DO WE REALLY KNOW HOW TOXIC LUNAR DUST ACTUALLY IS?

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Introduction: The ability of currently available lunar simulants to provide accurate information on lunar dust toxicity remains uncertain, as there are a variety of characteristics of lunar fines that are not replicated by available simulants. We have launched a major experimental effort to identify the most reactive and toxic components of natural lunar dust. This information, when coupled with our increasing ability to identify regolith components remotely, should permit assessment of the relative toxicity of a variety of compositionally distinct lunar terranes.

Lunar fines contain a variety of rock-forming minerals, such as olivine, pyroxenes and ilmenite, concentrated by comminution of rocks that have direct terrestrial analogs (e.g. [1]). Investigation of the toxicity and reactivity of these components of lunar dust is ongoing and based on the use of both synthetic and natural minerals (see, for example, Hendrix et al., this conference). Since such minerals dominate available lunar simulants, use of these simulants in toxicity studies should provide a bulk assessment of the toxicity of a composite of such minerals. However, full assessment of lunar dust toxicity must consider additional components unique to lunar fines, specifically agglutinates, micron- to nanophase-sized Fe° particles, sulfide and chloride salts and their potential metallic reductants, and Fe- and Ti-rich basaltic glass. We have launched an extensive effort to synthesize these materials both individually and by modifying available simulants, and to use these synthetic materials in the investigation of the toxicity and reactivity of lunar fines.

Metallic Fe and agglutinates: In order to provide material for reactivity and toxicity studies that is more reflective of the redox conditions of lunar fines, simulants LMS-1, LHS-1, and JSC-1A were roasted in a stream of H_2 at 850 ºC (thus, at or below QIF (~IW-1) and above the Si/SiO_2 buffer) [2]. This process resulted in reduction of some ferrous Fe in olivine and the formation of sintered material. Figure 1a shows the ground JSC-1A starting material and its modification (Fig. 1b) after roasting. Effort is continuing to analyze these products for agglutinate characteristics and to identify all products of the reduction process. This reduced material, as well as the starting material (ground JSC-1A), were used for studies of human lung epithelial cell viability and assessment of cellular DNA damage [3]. Importantly, the reduced material induces a significant decrease in cell viability and increase in DNA damage relative to unreduced JSC-1a. These differences indicate that the direct use of terrestrial simulants for toxicity studies may not provide an accurate picture of the hazards facing extended manned missions on the Moon (e.g. [4]).

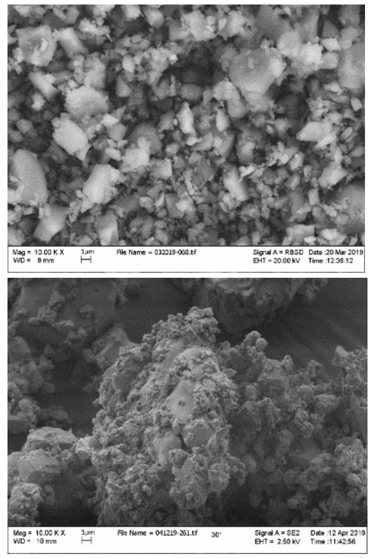

Figure 1. SEM images showing the effect of reducing JSC 1A in H_2 at 900 ºC (a) ground original (b) reduced.

Vapor-deposited phases: Sublimate coatings on pyroclastic glass beads consist of sulfides and halide salts and are enriched in Fe (with Cr), Zn, K, Cl, Cu, Ni and P and lesser amount of Ge, Cd, ^{204}Pb, Ag, Au, Ir, Re, and Br (e.g., [5-7]). These coatings are considered to have formed from gas associated with lava extrusion (specifically, fire-fountaining) or high temperature impact processes on the Moon. Some of these coatings are readily soluble and may contribute significantly to the toxicity of terranes with elevated abundances of these glass beads. We are conducting degassing experiments to indicate the nature of the sublimate phases that can be expected from lunar fire-fountaining and their modification by reduction during space weathering. These materials will be added to the simulants used for our toxicity studies.

Fe-Ti-rich mare basalt glass: It has been knows since the return of the Apollo 11 samples, that the lunar regolith contains fragments of basalt and pyroclastic glass beads with exceptionally high Fe and Ti contents [8]. As there are no terrestrial analogs of these materials, we will synthesize these and assess both their reactivity and toxicity.

References Cited: [1] Laul, J.C. & Papike, J.J. 1980 LPSC 11, 1395-1413. [2] Allen, C.C. et al. 1994. J Geophys Res, 99, 23173-23185 [3] Chang, H.-M. et al. Lunar Dust Workshop. [4] Linnarsson et al. 2012. Planet Space Sci, 74, 57-71. [5] Meyer, C. 1989 LPI Tech, Rep. 90-02 [6] McKay, D.S. et al. 2008. Metsoc 71, #5311. [7] McKay, D.S. et al 2010. LPSC 41, #2509. [8] The Lunar Compendium https://curator.jsc.nasa.gov/lunar/lsc/