breccia Allan Hills (ALHA) 81005, we aim to evaluate the potential that these complex meteorites have in recording evolutionary processes of the Moon. Uniquely, ALHA 81005 was the first meteorite to be classified as lunar in nature. Previous work has identified clast types that include main rock types found on the Moon today: troctolites, norites, Mg-Suite, mare basalt, impact melt breccias and granulitic breccias. ALHA 81005 allows for an excellent opportunity for study of diverse lunar rock types as well as unraveling the timing of events and processes that lead to their formation and incorporation into these breccias. There have only been three age studies examining ALHA 81005 which leaves a comprehensive understanding of its age and clasts lacking. Previous age studies of Pb-Pb (4.5-3.9 Ga)[1,2] and K-Ar gas retention (4.3 ± 0.9 Ga)[3] must be further constrained. ALHA 81005's composition is broadly consistent with the lunar near-side suggesting clasts within it are 4.0 Ga or older. Primary goals of this work are evaluating minerals and textures, identifying appropriate phases for *in-situ* geochronological analyses. Currently, three sections of ALHA 81005 are available for study (23, 80, 92).

Figure 1a: PPL image of section 80. **Figure 1b:** XPL image of section 80. **Figure 1c:** 15 minute Mg/Fe elemental map of the "duck bill" part of section 80. Strong Mg component may have been part of a clast. Grain size is significantly smaller in this area than areas with strong Fe component. **Figure 1d:** 15 minute Mg/Al/Ca/Fe elemental map of a large clast contained in the larger part of section 80. **Figure 2a and 2b:** PPL and XPL images of section 92. **Figure 2c and 2d:** 15 minute Mg/Fe and Al/Ca elemental maps of a large grain in section 92. The strong Fe and Ca signatures suggest a pyroxene composition. This grain also contains a Ti signature (not pictured). This grain and surrounding area pictured in **2c/2d** correlate with the EDS signature in **2f**.









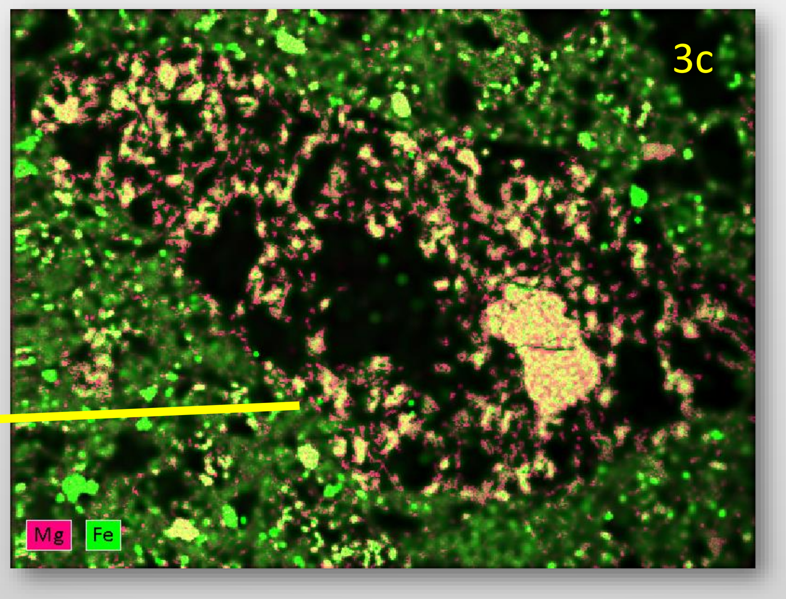


Figure 2g and 2h: 45 minute Mg and Al/Ca elemental maps of a large grain (the upside down turtle) in section 92. There is a stark contrast between the Mg and Fe (not pictured) signatures of this grain as the Fe component is very weak. Between the polarized light images and elemental mapping, this grain is believed to be an olivine with forsteritic composition. **2g and 2h** correlate with the EDS signature in **2e**. Notice the textures beginning to show in the lower left of **2h**. **Figures 2c/d/g/h** seem to be individual grains that remained intact, although are still highly fractured. **Figure 3a and 3b:** PPL and XPL images of section 23. **Figure 3c:** 15 minute Mg/Fe elemental map of a large clast in section 23.

Methods: Polarized light and backscatter electron (BSE) images of thin sections 23, 80 and 92 have been collected along with elemental maps and spectral data. This technique follows Joy et al., (2011) and Niihara et al., (2013) and was adapted for this instrumentation. Polarized light images were collected on a Leica DM2700 P Petrographic Microscope with attached MC190 HD Microscope Camera. They were stitched together using LAS X software. Clast 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 but has been adapted for this instrumentation and software. Elemental Maps included here are either 15 or 45 minute maps with a resolution of 512 x 384 and 1.2 µm spot size.

Discussion: The nature of sections 23, 80 and 92 are consistent with ALHA 81005s anorthositic classification. BSE imaging and elemental mapping reveal a strong background of glassy groundmass anorthitic in composition. Individual grains of plagioclase, clinopyroxene, olivine, ilmenite, spinel, taenite, troilite and pigeonite have all been observed. Shock and heat from the impact has fractured many grains and clasts, but enough cohesion exists for some structures to remain intact, albeit fragmented. In Plane Polarized Light (PPL), some areas of glassy groundmass a flow structure is observed. Each of the sections seem to have a very strong Mg component in that even with 15-45 minute elemental maps, areas containing Mg showcase extremely crisp boundaries. The nature of these sections' Mg component should be explored. Identification and classification of the different clast types throughout the three 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 higher resolution elemental mapping, as well as detailed HyperMapping of each section via SEM-EDS, complemented by detailed petrographic characterization. The hypermapping will also work to identify U-bearing phases which will be targeted for U-Pb chronological analyses.

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