AGE DISTRIBUTION OF LUNAR IMPACT-MELT ROCKS IN APOLLO DRIVE-TUBE 68001/2.

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Introduction: Understanding the bombardment history of the Earth-Moon system is a key scientific goal of the planetary science community for determining the modification of the lunar crust, as well as understanding the evolution of the inner Solar System [1]. Determining the ages and compositions of impact-melt rocks, in returned sample collections (Apollo and Luna) and lunar meteorites, have been used to address questions related to the impact history in the Earth-Moon system in addition to investigating the regional geology at collection sites. However, older impact-melt rocks may be gardened back into the regolith column, potentially making them volumetrically rare at the surface. Whereas, the opposite may be true for the youngest impact-melt rocks which could be over-sampled nearest the surface, particularly those collected near small, young craters. Therefore, the role of gardening could have caused a possible bias affecting the preservation of impact-melt samples in the near-surface regolith and needs further clarification.

Choosing samples from various depths in the lunar regolith is one way to understand the changes in impact-melt sample population that have been affected by gardening. The Apollo 16 double-drive tube 68001/68002 provides the opportunity to evaluate variations in age and composition of impact materials with depth. Previous work [2] has determined five compositionally distinct units in the core based on composition and the soil maturity parameter I_s/FeO. A small inflection in the I_s/FeO profile at 3 cm depth in the core, may be related to the nearby South Ray impact event, making this horizon similar to the Apollo 12 and 15 soils, containing dated spherules. As the five horizons can be distinguished from each other, each may contain a potentially distinct population of impact-melt rocks. These distinctions can provide an understanding of the complex history at the Apollo 16 site, as well as shed light on the gardening effect on these populations of samples.

We aim to separate the samples according to parent lithology, and then conduct ^{40}Ar-^{39}Ar dating on representatives from each lithology in each interval to build a complete picture of the materials contributed to that horizon.

Samples: Six 0.5-g bulk soil samples from each of the five horizons in 68001/2 were requested, plus one sample from the near surface. Each soil sample was sieved into aliquots of size fractions >250 μm, >106 μm, and fines. All aliquots had 50-70 individual particles in the 250+ size fraction that were used for continued analysis.

The initial grouping of particles was done visually using a petrographic microscope, followed by micro-XRF analysis to determine the major-element chemistry, along with several terrestrial K-feldspar grains for calibration. PCA and hierarchical clustering methods to analyse the datasets were used but not enough variations was found in the major-elements to form groupings, although the K-feldspar readily stood out.

68001/2 Groupings: To determine the petrology and composition and to achieve a more robust association of particles, each grain was mounted using superglue, hand-polished with SiC grinding paper, and analysed by a Phenom ProX desktop SEM providing texture and EDS elemental spectral data (i.e., mineral compositions), to distinguish volcanic, plutonic, and impact-melt samples [3-5].

Before EDS analysis of the Apollo 16 samples, a number of mineral standards were used to test the calibration of the SEM under the same sample acquisition settings. Fig 1 shows the uncertainty in measurements from a standard fayalite and anorthosite grain. We used this to determine the uncertainty in the measurements for the lunar samples and to fully understand the boundaries of using the EDS data to form representative groups. It is important to note that the EDS measurement are not used to perfectly identify parent lithologies but used as a technique to further group the individual particles for later classification.

So far, four horizons (1079, 1105, 1106, 1108) have been analysed. Using the back-scatter electron images from the SEM the individual samples were grouped by texture and then further defined by mineral and melt composition data from the EDS analysis (examples in Fig 2). From this 11 groups have been determined with every horizon containing at least 8 of the groups (Fig 3):

Group 1: Clast-rich impact-melt breccias with granulitic melt material and plagioclase mineral clasts. ***Group 2:*** Clast-rich impact-melts with subhedral fine-grained to medium-grained mineral fragments in a glassy mafic matrix. ***Group 3***: Impact-melt breccias with a subophitc texture***.*** ***Group 4:*** Regolith Breccias including a variety of impact melt and lithic clasts, not necessarily grouped together in terms of minerology, but as a rock type. ***Group 5:*** Granulites containing anhedral plagioclase and mafic minerals***.*** ***Group 6:*** Clast-bearing hypocrystalline impact-melts. The microporphyritic matrix exhibits both fine and coarse grained interstitial textures. ***Group 7***: Clastic feldspathic impact-melt breccias with pockets of mafic melt. ***Group 8***: Crystalline impact-melts with subophitic texture of tabular plagioclase and interstitial mafic minerals. ***Group 9***: Anorthosites with minor accessory minerals (e.g., FeS and FeNi). ***Group 10***: Hypocrystalline clast-free impact-melts with spinifex-like texture. They have very fine-grained acicular plagioclase crystals with interstitial mafic phase and some miner plagioclase clasts. ***Group 11***: Fragmental breccias dominated by basaltic material.

Ongoing work: Once all of the samples are polished and analysed, and groupings are finalised, representative polished sections from each group will be further classified using micro Raman spectroscopy and electron microprobe techniques, followed by Ar-Ar dating of individual impact-melt particles.

References: [1] National Research Council (2007), The Scientific Context for Exploration of the Moon, Final Report. [2] Korotev *et al.* (1997) *Geochim Cosmochim Acta* 61, 2989-3002. [3] Cohen *et al.* (2005) *Met Planet Sci* 40, 755-777. [4] Delano (1986) *J Geophys Res* 91, 201-213. [5] Zeigler *et al.* (2006) *Geochim Cosmochim Acta* 70, 6050-6067.

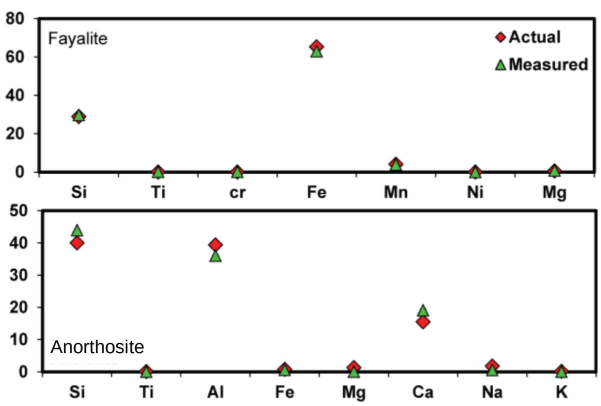

Fig 1: Comparison on measurement made on Phenom ProX SEM for a fayalite and anorthosite standard. Measured data and errors are based on 10 point measurements and the standard deviation of these measurements (2σ). Error bars are shown but are smaller than the data point.

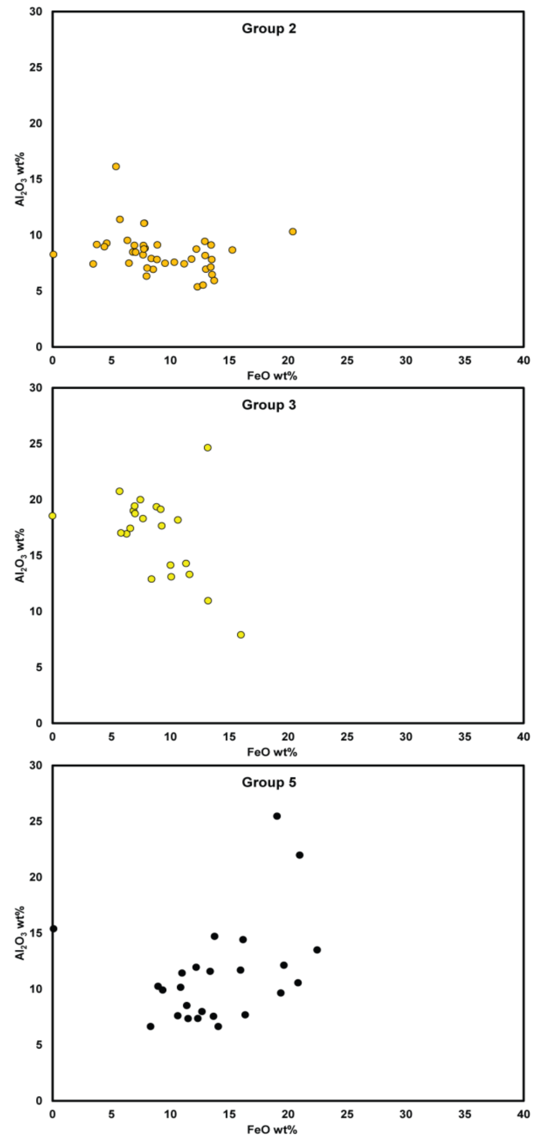

Fig 2: Al_2O_3 and FeO EDS spectral data (converted to oxide wt%) for groups 2, 3 and 5. This data was collected for several points from each of the individual particles and used to further classify the sample into groups. The data also provided evidence of anomalous grains that have similar texture but completely different mineral chemistry.

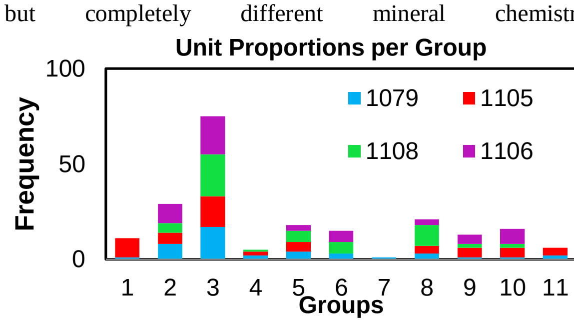

Fig 3: Frequency of the groups in each horizon of 68001/2.