Shape Analyses of Lunar Dust Particles for Astronaut Toxicological Studies.

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Introduction: The health of humans on the Moon is of paramount importance to the settlement of lunar bases. Study of the size and shape distribution of lunar dust, the <20 μm fraction of lunar soil, provides important information for determining its toxicity effects. We have conducted studies of particle size distribution and texture of the dust fraction of two lunar soil samples and a lunar soil simulant (JSC-1Avf) [1-5]. JSC-1Avf is the fine fraction (< 20 μm) of a clone simulant of JSC-1 [6] made from terrestrial basaltic tuff. The present study concentrates on the shape distributions of five lunar samples and the simulant JSC-1Avf, for particles both <1 μm and > 1 μm.

Methods: To a representative small portion (<5 mg) of each sample, ~5 ml of a surfactant solution (poly N-vinylpyrrolidone in isoproponal) was added; this mixture was sonicated for 10-30 min. A small amount (~3 μl) of the mixture was then taken with a micropipette and dropped on a cleaned silicon wafer, placed above a magnet to keep particles from clumping [1].

Secondary electron images of the sample at two different magnifications (1000x and 5000x) were taken with a JOEL LSM-6060LV scanning electron microscope (SEM). Areas and perimeters of the 2-D digital photos of the particles were measured directly by ImageJ software (http://rsb.info.nih.gov/ij/) (Fig. 1). The circular-equivalent diameter was calculated using the measured area. An ellipse was also least-squares fit to the measured area (Fig. 1).

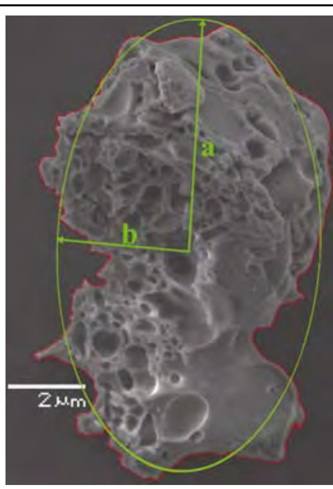

Fig. 1. Example of ImageJ measurements. Measured area is enclosed by the red curve, which is the measured perimeter (P). Least-square fit ellipse to the particle area is green. Aspect ratio is defined as 2b/2a and the complexity is $P_{measured}/P_{ellipse}$.

Shape Parameters: With the fitted ellipse, aspect ratio and complexity factor were used to characterize the shape of particles (Fig. 1). **Aspect ratio**, a measure of elongation, is defined as the (minor axis) / (major axis) of the fitted ellipse (Fig. 1). The **complexity factor**, a measure of angularity of the particle, is the ratio of the measured perimeter to the calculated ellipse perimeter. Figure 2 shows the aspect ratio and complexity of several geometrical shapes. The fitted-ellipse approximates well the real elongation of different shapes. Although aspect ratio is same, the complexity factor increases with increasing angularity or irregularity of the shape.

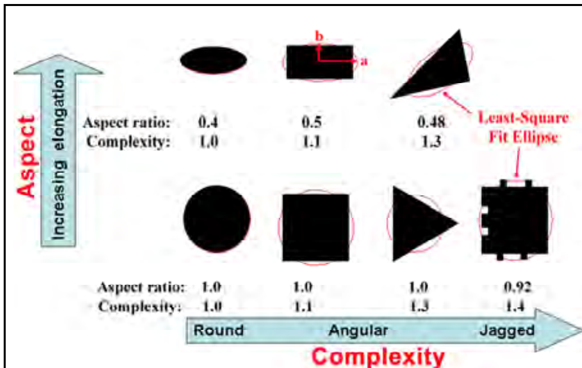

Fig. 2. Aspect ratio and complexity of several geometrical shapes.

Results: Five lunar soil samples (10084, 12001, 15041, 70051, and 79921) and the lunar soil simulant (JSC-1Avf) were studied (Figs. 3-4). For each sample, more than 400 particles were measured. The data are separated into two size categories (>1 μm and < 1 μm) using the circular-equivalent diameter.

Aspect Ratio of Lunar Samples: Distributions of aspect ratios of all five lunar particles show a peak at ~0.7 (Fig 3), which is similar to the results of six Apollo 14 and 15 soils by [7, 8]. Grains that are >1 μm and < 1 μm have similar distribution, except for < 1 μm grains of 12001 and 15041 with more broad distributions. All distribution curves, however, are skewed toward a small aspect ratio. About 3-12 % (in numbers) of particles has an aspect ratio < 0.4.

Complexity of Lunar Samples: Complexity factors of all five lunar samples center at ~1.15. These distribution curves skew slightly toward complexity factors

>1.25, indicating a significant proportion of angular and jagged grains. These numbers are slightly larger than reported by [8]. Contrary to [8], complexity is slightly larger for more mature samples (1.2-1.3 for 79221, 1.2 for 15041) than those of sub-mature (1.1-1.2 for 10084) or unmature samples (1.1-1.2 for 12001).

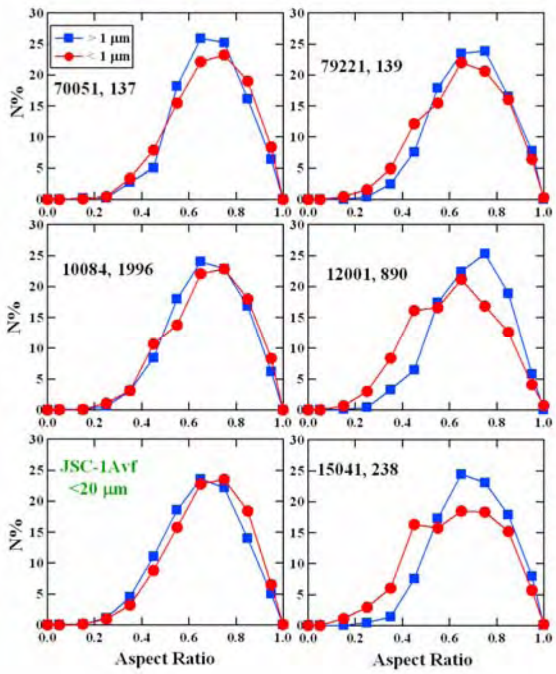

Fig. 3. Aspect ratios of five lunar soils and a simulant JSC-1Avf.

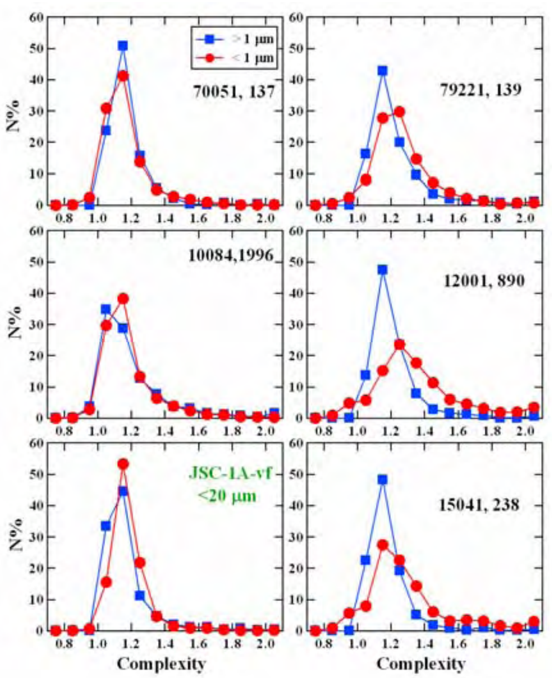

Fig. 4. Complexity of five lunar soils and a simulant JSC-1Avf.

Lunar Soil Simulant: JSC-1Avf has similar aspect ratios and complexity factors compared to lunar samples (Figs. 3 and 4). However, JSC-1Avf is coarser in grain size than lunar sample (Fig. 5). This simulant may suffice for toxicity studies with animal subjects.

Conclusive Remarks: In summary, our results suggest that most lunar dust particles are subangular to angular grains and are slightly elongated. This study provides the information needed for toxicity study.

References: [1] Park J. S. et al. (2006) *JAE. (submitted)*. [2] Liu Y. et al. (2006) *JAE. (submitted)*. [3] Park J. S. et al. (2006) *LPS XXXVII*, Abstract #2193. [4] Liu Y. et al. (2006) *ASCE 2006*. [5] Liu Y. et al (2005) *68th Annual Meteoritical Society Meeting*, 5207. [6] McKay D.S. et al. (1992) *Space IV*, *ASCE*, 857-866. [7] Görz et al. (1971) *PLSC 2nd*, 2021-2025. [8] Görz H. et al. (1972) *PLSC 3rd*, 3195-3200.

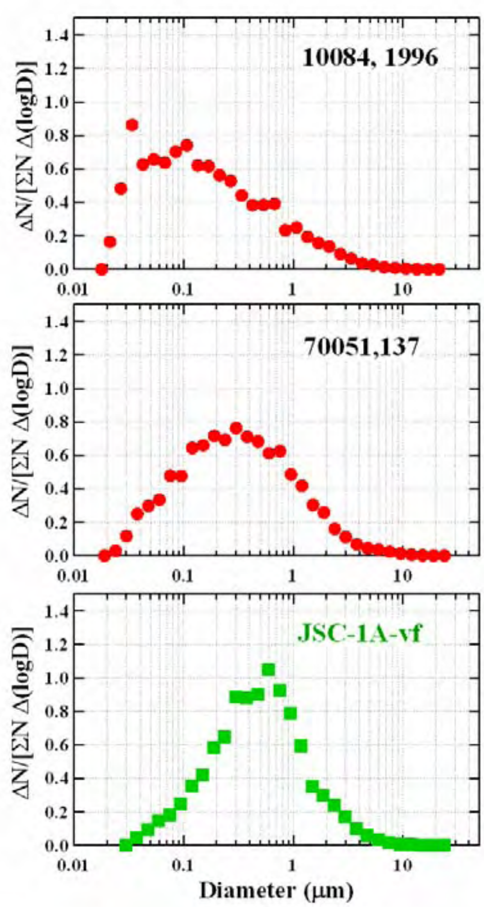

Fig. 5. Particle size distribution. Re-plotted from Park et al. [1].