THE ROLE OF GRAIN SHAPE IN REGOLITH PROCESSES. D. Y. Wyrick[1], D. L. Buczkowski[2], [1]Southwest Research Institute (6220 Culebra Road, San Antonio, TX; dwyrick@swri.org); [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD, USA

Introduction: Common to all solid planetary bodies is surface regolith, unconsolidated material typically comprised of dust and broken rock fragments. Planetary bodies with atmospheres (Earth, Venus, Mars, Titan) have regolith surfaces that are also subject to aeolian and fluvial erosional processes that serve to round individual grains, creating an unconsolidated material with well-rounded grains of high sphericity. This inherent roundness of the grains exerts a fundamental control on the macroscale behavior of the unconsolidated material. Additionally, common sources of erosion also serves to sort grains by size, often creating sediments that are well sorted and uniform in grain size.

Less well understood is the behavior of regolith materials on dry airless bodies such as the moon and asteroids. Regolith materials on these smaller planetary bodies are produced and modified by processes that grade grain shapes toward both high angularity and low sphericity [1]. Both angularity and sphericity influence grain aspect ratios and surface area availability at the microscale and bulk transport processes such as settling at the multi-particle macroscale. Grain sphericity and size distribution influence a material's overall porosity and may influence the resultant geomorphic expression [1,2].

Physical models and numerical simulations frequently utilize glass beads or spherical particles to simulate regolith. However, while glass beads can be a good analog for spherical terrestrial regolith particles and simplify computation, they do not have the correct shape or aspect ratio for the grains of an airless body's regolith.

Porosity vs grain shape: Grain sphericity and aspect ratios were determined under a scanning electron microscope (SEM). Notably, porosity distribution in sediment samples was markedly different. CT scans of glass beads (illustrated in Fig 1) show more diffuse porosity distribution (black pixels) compared to the CT scans of pumice (45-90 µm) and JSC-1A, which both produce discrete clusters of higher porosity relative to the sample average. The Apollo 17 core sample of regolith (79002), taken near the Van Serg crater, serves as a fiducial regolith sample for the Moon, as it closely fits the average grain size range from the Lunar Source book (1991). When comparing the material size distribution of analog materials to the Apollo lunar sample return materials, it becomes evident that spherical particles are not an appropriate analog (Fig 1).

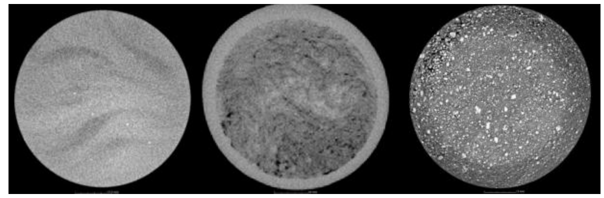

Fig 1. CT scans of sediments (A) glass beads, 45-90 µm, (B) pumice, 44-70 µm, and (C) JSC-1Alunar regolith simulant. Black pixels represent void space, or bulk porosity.

Grain shape vs surface area and volume: It is important for physical models and numerical simulations to use particles that are the most similar in shape to the regolith grains on airless bodies when attempting to simulate the regolith processes on these bodies. Both the internal porosity and angle of repose of the deposited particles will be different for angular grains than for spherical grains. This can be demonstrated by the thought experiment of evaluating the surface area of different shaped grains. We compare a number of 3D regular-shaped (e.g., spherical, prism-shapes, triangular pyramid) and 3D irregular-shaped (e.g., dodecahedron, stellated dodecahedron) putative grain particles (Fig 2). When looking at particles of the same volume but different shapes (Table 1) it becomes evident that the irregular particles have a far greater surface area. The magnitude of surface area availability is critical in estimating the potential storage capabilities of volatiles within the bulk regolith. Using spherical particle shapes in numerical simulations and physical modeling may significantly underestimate the surface area availability for adsorption and storage of volatiles.

Fig 2. Schematic drawings of geometric shapes in Table 1.

Cohesion vs grain shape: Shear testing of various unconsolidated materials were performed to characterize the cohesion values as a function of grain shape (Fig 3). Materials were handled consistently in regards to emplacement of materials, in that they were poured from a fixed height, rather than sifted or compacted,

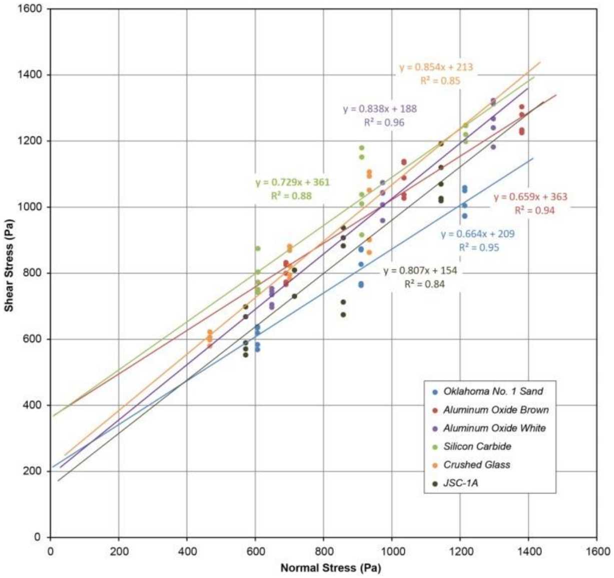

Fig 3. Shear test results from various materials of similar grain size range. Note that the JSC-1A produces a steeper slope in the friction angle but has lower cohesion values.

which can influence the arrangement of grains [3]. Friction angle and cohesion of materials was determined by shear testing using the apparatus and procedure of [3] and [4]. Shear stress at slip as a function of applied normal stress was measured at various normal stresses for each sample so that a bit-fit solution can be derived for friction angle and cohesion. Friction angle is the arctan of the best fit slope line and cohesion is the intercept on the shear stress axis of the best fit slope line. Sediments with well rounded grains, such as sand, exhibit lower angles of repose and relatively low cohesion; conversely, grains with high aspect ratios and/or highly angularity exhibit higher angles of repose. JSC-1A has a very low cohesion value yet a relatively high angle of internal friction and high angle of repose.

Discussion: Current understanding of the geomechanical behavior and processes of regolith is growing in response to new data and better computing and laboratory resources. However, the role of non-spherical and high aspect ratio grain shapes in influencing bulk porosity, shear strength and surface area availability needs to be considered in order to better understand the degree of volatile capture, storage, and transport capabilities of regolith materials on a variety of planetary bodies.

Acknowledgments: These investigations have been supported in part by the SSERVI project GEODES, NASA contract #80NSSC19M0216 (N. Schmerr, PI).

References: [1] Wyrick et al. (2017) 48th LPSC, #2776; [2] Wyrick D.Y. and D.L. Buczkowski (2006) 37th LPSC, #1195; [3] Krantz, R. (1991) *Tectonophysics* 188, 203–207; [4] Schellart, W.P. (2000) *Tectonophysics* 338, 1-16.

Table 1. Sphericity and aspect ratio influence the ratio of surface area for a given volume of particle size.

	Shape	Length	Width	Height	Volume	Edge	Surface Area
SPHERICITY	Sphere	5	5	5	500		305
	Dodecahedron				500	4	335
	Small stellated dodecahedron				500	3	438
	Great stellated dodecahedron				500	4	831
ASPECT RATIO	Sphere	5	5	5	500		305
	Cube	8	8	8	500		378
	Tablet	5	10	10	500		400
	Square rod	5	5	20	500		450