USING CT SCANNING TO EXAMINE LUNAR REGOLITH POROSITY AS A FUNCTION OF GRAIN SHAPE AND DEPTH. R. V. Patterson[1] and D. Y. Wyrick[1], [1] Southwest Research Institute (6220 Culebra Road, San Antonio, TX 78238, rubypatterson1@gmail.com; dwyrick@swri.edu)

Introduction: Recent press releases by organizations such as NASA, ESA, Bigelow Aerospace, Moon Express, and SpaceX have centered around the idea of sending humans to the moon for tourism and, ultimately, permanent settlement [1]. Before any human settlements can begin the construction phase, it is of vital importance to understand the behavior and geomechanical properties of the globally-ubiquitous layer of lunar regolith.

Regolith is unconsolidated material comprised of dust and broken rock fragments [2]. Lunar regolith grains are highly angular and non-spherical due to the absence of wind and water-driven erosional processes present on the moon's surface [3,4].

The motivation behind using a Computed Tomography (CT) scanner for this experiment is to better quantify the porosity change, if any, in near surface ranges of regolith between a depth of 0-10 cm. In particular, we sought to test how grains of the same size range but different particle shapes influenced the resultant porosity. Regolith porosity can influence the geomechanical behavior of the sediment as well as influence the storage capacity for volatile chemical species.

Methods: Three shapes of particles meant to simulate lunar regolith grains were used for this experiment: spherical glass beads, angular pumice fragments, and JSC-1A. The sediment size ranges used for this experiment were spherical glass beads in 45-90 μm and 150-212 μm, angular pumice fragments in 44-74 μm and 150-212 μm, and JSC-1A (mean particle size of 100 μm) [5].

A 10 mL graduated cylinder was affixed to the turntable inside of a CT machine (Fig 1). A catchment system was attached to the outside of the top of the cylinder to prevent excess particles from polluting the CT machine and blocking the highly sensitive charged plates. The sediment was incrementally deposited into the 10 mL plastic graduated cylinder using a sieved shaker affixed with a mesh cap over the opening. The sediment was made to flow very steadily and gently into the graduated cylinder until it accumulated to 10 cm in height. CT scans were then performed for each sediment type.

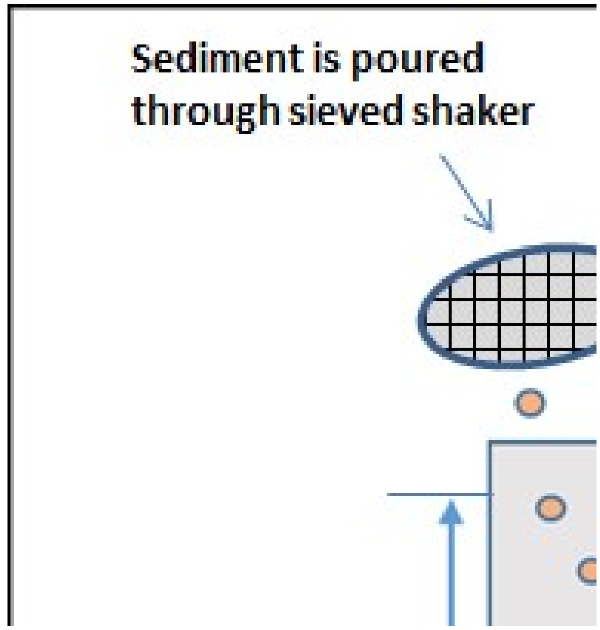

Fig 1. A conceptual drawing of sediment being deposited into the graduated cylinder prior to scanning. The arrows on the right indicate the 2D slices taken at 1 cm increment within the scanned volume and exported for analyses..

CT Scanner processing software, myVGL 3.0, was utilized to process and examine the voxel data for each CT scan. Horizontal planar cross sections were taken at 1 cm intervals within the scanned volume, giving a two-dimensional view at varying depths within the cylinder. Each of these cross sections was then cropped to capture the interior not subjected to boundary effects. Each cross section image was then imported into ArcGIS for statistical analyses. Pixel greyscale values were extracted and tallied, then exported to Microsoft Excel for further statistical analysis. Values of kurtosis, skew, and weighted averages were calculated. A plot the cross section number (where 0 = bottom of cylinder, with ascending values equal to cms of overburden sediment) versus the weighted average of the color value in horizontal cross section illustrates changes throughout the sediment column (Fig 2). Color values of 0-256 were used to quantify porosity. A value of zero would indicate a weighted average of pure void space/no particles present in cross section. A value of 256 would indicates a weighted average of a dense solid with no pore space.

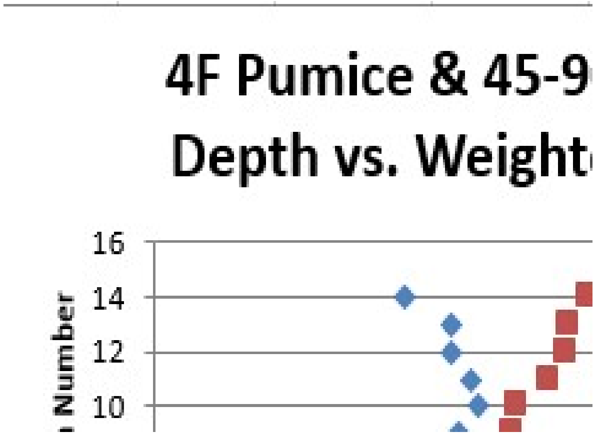

Fig 2. Plot of pumice and glass beads with depth.

Results and Discussion: The preliminary results of the CT scans showed the 45-90 µm spherical glass beads sustained an average higher weighted color value than the 45-90 µm angular pumice fragments throughout the entirety of the graduated cylinder scans (Fig 2). The two sediment types, despite being identical in size ranges, exhibited near mirror-image opposite behavior in porosity throughout the sediment column. The angular pumice grains have an average color value of about 100 (more pores than grains), and the cross sections show an increase in porosity (deflection of weighted color values toward a value of zero) as the overburden is decreased near the top of the graduated cylinder (Fig 3). Conversely, the 45-90 µm spherical glass beads showed an decrease of porosity with a decrease of overburden materials.

Future Work: Analyses of the JSC-1A and larger particle size ranges of highly angular pumice fragments and spherical glass beads are being peformed. In the future, additional CT scans will be performed on the JSC-1A, and possibly other lunar regolith simulants.

References:

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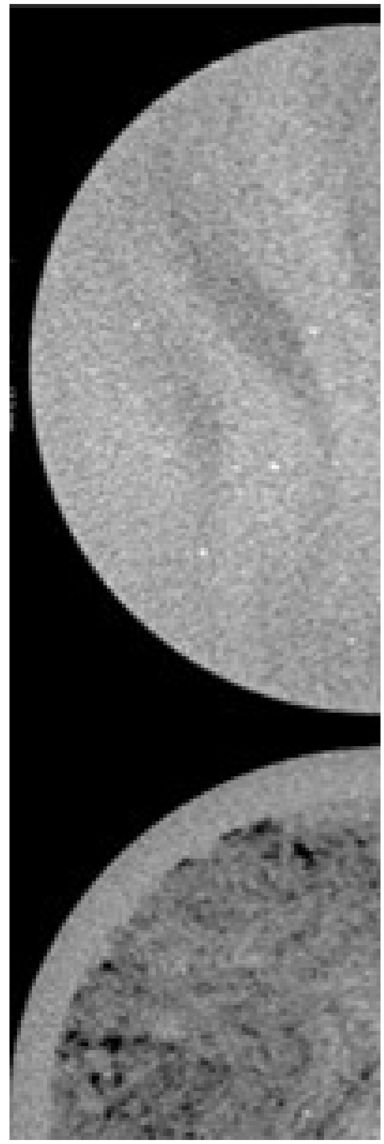

Fig 3. Cross section images of 45-90 µm spherical glass beads (top), 45-90 µm angular pumice fragments (middle), JSC-1A lunar regolith simulant (bottom) taken from CT scans.