

SPACE WEATHERING OF THE REAL LUNAR SURFACE: FROM THE *IN SITU* ROVER DETECTION. Y. Z. Wu^{1,2}, Z. C. Wang¹, T. Y. Xu², ¹Key Laboratory of Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210034, China (wu@pmo.ac.cn). ²Space Science Institute, Macau University of Science and Technology, Macau, China.

Introduction: Space weathering is an important surface process occurring on the Moon and other airless bodies, especially those that have no magnetic field. The optical effects of the Moon's space weathering have been largely investigated in the laboratory for lunar samples [1-3] and lunar analogues [4]. However, none of these can realistically duplicate the actual conditions on the lunar surface. The *in situ* spectra measured by the Visible-Near Infrared Spectrometer (VNIS) onboard the Chang' E-3 (CE-3) "Yutu" rover provide an unique opportunity of investigating space weathering by measuring the regolith in its undisturbed state, as well as comparison to the regolith naturally disturbed by rocket exhaust from the spacecraft. Here we report the space weathering of real lunar surface derived from CE-3 *in situ* spectra [5].

During the 114 m distance traveled by the Yutu rover, four measurements of the regolith (sites 5, 6, 7 and 8; Fig. 1) were made by the VNIS. Refer to [6] for details of the VNIS instrument and data processing.

Unrepresentativeness of lunar samples for real lunar surface. Figures 1 & 2 show that reflectance and the strength of absorption bands increased after CE-3 landed, indicating that the maturity of regolith becomes less for sites closer to the lander. This is because rocket exhaust blew away the uppermost mature dust and soils and exposed less-mature materials. Considering that the disturbance depth was very shallow and only the finest fraction of the regolith was disturbed, it suggests a different model of space weathering from that derived from lunar samples. The space weathering model from the lunar samples shows that maturity does not change significantly within the first tens of centimeters of regolith depth and there appears to be little difference in soil properties inside and outside the blast zones [7]. Figure 3 shows the enhanced space weathering model of lunar surface based on the CE-3 observations:

1) the uppermost surficial regolith, perhaps several millimeters to tens of centimeters, is much more weathered than the regolith immediately below (named as Extreme Weathered Skin Layer (EWSL) in this paper), and

2) the finest fraction is much more mature than the coarser fraction. The weathered products are very dark and exhibit attenuated spectral features at all wavelengths, which mask the absorption features and reduce the overall reflectance of covered original minerals.

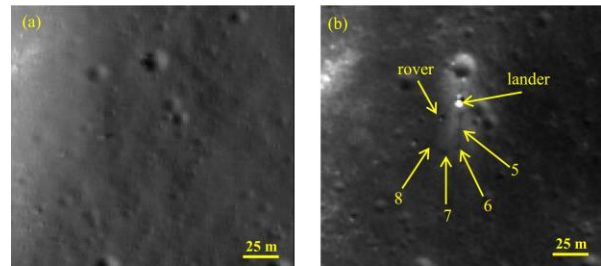


Fig. 1. Before (a; NAC image M1127248516R) and after (b; NAC image M1147290066R) images of the CE-3 landing site.

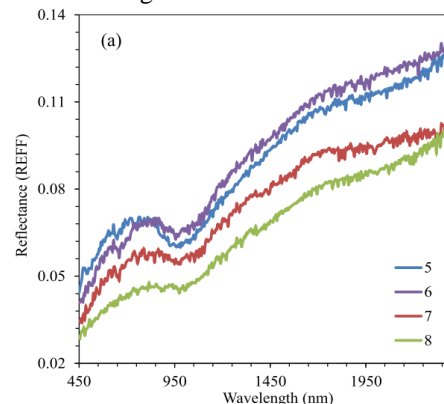


Fig. 2. The VNIS reflectance spectra of 4 sites [6].

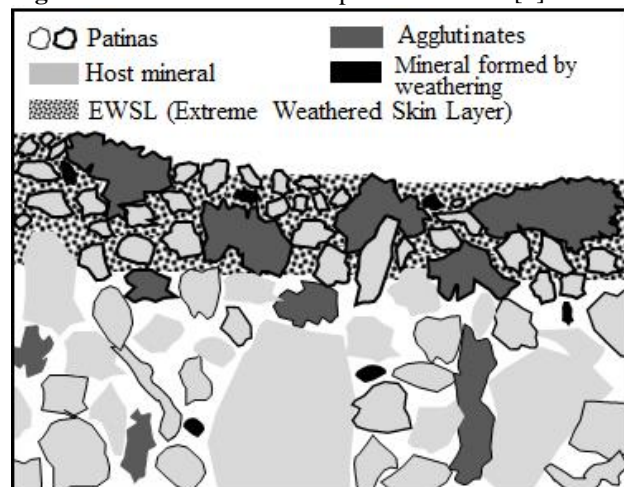


Fig. 3. Model on space weathering of the real lunar surface [5].

Maturity causes the slope in the visible to become shallower (bluer) in contrast to traditional opinion (becoming redder). Canonical opinion thought that space weathering increases the spectral slope in the visible and near-infrared, such that the

415/750 nm ratio becomes smaller with increasing maturity.

The *in situ* spectra show that space weathering decreases the visible slope. That is, the *in situ* spectra reveal an opposite trend in the visible slope with respect to space weathering to the previously known trend. The results from the images also show that immature regolith exhibits a larger visible slope than more mature materials, consistent with the finding from the VNIS data. For example, bright halos in Fig. 4b & d indicate that the visible slope of young craters is larger than surrounding regolith. Correspondingly, the 415/750 ratio of fresh craters is smaller than the surrounding regolith (e.g., dark halo in Fig. 4a & c). Note that mathematically a slope is the difference of two bands rather than a ratio of two bands. In a new study using the Panoramic Cameras (PCAM) on-board the Yutu rover also find that soils have smaller visible slope than rocks. For details refer to [12] in this LPSC abstracts.

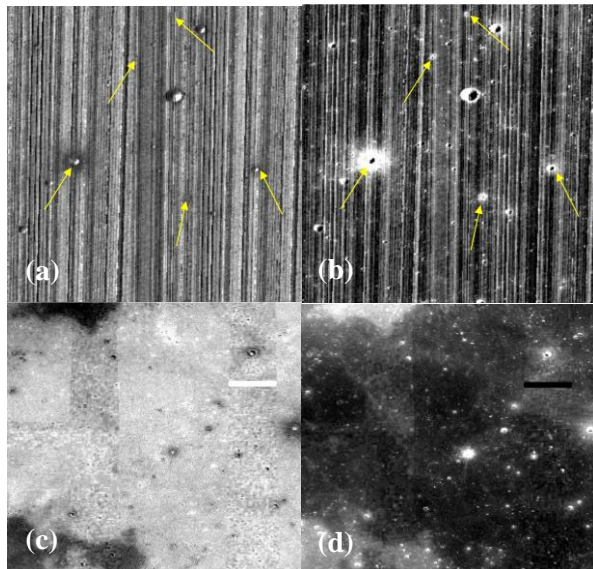


Fig. 4. Images showing that space weathering reduces visible slope. (a) Ratio image (540-nm/730-nm) of M³ data. (b) Difference image (730-nm—540-nm) of M³ data. (c) Ratio image (415 nm/750 nm) of Clementine data. (d) Difference image (750 nm—415 nm) of Clementine data.

All the spectral parameters such as brightness, band depth (BD), band area (BA), visible and near-infrared continuum slope (VNCS), visible slope (VS), band ratio (BR) and optical maturity parameter (OMAT) proposed by [8] describe the optical effects of space weathering and can be used as optical maturity indices. Similarly, All of them also describe the optical characteristics of compositions. The essence of the optical effects of space weathering is the compositional alteration. Therefore, whether for measuring maturity or evaluating composition, the spectral parameters are

only valid locally. Previous researchers also note that OMAT works as a good measure of relative exposure age for a regional surface but not its absolute age because it is affected by several factors such as component and grain size [8-10].

Summary: The CE-3 *in situ* spectra show that the returned samples do not represent the pristine space weathering of the lunar regolith. The uppermost surficial regolith, perhaps several millimeters to tens of centimeters, is much more weathered than the regolith immediately below, indicating a rapid development of SMFe and other space weathering products. The finest fraction of the skin regolith is very dark and attenuated throughout the VNIR wavelengths, indicating rich in various space weathering products.

The effects on the spectral slope caused by space weathering are wavelength-dependent: the VNCS increasing while the VS decreases. At UV to visible wavelengths, space weathering blues the regolith rather than reddens it. It has the same sense as spectrally neutral minerals or elements (e.g., ilmenite or TiO₂). This suggests that the development of a new TiO₂ abundance algorithm is needed.

Optical maturity indices are composition related and hence only locally meaningful. Since optical remote sensing can only sense the uppermost regolith and since this surface tends to be very weathered, the interpretation of surface composition using optical remote sensing data needs to be carefully evaluated. Sampling the uppermost surface is suggested.

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