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Lunar Regolith Characterization for Simulant Design and Evaluation

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NASA's Marshall Space Flight Center (MSFC), in conjunction with the United States Geological Survey (USGS), is implementing a new data acquisition strategy to support the development and evaluation of lunar regolith simulants. The objective is to characterize the variance in particle composition, size, shape, and bulk density of the lunar regolith. Apollo drive and drill cores are the preferred samples as they allow for investigation of variation with depth, and many proposed operations on the moon will involve excavation of lunar regolith to depths of at least tens of centimeters. Multiple Apollo cores will be sampled multiple times along their vertical axes and analyzed. This will permit statistical statements about variation both within a core, between closely spaced cores, and between distant areas. In addition to acquiring new analyses, personnel from other NASA centers like the Astromaterials Research and Exploration Science

(ARES) at Johnson Space Center and the Glenn Research Center are supplying expertise and offering knowledge of previous published and unpublished studies.

The first analyses of lunar regolith samples by the simulant group were carried out in early 2008 using QEMSCAN® beam analysis. This technique combines multiple fully automated energy-dispersive X-ray detectors and off-line image processing to produce digital mineral maps of particles, and the result is an unprecedented quantity of mineralogical and petrographic data. This is the first application of this technique to lunar regolith and it yielded >20 million points of spectral data. The textural complexity of the material is such that data are still being processed and that the results are considered preliminary.

We present preliminary modal data (area%) of Apollo 16 samples from drive core 64001/2. The analysed lunar samples are thin sections 64002,6019 (5.0-8.0 cm depth) and 64001,6031 (50.0-53.1 cm depth) and sieved grain mounts 64002,262 and 64001,374 from the depth intervals corresponding to the thin sections – 5.0-5.5 cm and 52.0-52.5 cm, respectively. Four size fractions were analysed for each of the sieved samples: 500-250μm, 150-90μm, 75-45μm, and <20μm.

It is one aim of this project to use the QEMSCAN® method to obtain data on individual particle size and shape in the lunar regolith. At this point in the data processing, the results are modal% by phase rather than by particle type, so they are not directly comparable to most previously published lunar data that report lithic fragments, monomineralic particles, agglutinates, etc. Some initial findings include: the finest fractions (<20 μm) in the sieved lunar samples are enriched in glass relative to the integrated compositions by ~30% for 64002,262 and ~15% for 64001,374. Plagioclase, pyroxene, and olivine are all depleted in these finest fractions. Contrary to previously reported modal analyses of monomineralic grains in lunar regolith, these area% modal analyses do not show a systematic increase in plagioclase% or in plagioclase/pyroxene as size fraction decreases.

Results from QEMSCAN® are being checked against SEM and image analysis at the USGS beam lab in Denver, Colorado. Furthermore, the USGS beam lab is providing supporting work on phase chemistry and trace mineral occurrence and chemistry using their SEM and electron microprobe facility.

NASA's current lunar architecture puts the eventual locus of habitation in a lunar polar region. Since the lunar poles are believed to have highlands-type geology, we are first analyzing samples from Apollo 16 – as it is the only purely highlands Apollo site. The data acquisition project will expand to incorporate other Apollo sites including mare and KREEP-enriched *Procellarium* terrane samples.