THE EFFECT OF SPACE RADIATION PROCESSING ON THE SURFACE CHEMISTRY OF LUNAR REGOLITH GRAINS: EXPERIMENTAL CONSTRAINTS.

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Introduction: Space radiation processing by energetic ions, mostly from the solar wind, plays a major role in space weathering on the Moon and other airless bodies. We are currently investigating the detailed effects of ion irradiation on the surface properties of lunar grains through a combined X-ray photoelectron spectroscopy (XPS) and field-emission transmission electron (FE-STEM) study of experimentally ion irradiation lunar soil as well as key lunar soil minerals. Here we report coordinated findings that synchronize the effects of ion irradiation revealed on the different depth scales probed by XPS and FE-STEM.

Lunar Regolith Irradiation: On surface depth scales probed by XPS, we have previously shown that laboratory irradiation with both 4 keV He^+ and Ar^+ ions progressively converts Fe on the surface of mature lunar soils from a +3 oxidation state caused by terrestrial exposure, to a metallic state (Fe^o) likely characteristic of lunar conditions [1]. We have now additionally calibrated the structural effects of the ion doses used in these experiments to determine whether Fe reduction was accompanied by changes such as ion-induced amorphization observable on the TEM scale. For <20 μm grains of crushed lunar basalt 70215 irradiated to a dose of 6.9 x 10^{15} He^+/cm^2, only slightly higher than the dose at which XPS shows removal of Fe^{3+} from the surfaces of the lunar grains, FE-STEM observations show incipient amorphous rims on pyroxene and plagioclase grains. The width of these rims agree with ion damage depths predicted by SRIM [2] calculations, but rim development around the grain circumference is not uniform, likely reflecting preferential damage of uneven grain surfaces and some shielding of grain undersides. The level of damage as observed by FE-STEM is suggestive of an intermediate, non-uniform degree of modification to the outer margin of the grains that likely would increase at higher ion doses, which we are currently investigating.

Implications: Although XPS is extremely sensitive to subtle changes in surface chemistry produced by ion irradiation, our results suggest that at least for lunar regolith silicates, deeper structural changes 5-10 nm below the surface are also happening at the same time that Fe is undergoing surface reduction. This indicates that Fe reduction is not simply a “monolayer” process but is occurring on a grain surface that is changing its structural state dynamically in concert with the changes in surface chemistry.

References: [1] Dukes, C. et al. 2009, *Meteoritics & Planetary Science Suppl., 5411*. [2] Ziegler, J. F. et al., 2008, SRIM: The Stopping and Range of Ions in Matter, Lulu Press.