Examining the Uppermost Surface of the Moon. S. K. Noble[1], [1]University of Alabama Huntsville / MSFC, Mail Code VP62, 320 Sparkman Dr., Huntsville AL 35805 Sarah.K.Noble@nasa.gov

Introduction: Understanding the properties of the uppermost lunar surface is critical as it is the optical surface that is probed by remote-sensing data, like that which is and will be generated by instruments on orbiting missions (e.g. M^3, LRO). The uppermost material is also the surface with which future lunar astronauts and their equipment will be in direct contact, and thus understanding its properties will be important for dust mitigation and toxicology issues. Furthermore, exploring the properties of this uppermost surface may provide insight into conditions at this crucial interface, such as grain charging and levitation [1].

Background: The Apollo16 Clam Shell Sampling Devices (CSSDs) were designed to sample the uppermost surface of lunar soil [2]. The two devices used Beta cloth, similar to the outer layer of Ap space suits, (69003) and velvet (69004) to collect soil from the top ~100 and ~500 μm of the soil, respectively. Due to the difficulty of the sampling method, little material was collected (Fig. 1) and as a result little research has been done on these samples to date.

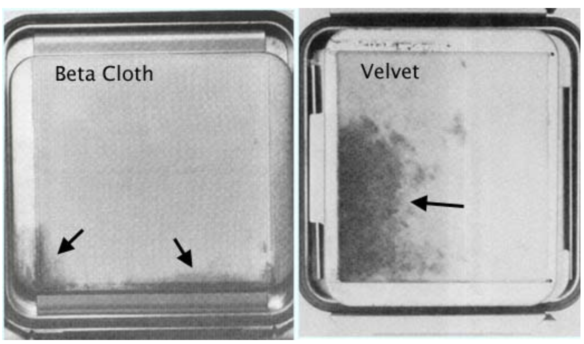

Figure 1. Apollo 16 Clam Shell Sampling Devices. Black arrows indicate the collected material.

Our initial studies attempted to look at the material that had fallen off of the fabrics and were subsequently collected from inside the sample containers [3]. However, this material was found to be size fractionated, i.e. larger grains preferentially fell off, and the material thus, could not provide an adequate picture of the uppermost surface. Recently, samples were obtained directly from the beta cloth. While still fractionated, these samples provide a unique glimpse into the undisturbed soil exposed at the lunar surface. Initial results suggest that the surface may contain a higher proportion of fine grains (<2 μm) than the bulk soil. We have not yet attempted to remove samples directly from the velvet sample, though we intend to do so in the future.

Methods: Samples were pulled from the Beta cloth (69003) using carbon tape on aluminum stubs. The samples were coated with a thin layer of carbon to prevent charging in the SEM. For comparison, a scoop sample (69941) was collected at the same location, just centimeters from the CSSDs. Samples were prepared from this bulk (<250 μm) soil as well. The bulk soil was thoroughly mixed and a small amount was sprinkled onto carbon tape and carbon coated. SEM images were taken of both samples at the same resolution and analyzed using Image J software to determine the size distribution.

Results: In Fig. 2 are backscatter images and size distributions for 69003 and 69941, the Beta cloth and scoop samples, respectively.

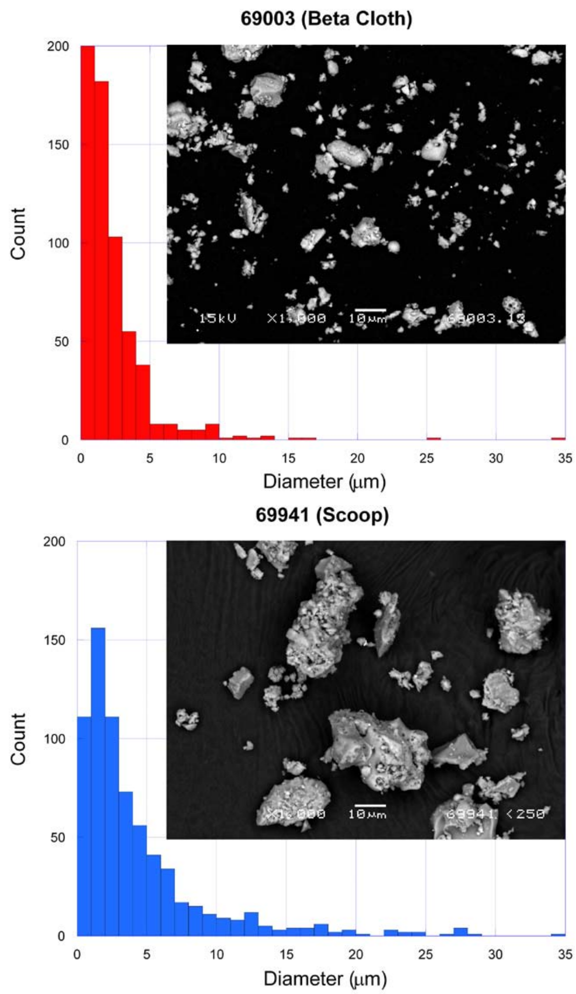

Figure 2. Size distributions for the Beta cloth sample and the associated scoop sample.

Discussion: The Beta cloth sample contains significantly more <2 μm grains compared to the scoop sample. However, there are several possible sources of sample bias that must be taken into account. There is a sharp falloff in the Beta cloth sample at ~5 μm. This is likely due to larger grains preferentially falling off during transport and handling on the return trip from the Moon. This is consistent with our initial studies of the material that had fallen off [2], which was noticeably depleted in <5 μm grains, as well as our study of space suit fabrics (also Beta cloth) which show a concentration of fine-grained material [4]. Likewise, larger grains may not be easily picked up by the Beta cloth.

Because of these known and suspected biases among larger grains, we concentrated on understanding the distribution among the finest grains using high magnification images (1000x). As a consequence, no grains larger than ~35 μm were counted in the above graphs, but larger grains were present in both samples. The largest grain seen in the Beta cloth sample was about 75 μm in diameter, while the scoop sample contained many grains into the 100 and 200 μm range.

One final concern is that Beta cloth itself (composed of Teflon-coated fiberglass), may shed material when the carbon tape is pulled off. To explore these biases, samples were prepared using JSC-1a soil simulant. Beta cloth was gently pressed into JSC-1a and then pulled off with carbon tape (sample 1). The Beta cloth was then vigorously tapped and shaken to remove the loosely adhering material and samples were collected from both the remaining material (sample 2) and the material which had fallen off (sample 3). Finally a sample was also produced by pulling carbon tape from "clean" Beta cloth with no JSC-1a (sample 4).

The first sample demonstrated that grains from submicron to several tens of microns do indeed stick to the Beta cloth. The Beta cloth however, picked up few grains greater than ~70-80 μm, which is consistent with the largest sample seen on 69003 being about 70 μm. Samples 2 and 3 confirmed that larger grains (> 5μm) preferentially fall off when the Beta cloth is disturbed (tapped), although several large grains did remain stuck to the fabric (Fig. 3).

The carbon tape pull from the "clean" Beta cloth shows bits of Teflon and rods of fiberglass can be shed from the sample (Fig 4). Salts and other contaminants were also identified through EDX analysis, owing to the non-pristine nature of the fabric swatch used. There are particles present which are below the resolution necessary for EDX analysis (~1-2 μm); these might also be contaminants, or possibly fiberglass dust. EDX analysis of 69003 found no non-lunar particles down to the ~1 μm limit of the EDX.

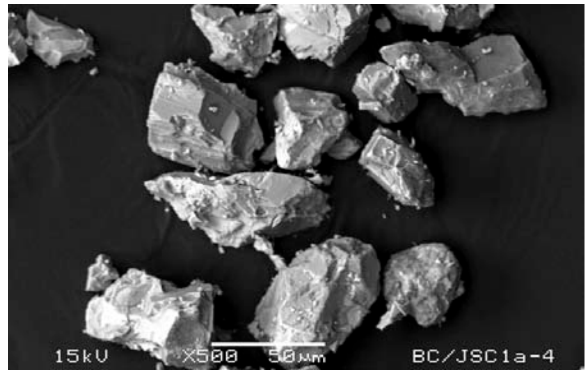

Figure 3. From sample 4, grains of JSC-1a that fell off of the sample which was tapped.

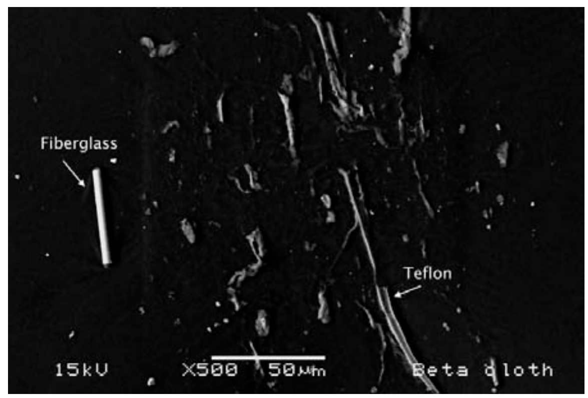

Figure 4. Carbon tape pull off of "clean" Beta cloth.

Conclusions: Initial results suggest that ultrafine (<2 μm) particles dominate the uppermost lunar surface, however, there are biases introduced by the sampling method that must be carefully considered. While larger grains were almost certainly preferentially lost from the Beta cloth, fines grains (<5 μm) do not appear to have been significantly fractionated and still indicate a significant enrichment in grains <2 μm vs. the scoop sample. Further analysis is necessary to determine whether material shed from the Beta cloth is contributing to the results, though to date, no non-lunar materials have been identified in 69003.

The Clam Shell samples are not perfect, but they represent the only attempt made to sample the uppermost lunar surface. It is clear that better sampling methods are needed for future missions to address this problem, however, in the meantime, we will continue to try to get the most information we can out of the available samples.

References: [1] Wendell W. W. and S. K. Noble (2010) *LPSC XLI (this volume)*. [2] Horz et al (1972) Apollo 16 Special Samples in *Apollo 16 Preliminary Science Report*. [3] Noble S. K. et al. (2007) AGU Fall Mtng 2007, abst #P44A-06. [4] Christoffersen R. et al. (2009) NASA Technical Publication #21476.