GRAIN SHAPE (FORM AND SURFACE TEXTURE) ANALYSIS OF SOME MARS AND LUNAR REGOLITH SIMULANTS. M. A. Velbel[1], E. P. Alemao[2], B. L. Bischer[2], S. Gorantla[2], K. F. Hawkins[2], C. L. Herz[2], R. E. Loren[2], M. R. McGillis[2], P. Mohanraji[2], J. G. Ortiz[2], L. E. Pingilley[2], K. P. Satheesh Kumar[2], P. G. Terzini[2], R. K. Vallurupalli[2], B. A. Wert[2], B. F. E. Afonso[2], N. Denning[3], X. Ni[3], M. Leon[3], and Q. Jin[3] [1]Department of Earth and Environmental Sciences, Michigan State University, East Lansing, MI 48824 USA (velbel@msu.edu), [2]Honors College, Michigan State University, [3]Department of Civil & Environmental Engineering, Michigan State University (billjin@egr.msu.edu).

Introduction: Terrestrial analogs and simulants of lunar and martian "soil" have been used for decades to support surface-mission design and operations [1,2,3] and to support the interpretation of *in situ* regolith geotechnical properties from lander and rover measurements of soil physical properties [4,5]. A number of science-community endorsed investigation strategies for future samples from Mars identify grain shape as one of the observation-measurement types needed to advance the science investigations [6,7]. These include geological studies of silt, sand, and coarser grains in ancient lacustrine and fluvial sedimentary rocks to understand ancient conditions and processes of sediment transport and deposition in ancient rivers and lakes (iMOST 1.1A & 1.1E), ancient and modern aeolian deposits to infer conditions and processes of sediment transport and deposition by wind (iMOST 1.1F), and material characterization studies of modern regolith to better understand geotechnical properties and support future development of high-fidelity simulants for use in ISRU test beds (iMOST 7B). Similar considerations apply to use of simulants to support future lunar ISRU [8].

The pioneering NASA JSC Mars-1 Mars Soil Simulant consists of glassy phyllosilicate-poor palagonitic volcanic ash from the late Pleistocene Pu'u Nene cinder cone at 1850 m elevation on the south flank of Mauna Kea volcano on Hawai'i [1]. It was selected primarily for its spectroscopic, chemical compositional, and magnetic similarity to regolith at the Viking Lander sites [1].

This presentation reports results of ongoing efforts to describe and interpret similarities and differences in grain shape (form and surface textures) among different synthetic regolith simulants.

Samples: Seven (7) terrestrial materials regarded by the community as being analogous to fine-grained regolith ("soil") were examined. All simulants examined in this work were formulated by crushing natural terrestrial rocks [2] or minerals [3]; the crushed materials were sorted, and crushed minerals were artificially mixed to arrive at the desired grain size distribution and mineral proportions [2,3].

Mars regolith simulants. The Mojave Mars Simulant (MMS) consists of granular crushed fractions of Saddleback Basalt near Boron, California, in the Western Mojave Desert [2]. MMS was suggested as a Mars soil geotechnical simulant because JSC Mars-1 was found to be too hygroscopic, gaining moisture too quickly during experiments to measure water sublimation loss on excavated permafrost under ambient Mars conditions [2].

Mars Global Simulant 1 (MGS-1) was formulated by the Center for Lunar & Asteroid Surface Science (CLASS) Exolith Lab by mixing terrestrial minerals plagioclase, pyroxene, olivine, magnetite, anhydrite, hematite, ilmenite, and quartz in the same mineral proportions [3] as those reported from CheMin XRD measurements of the Rocknest wind-sculpted regolith landform at Gale crater [9,10]. Clay- and sulfate-mineral-bearing variants (MGS-1C and MGS-1S, respectively), and a variant containing both sulfate and clay minerals and formulated based on orbital remote-sensing data for Jezero crater (JEZ-1), were similarly produced by the CLASS Exolith Lab later.

Lunar regolith simulants. Lunar Highlands and Lunar Mare High-Fidelity Moon Dirt Simulants (LHS-1 and LMS-1, respectively) were formulated and produced by the CLASS Exolith Lab [11,12].

All the simulant materials examine for this study have been previously documented to contain the primary rock-forming mineral plagioclase [2,13], along with other phases.

Methods: Grains were characterized by optical reflected light microscopy and backscattered scanning electron microscopy (BSEM). Each was described manually from the optical images and described and measured manually from the SEM images.

Sample preparation. Grains from each sample were mounted on aluminum stubs using adhesive tabs and coated with carbon.

SEM image acquisition. Grains were imaged using a JEOL 6610LV scanning electron microscope in secondary electron imaging mode (SSEM), with energy dispersive spectroscopy (EDS). Forty to 50 grains in each sample mount were imaged at one grain per frame to measure grain dimensions, observe grain roundness-angularity, and survey and inventory grain-surface textures. Previously acquired imagery and compositional data of Mars regolith simulants MMS

[14,15] and MGS-1 [16] were re-examined. New imagery and EDS data were acquired from the five other simulants: Mars regolith simulants MGS-1S, MGS-1C, JEZ-1, and Lunar regolith simulants LHS-1, and LMS-1. All told, 1,390 grains were individually imaged.

Grain characterization. Characteristics examined included grain dimensions, grain roundness-angularity (equantcy[17]/elongation), and grain-surface textures. Length (L) and width (W) were measured on 40-50 sand grains per sample mount. W, L, W/L are easy to standardize, easy to convert to measurements of both grain size and "shape" (in this presentation, L/W; aspect ratio, elongation), and are transferable among imager capabilities (none involve measuring any scale of "roughness" or surface textures of the grain envelope) [17]. Grain roundness was categorized using the Powers classification [18]. Inventories of grain surface-features were taken using categories we selected based on observations of MMS and MGS-1, to establish criteria applicable to grains comminuted by crushing. Tabulating the categorized observations on a Higgs-Vos-style [19,20] table enables classifying and inferring the dominant surface-texture forming processes.

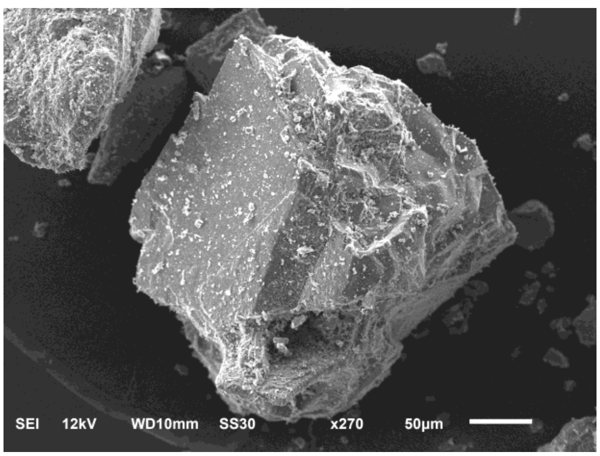

Figure 1. Sand-size grain from MMS with planar surfaces approximately perpendicular to one another, irregular surface that meet at sharp edges, and sparsely distributed dust particles. SEM secondary electron image.

Results: Previous work [14,15] showed that over one-third of all *MMS* grains exhibit at least some planar surfaces approximately perpendicular to one another (Figure 1); this is consistent with the cleavage planes of plagioclase, known from prior work to be present in the basalt from which MMS was prepared [13]. Fine particulate debris resolvable in whole-frame images of individual grains (Figure 1) is the dominant grain-surface texture on more than one-half of the grains.

Ongoing work: The six (6) regolith simulants being characterized for grain shape and surface textures are being used as a feedstock to be mixed with cement for producing concrete on the Moon and Mars [21]. Producing cementitious composites from local materials (regolith) on the Moon and Mars is one aspect of In Situ Resource Utilization (ISRU) for human exploration of the solar system. For ISRU, it is important to determine which types of grains (minerals) react during cement production, and which remain inert. The images of the as-acquired simulants reported here will serve as the "before" images of grain surfaces, serving as the baseline for comparison with grain surfaces after cement production using each simulant as feedstock.

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