**INVESTIGATING THE APOLLO 16 REGOLITH RECORD IN PREPARATION FOR SURFACE MISSIONS.** S. L. Halwa¹, K. H. Joy¹, R. Tartèse¹, M. Nottingham¹, and S. K. Bell¹,², ¹Department of Earth Sciences, The University of Manchester, UK, ²Stratum Reservoir, Sandnes, Norway (stephanie.halwa@postgrad.manchester.ac.uk).

**Introduction:** Remote sensing data has shown there may be enhanced hydrogen (i.e., water ice?) and volatile concentrations stored in the regolith in permanently shadowed regions (PSRs) at the lunar poles [1-4]. The European Space Agency will send an experiment package called PROSPECT to the lunar south polar region to determine the abundance and isotopic composition of these volatiles [5]. The regolith in the proposed landing site area is dominated by lunar highland crustal material [6], likely similar to the samples returned by the Apollo 16 mission, which visited the central nearside lunar highlands. In preparation for PROSPECT, it is important to understand impact mixing processes in the lunar highlands, and how this has affected the volatile budget of ‘typical’ ice-free feldspathic regolith.

We aim to (i) determine how Apollo 16 (A16) highland regolith has been mixed by impact events, (ii) define a ‘dry’ highland regolith baseline volatile budget, and (iii) investigate the sources of volatiles in such samples of ‘dry’ lunar highlands regolith.

**Methods:** We studied 25 thin sections from various depths within 4 double drive tube cores, which sample the central and southern areas of the A16 landing site. Their mineralogy has been determined using an FEI QUANTA 650 field emission gun (FEG) scanning electron microscope (SEM), at The University of Manchester, with an accelerating voltage of 25 kV, a beam current of 10 nA, a step size of 5 μm (1 pixel = 5 μm) and scanned in field image mode. The QEMSCAN software assigns a mineral to each pixel based on energy dispersive spectroscopy (EDS) X-ray spectra and backscatter electron (BSE) brightness collected at each point. A modified version of the Bell et al. [7] lunar SIP list was used to analyse the phase components of samples. We compare our data with published datasets for the cores.

**Results:** Changes in regolith maturity (i.e., space weathering history) is quantified using a sample’s L/FeO index [e.g., 8], agglutinate abundance, optical properties (e.g., grain size, glass abundance) or solar wind noble gas abundances [e.g., 9,10]. For the A16 core samples, plots of some maturity properties with depth (Fig. 1) highlights the presence of varied stratigraphic horizons (black arrows), with the potential of stratigraphic correlation across the landing site. At A16 station 4 (sample 64002/64001), there is a sharp change at 50 cm depth, where below this depth samples are more feldspathic, more abundant coarser (>1 mm) clasts and higher maturity (Fig. 1A). Above this depth (at 42-50 cm) there is an enrichment in basaltic mafic components. For station 8 (68002/68001), there is a decrease in L/FeO from sub-mature (~32) to immature (~18) at 37 cm depth (Fig. 1B). The base of this core (>37 cm depth) has a higher abundance of large (>5 mm), clast-rich, impact melt breccias. At the 39-43 cm depth, the agglutinate abundance does not correlate with maturity, which may represent a “baked” horizon [11] (Fig. 1B).

For station 10 (60010/60009) there is a change at 50-53 cm depth (Fig. 1C), where we observe an increase in coarse (>1 mm) anorthositic plagioclase fragments in a layer that has a CRE age of 125 Myrs [12], but this has yet to be related to a specific impact event. Finally, core 60014/60013 contains no apparent horizons, indicating a well-mixed regolith in this area (Fig. 1D).

**Figure 1:** Plots of L/FeO (purple line [8,11,13,14]) and agglutinate abundance (modal % area; blue line) vs. depth for 4 A16 double drive tube cores: 64002/64001 (A), 68002/68001 (B), 60010/60009 (C) and 60014/60013 (D). Red arrows represent the depth of surficial reworking, black arrows represent stratigraphic horizons. Sample depths from our study are highlighted by blue stars. Green and yellow lines [16,17] are optical counts of agglutinate particles from soil fractions 90 – 150 μm grain size.
Maturity indices can also highlight the depth of the uppermost recent surficial reworked layer (Fig. 1 - red arrow). Below this layer glass contents, agglutinate abundance and grain size all decrease, while the abundance of monomineralic fragments and lithic clasts increases. For the A16 cores from stations 4 and 10, we observed this depth to be 10-13 cm (Fig. 1A, C & D) [8,13,14]. However, at station 8, the surficial layer is homogenous (with respect to maturity) up to a depth of 27-29 cm (Fig. 1B), where the surficial layer may have been removed, or the regolith is better mixed.

Discussion: With the lack of depth-correlated stratigraphic horizons between the stations we have studied, it is challenging to understand correlations of impact layers across the A16 landing site. Additionally, as core 68002/68001, collected closest to South Ray crater, does not appear to contain any significant South Ray ejecta contributions [11], the distribution of material relating to this event remains unclear.

The A16 landing site is composed of material from the Cayley Plains and Descartes Highland units. Mineralogically, Descartes material is more feldspathic (i.e., plagioclase-rich) than Cayley material [15], where Cayley material has a significant input of a mafic component, resulting from the incorporation of distal, basin impact ejecta, such as Imbrium [15]. Descartes material also typically exhibits higher olivine/pyroxene ratios (0.6 – 0.8) than Cayley material [15]. At station 4, which sampled the slope of Stone Mountain, all samples from the 64001/64002 core are highly feldspathic (45 – 55 % plagioclase) akin to the Descartes mineralogy, except for a sample from 42 cm depth (64001,6049; Fig. 2), which is more akin to Cayley material, with a lower plagioclase abundance (~40 %) and olivine/pyroxene ratio (0.3). This could be the result of an input of mare-rich ejecta, which lowers the olivine/pyroxene ratio to appear more Cayley-like. Alternatively, this could be due to an influx of mafic impact melt breccias, which are chemically akin to Cayley material [16]. At station 10, which is close to the lunar lander, samples from both cores are mineralogically more similar to Cayley material, apart from the 54 cm depth sample (60009,6066; Fig. 3), which has feldspathic rock fragments, but a low olivine/pyroxene ratio (0.27). This is not characteristic of Descartes or Cayley material, indicating possible input of ejecta from another feldspathic region.

Future analyses: We plan to analyse the noble gas concentrations of regolith sub-splits sampled from the same depth intervals as our thin sections, and couple this with the chemistry to calculate cosmic ray exposure (CRE) ages. We will provide noble gas abundance data for a range of ‘dry’ highland regolith samples and untangle the relative sources of noble gases (and, thus, volatiles) using their isotopic ratios (such as 22Ne/20Ne and 21Ne/20Ne) and assess if implantation methods are constant both temporally and with depth. This can also be coupled with the QEMSCAN observations to understand how the maturity of a sample impacts its noble gas budget, and the retention of volatiles in impact produced fragments e.g. glasses. These noble gas data may also allow us to better decipher regolith processing with depth at the Apollo 16 landing site.

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