

## Forensic Analysis of Lunar Dust

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**Introduction:** There have been twelve humans that have walked on the moon. Although they could not imagine creating a permanent habitat on the moon, these astronauts gleaned vast amounts of information during their short stays and facilitated the planning to create the best possible station on the moon- a lunar habitat. While there, the astronauts collected lunar regolith with which to study and perform experiments.

One of these challenges that must quickly be solved is what those on the moon will wear while exploring and studying. The spacesuits from the Apollo missions were not meant for long term use. They were designed simply for a short day trip on the moon or out in space. Many lunar grains attached themselves to these suits, and while the dirt sticking to the suit is not inherently dangerous, the main issue is that the debris sticking to the suits can get brought into the habitats. The dirt can abrade the fabric over time, destroying the only barrier between human skin and the nothingness of the lunar environment. The toxicological affects of contact with and inhalation of lunar dust are still being studied, but minimizing such contact is the safest way to ensure astronaut health.

In addition, the spacesuit engineers also added a layer of fiberglass which found its way to the outside of the suit and was frequently attached to our tape. Fiberglass can pose serious health problems; according to idph.com [1], "Smaller fibers have the ability to reach the lower part of the lungs increasing the chance of adverse health effects."

The goal of this study is to analyze dust lifted from Jack Schmitt's EVA space suit from Apollo 17 for mineralogy and grain size distributions for the sampled particles. This information will guide the design of the next generation of spacesuits as a necessary quality of each suit is resistance to lunar particles. Dangers to the engineering of the suits and the health of the astronauts arise once these particles are attached to the suits. As of now, it is uncertain precisely what health problems may present from these lunar materials, but research is ongoing to find out determine safe level of exposure. This study will help toxicologists better understand the types of particles that are likely to be brought into a habitat by the astronauts.

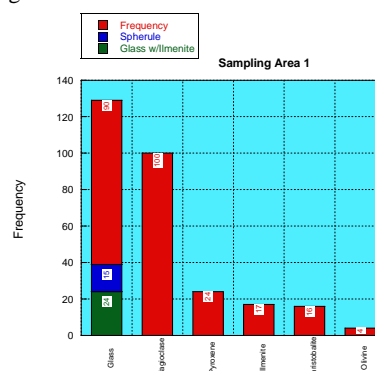
**Methods:** In order to efficiently test the mineralogy and size distributions of grains stuck to the spacesuits, unorthodox methods were introduced. First, 3M magic tape® was, after extensive testing, placed onto the EVA spacesuit and peeled off in strategic locations to ensure even sampling of the suit as shown in Figure 1.



Figure 1. The sampling strategy for tape placement on the front of the suit. This process was also mirrored on the back of the suit.

Then the pieces of tape were placed on dots carbon coated to remove excess charges under the electron beam. The samples were analyzed with a JOEL 5910 scanning electron microscope equipped with EDS at Johnson Space Center where we were able to view each grain in detail. Representative grains were photographed and EDS spectra taken to determine the chemistry and mineralogy of each particle. The EDS, however, does have its limits. For grains below two microns, mineralogy was nearly impossible and erroneous therefore all calculated grain sizes are limited to this constraint. From this chemical information and grain morphology, it was determined whether the grain was of lunar origin or terrestrial contamination. If it was lunar, the mineralogy was noted. Then, each photo was placed into ImageJ and each particle was separated and measured. The exact areas and diameters were calculated and measured and then the size distributions were computed. Finally, I utilized "The Lunar Regolith: Chemistry, Mineralogy, and Petrology" written by J.J. Papike and S. B. Brown [2] which calculated size distributions for particles that the astronauts picked up off of the moon on each mission. This information is in the graph below. It was then compared with the graph which shows the percent volume of grains from the tape peels. To arrive at the percent volume, it was assumed that all particles were spherical in shape and to ensure an accurate representative population, 1,200 grains were measured which accounted for a total margin of error of approximately 2.8%. Then, the suit was separated into three sampling areas with an approximately 5% margin of error for each. The percent error is raised slightly to 3.4% when only lunar grains are counted. This does not take into account for human error i.e. misreading the mineralogy or miscalculation of grain size which is possible considering the small size and high number of these grains.

**Results:** The first three graphs are frequency graphs which show the most frequent grains viewed for each sampling area. To understand where each sample area starts and finishes take a look at Figure 1 once more. Sampling Area 1 is region 1 through 4, Sampling Area 2 is region 9-12 and Sampling Area 3 is region 13-18. This includes both front and rear of the suit.



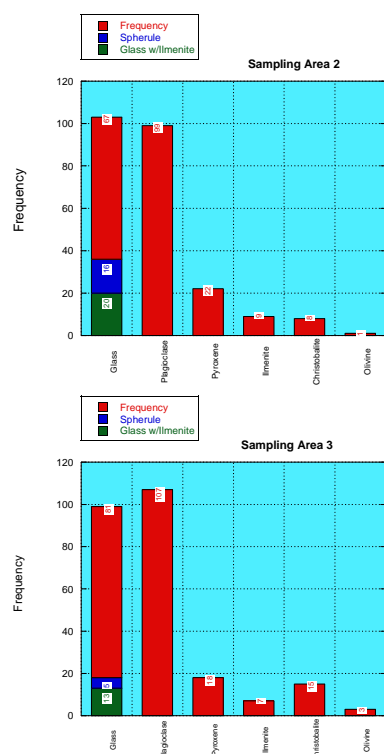


Figure 2. Frequency distributions of mineralogy for the 3 sampling regions noted in above text.

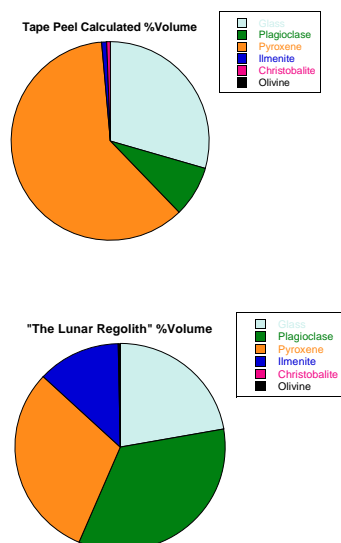


Figure 3 a) This chart is a breakdown by percent volume of lunar grain type for grain between 20-90 microns from Apollo 17 (Mare, grains 72501, 76501, and 78221) [2]. b) Percent volume graph for each lunar grain from the tape peels.

There were almost 400 grains of lunar glass identified and nearly 350 grains of plagioclase identified in this experiment alone making them the most frequently found grains. Many types of contamination including bits of Teflon, fiberglass, salt, calcium, and sulfur were also found on the tape peels. Furthermore, an average diameter for the 840 lunar grains analyzed was found to be 10.71598. The median was found to be while the mode 8.290083 was 5.498608.

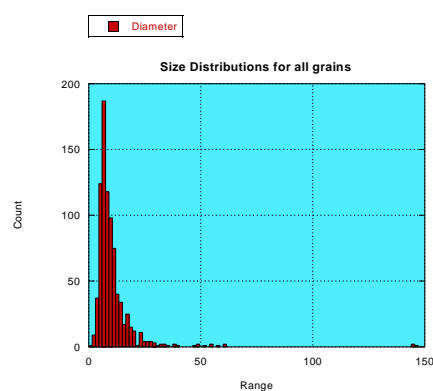


Figure 4. Grain size distribution for all grains of lunar origin.

**Discussion:** Some fascinating results were found in this research. As expected, most of the grains were ten microns or less, and as expected, most of the small grains were glass and plagioclase because they are easily broken down [3]. It was surprising to find that most of the volumes of grains attached to the suits were grains of pyroxene. This was in contrast to the Ap17 soils. 58% by volume of the tape peel grains were pyroxene compared to only 30% in typical Apollo 17 soils [2].

**Conclusion:** The suits were covered with a layer of lunar dust even after being vacuumed and 30+ years of handling. This dust was more concentrated in areas such as the knees and elbows where significant wear on the fabric was also noted. Dust will be one of the major difficulties we must face on our next journey to the moon. Understanding its behavior in the lunar environment and its interaction with astronauts and their suits is important to ensure their safety. Some interesting results were found that suggest the composition of material clinging to the suits may differ from the typical soil composition of the area. Furthermore, it was found, as expected, that the clinging particles are generally small, which has implications for astronaut health and habitat design.

**References:** [1] Fiberglass Fact Sheet." Illinois Department of Public Health. 2 Aug. 2007 <<http://www.idph.state.il.us/envhealth/factsheets/fiberglass.htm>>. [2] Papike, J. J., and S. B. Simon. "Reviews of Geophysics and Space Physics." Diss. Institute for the Study of Mineral Deposits, South Dakota School of Mines and Technology, 1982. Abstract. The Lunar Regolith: Chemistry, Mineralogy, and Petrology 20 (1982): 795. [3] Horz F. and Cintala M. (1997) Impact experiments related to the evolution of planetary regoliths. Meteoritics and Planetary Science 32, 179-209.