POTENTIAL TOXICOLOGY OF LUNAR DUST.

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Introduction: As NASA plans returning humans to the Moon, then on to Mars and the great Beyond, it is imperative that we recall experiences from the Apollo Era. As reviewed by Taylor et al. [1], one problem that was not well anticipated was the ubiquitous, adherent, abrasive, and floating dust – generally the <20 µm portion, which is ~20 wt% of the lunar soil. All "Rock Boxes" on all six Missions leaked from the lunar atmosphere of 10^{-12} torr, in spite of the knife-edge In-metal seals. Habitats will need to be over-pressurized to account for inevitable leaks, especially around entrances. The most critical effect of lunar dust, however, may be on the astronaut's health. With each Apollo Mission to the Moon, astronauts remarked about the "gun powder" smell when they took off their helmets in the LM, upon returning from an EVA. Several astronauts reported respiratory or eye irritations; Jack Schmitt was affected the most with coughing and transient congestion. It was obvious that there was something unusual about the lunar dust.

Flash back to the Viking Missions to Mars, with the fizzing of the "chicken soup" placed on the Martian soil – not life, just UV-induced, highly reactive, oxidizing soil. Take the red planet and move it to 1 AU, take away any vestige of an atmosphere, and that is the Moon. The intense UV radiation, solar wind, plus the extreme micro-meteorite induced comminution of the soil should make the lunar soil and dust extremely chemically reactive, and therefore potentially toxic. But exiting Apollo samples are no doubt passivated by exposure to terrestrial air and moisture, and by exposure to the traces of oxygen present in the nitrogen atmosphere used to preserve them. One of the most important experiments to be performed with the first lunar lander is "the chemical reactivity" of pristine lunar dust in the respirable size range.

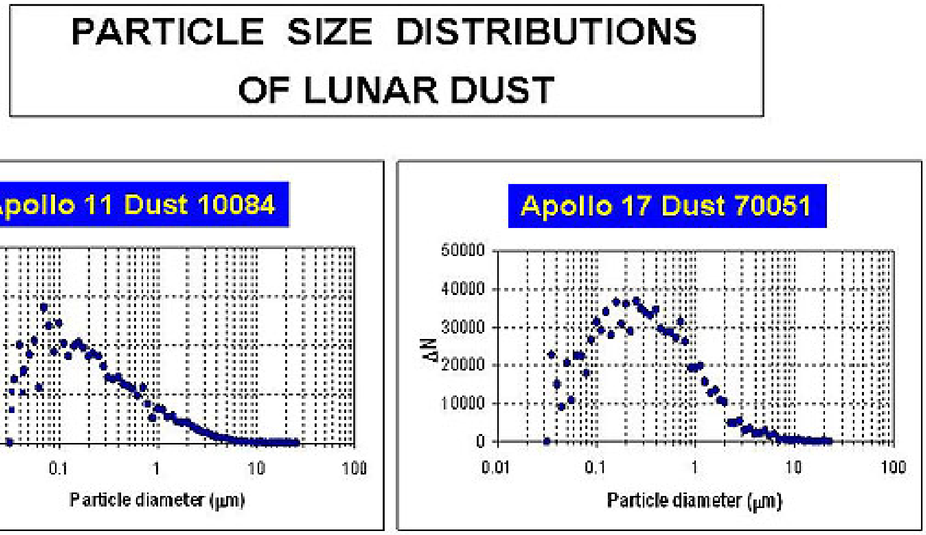
Lunar Dust is a unique portion of the regolith on the Moon, consisting predominantly of impact-produced glass containing myriads of nano-sized metallic Fe particles (3-33 nm; Fe like that in a Fe nail; Taylor et al., 2001). It is this nanophase Fe that gives the lunar dust its property of being attracted to a magnet [1] and as discovered by Taylor & Meek [2], its tremendous response to microwave energy. However, the particle-size distribution (PSD) and morphologies are unusual as well and are the subjects of this paper.

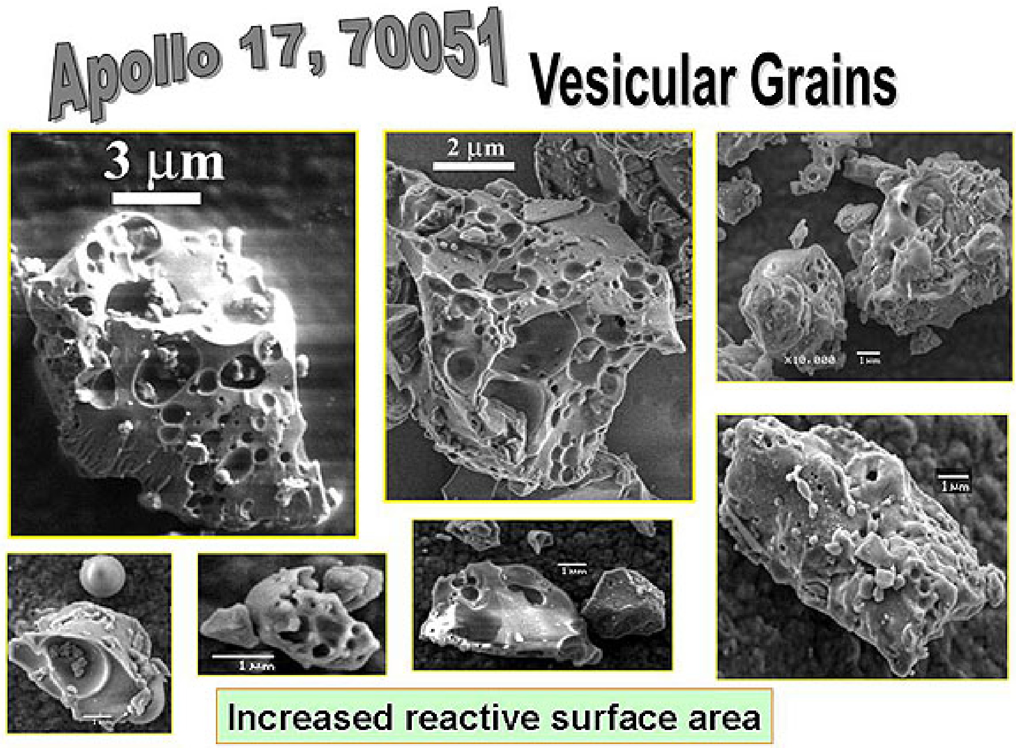
Particle-Size Distribution: From the selected number of lunar dust samples that have been processed to date, it is obvious that the dust has a mode of maximum particles at 100-200 nm (Fig.1), exceptionally small. These small particles are capable of moving from human lungs directly into the blood stream. It should be emphasized that these fine particles consist almost entirely of glass containly myriads of nanophase metallic Fe. This highly reduced form of Fe may interact with hemoglobin for oxygen depravation effects. Finding a proper lunar dust simulant to replicate these particle sizes will be difficult. The freshly produced JSC-1Af dust simulant has a particle maximum of 500-700 µm [3-4].

Particle Morphology: Broken pieces of agglutinitic glass make up the majority of the dust particles. Some of the first-cycled agglutinitic glasscontains minute vesicles rendering extreme reaction-surface areas to these particles (Fig. 2). Many of the grains have splash surfaces from melt; others are essentially rounded beads of impact melt. In almost all cases the surfaces of the dust particles are not smooth. Although the aspect ratios are near 1, the effective surface areas of each particle are not well-represented by a sphere. Also, the greatly increased reactive-surface areas of the dust can add significantly to the toxic nature of the dust as this aids surface reactions and dissolution of chemical constituents into the blood stream [5-6].

References: **[1]** Taylor, L., Schmitt, H.H., Carrier, W.D., & M Nakagawa, M., 2005. AIAA, Proc. 1st Space Explor. Conf., Orlando, FL; **[2]** Taylor, L.A., & Meek, T., 2005, *Jour. Aerosp. Engr.* 18, No. 4, 188-196; **[3]** Park, J., Liu, J., Kihm, K.D., Hill, E., & Taylor, L.A., 2006, SPACE 2006, ASCE Proc., Houston, TX, CD_ROM; **[4]** Park, J. S., Liu, Y., Taylor, L. A., & Kihm, K. D., 2006, *J. Aerospace Engr.,* in review; **[5]** Liu, Y, Park, J., Hill, E., Kihm, K.D., and Taylor, L.A., 2006, Space 2006, ASCE Proc., Houston, TX, CD_ROM; **[6]** Liu, Y, Park, J., Hill, E., Kihm, K.D., and Taylor, L.A., 2006, *Jour. Aerospace Engr.*, in review.

<u>Figure 1</u>. Particle Size Distributions of Apollo 11 and Apollo 17 dust. Note the particle modes at only 100-200 nm, where grains can move directly into an astronaut's blood stream from their lungs. Taken from Park et al. [3-4].





<u>Figure 2</u>. Different morphologies for dust particles in Apollo 17 soil 70051, taken from Liu et al. [5-6]. These morphologies are relatively continuous with decreasing grain size. Note the "Swiss-cheese" texture formed by the escape of solar-wind volatiles during the melting process. Also, note the greatly increased reactive-surface areas because of such textures, in addition to the splash glass see in the lower right.