Space Weathering: Major Effects of "Vapor-Deposited" Nanophase Fe0 on Reflectance Spectra

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Space weathering is responsible for the formation of regolith and soil on airless heavenly bodies, such as the Moon, Eros, Vesta, Phobos, et cetera. Micrometeorite and meteorite impact-processing brings about the comminution of rocks into soil particles, and the formation of aggregates of grains into agglutinates. The reducing conditions imposed by solar-wind hydrogen during impact melting produces a myriad of small metallic iron crystals particles (nanophase Fe0 particles) in the agglutinitic glasses and accompanying vapor- and sputter-deposited patinas on the soil particles. These effects of space weathering result in a reduction in spectral reflectance; attenuation of mineral absorption bands; and development of a red-sloped continuum, all a function of soil maturity. Many of the processes which produce nanophase Fe in lunar soils are operative for regoliths of other airless bodies (e.g., Hapke, LPSC31, Pieters et al., 1993) and have important implications for interpretation of reflectance spectra of asteroids and the Moon.

It is the finest fractions (<45 mm) of the soils that contribute to and effectively form the major portion of the overall soil reflectance spectra, and they are the subjects of this study (Pieters, 1993). The Lunar Soil Characterization Consortium, a group of lunar-sample and remote-sensing scientists [L.A. Taylor, C.M. Pieters (Brown Univ.), R. Morris (JSC), D.S. McKay (JSC), & L. Keller (MVA Co.)], recently began the extensive task of characterization of the finest fractions of lunar soils, with respect to their mineralogical and chemical makeup. These data form the basis for integration and modeling with the reflectance spectra of these same soil fractions. This endeavor is aimed at deciphering the effects of space weathering of soils on airless bodies in order to refine and fully quantify remotely sensed reflectance spectra, as well as to understand the complexities in the formation of lunar soil. A "library" of fully characterized lunar soils is being established.

The scientific potentials from having finely-tuned, highly-accurate, compositional and mineralogical, remote-sensing capabilities are immense.

Apollo mare soils, selected on the basis of composition and maturity (Is/FeO), were sieved into 20-45 mm, 10-20 mm, and <10 mm size fractions. Splits of these were subjected to bulk chemistry, X-ray digital Imaging for modes and average compositions of all minerals and glasses, Is/FeO analyses, SEM/TEM examination, and reflectance spectroscopy. Perhaps, the most significant finding to date has been with respect to the presence of vapor-deposited nanophase Fe0 (Keller & McKay, 1997).

The large increase in Is/FeO with decreasing grain sizes, with only small increase in agglutinitic glass contents, is direct proof of the presence of another source of nanophase Fe0, besides the agglutinitic glass. Subtracting out the contribution to the Is/FeO made by the agglutinitic glass, there is still a 2-5X increase in Is/FeO between decreasing fine-size fractions. This is from the nanophase Fe0 in the surface-correlated, vapor- and sputter-deposited patinas present on virtually all grains of a mature soil. The 2-5X increase in Is/FeO correlates well with the predicted 4X increase based upon surface-area considerations (Taylor et al., LPSC 31).

The presence of nanophase Fe0 in the vapor- and sputter-deposited patinas (rims) provides an abundant source for the greatly increased Is/FeO values. It is reasoned that it is this enormous contribution of surface-correlated nanophase Fe0 that contributes to the major space-weathering effects upon reflectance spectra from airless bodies.