USE OF RADIATIVE-TRANSFER MODELING TO ESTIMATE NANOPHASE IRON ABUNDANCE AT THE CHANG'E-3 SITE. Z. C. Wang[1], Y. Z. Wu[2], Y. C. Zheng[3], D. T. Blewett[4], and E. A. Cloutis[5], X. Tang[2]. [1]Institute of Surficial Geochemistry, Department of Earth Sciences, Nanjing University, Nanjing 210023, China (wangbianma@gmail.com); [2]School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing, 210023, China; [3]Key Laboratory of Lunar and Deep Space Exploration, National Astronomical Observatories of Chinese Academy of Sciences, Beijing 100012, China; [4]Planetary Exploration Group, Johns Hopkins University Applied Physics Laboratory, Laurel, MD, 20723, USA; [5]Department of Geography, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB R3B 2E9, Canada.

Introduction: On Dec. 14, 2013 the *Chang'E-3* (CE-3) spacecraft landed on the Moon in northern Mare Imbrium (19.11 °W, 44.12 °N) [1]. The rover *Yutu* made measurements with its four scientific instruments along a 114-m traverse (Fig. 1). Reflectance spectra (0.45 to 2.40 μm) of the surface were acquired by the Visible and Near-Infrared Spectrometer (VNIS, [2]) at four locations; these data represent the first such spectra obtained *in situ* on the Moon. We have carried out radiative-transfer modeling of the spectra with the goals of quantifying the abundance of nanophase iron (also named $npFe^0$ or SMFe) in the soil, relating the $npFe^0$ abundance to distance from the lander, and gaining insight into the cause of spectral changes in response to modification by lander rocket exhaust.

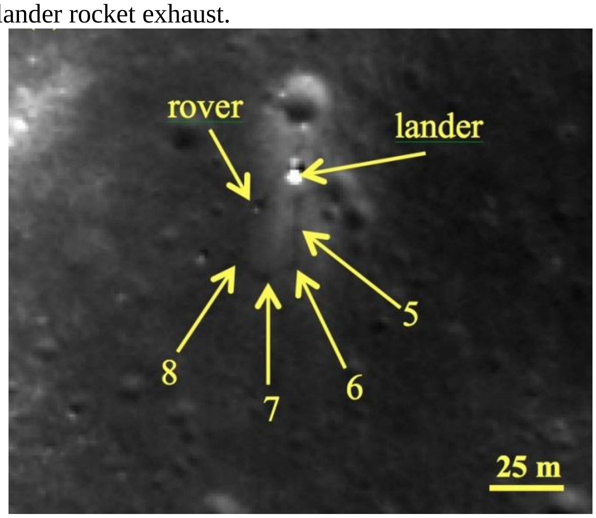

Fig. 1. LROC NAC (http://lroc.sese.asu.edu/) view of the CE-3 landing site. VNIS measurement locations 5 to 8 are labeled.

Instrument and Data: The VNIS instrument performs wavelength selection with an acousto-optic tunable filter. VNIS has two channels: an imaging spectrometer covering 0.45 to 0.95 μm (visible-near-infrared, VNIR, 100 bands), and a spot spectrometer for the wavelength range 0.90 to 2.4 μm (short-wavelength infrared, SWIR, 300 bands). A cover protects the instrument from dust contamination while it is not in use. The inside of the cover holds a Spectralon target, permitting calibration data to be obtained closely in time with the surface observations.

Surface observations were made at four locations (Fig. 1). All data are for relatively flat, smooth areas of soil; no rocks or rover tracks were measured. The spectra (Fig. 2) show systematic differences that are consistent with increasing maturity from Sites 5 to 8. For example, Site 5 has the deepest 1-μm band, and also the greatest (freshest) value of the OMAT optical maturity parameter [3] as computed from the VNIS spectra.

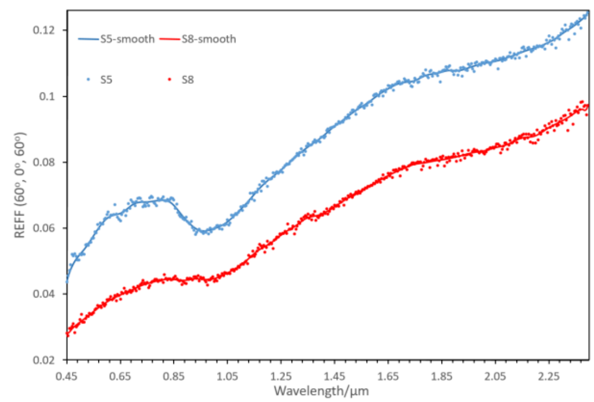

Fig. 2. CE-3 VNIS spectra for Site 5 and Site 8. Points are the original reflectance data and the curves represent smoothed spectra. The red points and line are for Site 8, and the blue are for Site 5.

Method: This work modeled the abundance of $npFe^0$ at Site 8 (the most mature) and at Site 5 (the freshest) in two steps.

The abundance of $npFe^0$ at Site 8 is computed by comparison with a very fresh location (Site Fresh, located at 19.712° W, 44.032° N) near the CE-3 landing site. Site Fresh is assumed to contain no $npFe^0$ based on its surface rock abundance and strong "1 μm" absorption in a spectrum extracted from Moon Mineralogy Mapper(M^3) data. Since M^3 data and CE-3 data have different ranges of wavelength, CE-3 data were interpolated to the M^3 wavelengths by resampling. To reduce the influence of spectral noise on the analysis, both spectra were smoothed by a least-squares spline approximation method. Also, CE-3 data have been calibrated to Reflectance Factor (REFF), but M^3 is in Radiance Factor (RADF). Therefore, the CE-3 spectrum of Site 8 was converted to RADF, normalized to 30 °incidence angle and 0 ° observation angle [4].

We employed Hapke's treatment [5] to model the abundance of $npFe^0$ in the soil at Site 8 by comparing with Site Fresh. Model spectra were created by adding $npFe^0$ to the spectrum of Site Fresh. Spectra containing $npFe^0$ have steeper slopes and shallower absorption bands, more like the spectrum of Site 8. The model spectra were compared to Site 8 by matching spectral shapes through the Spectral Angle (SA) parameter [6]. The comparison was performed over the wavelength range 0.78–1.90 μm, where the spectra have the highest quality. The abundance of $npFe^0$ at Site 5 was computed by comparison with Site 8. We added $npFe^0$ to the spectrum of Site 5 and found the best SA match with the Site 8 spectrum. Spectra for both Site 5 and Site 8 are in the same units (REFF at angles of 60 °, 0 °, 60 °), so no spectral conversion was needed.

Result: The best SA match between the Site 8 M^3 spectrum and a model spectrum was found for an $npFe^0$ abundance of 0.335 wt.% (Fig. 3a). Also, adding 0.1 wt.% abundance of $npFe^0$ to Site 5 matches best with Site 8 (Fig. 3b). This analysis suggests that the maturity difference between Site 5 and Site 8 is a result of greater $npFe^0$ abundance in Site 8. Site 5 is closer to the lander, and Site 8 is at a greater distance. Therefore, the brightening observed around spacecraft landing sites (Fig. 1; [e.g., 7]) may be related to maturity differences caused by removal of fine, highly mature particles by rocket blast. Using Eq. 4 of Morris [8], the value of the Is/FeO maturity index was computed from the contents of $npFe^0$ and FeO. Assuming the content of FeO in the CE-3 basalts is 20 wt.% [1], the Is/FeO of Site 8 was determined to be ~52. This value falls in the "submature" range (30–60) [9]. Comparing this value with that of Steno crater [10] at Apollo 17 and Surveyor crater [11] at Apollo 12, the age of the soil at Site 8 is estimated to be more than 110 m.y. and much less than 240 m.y.

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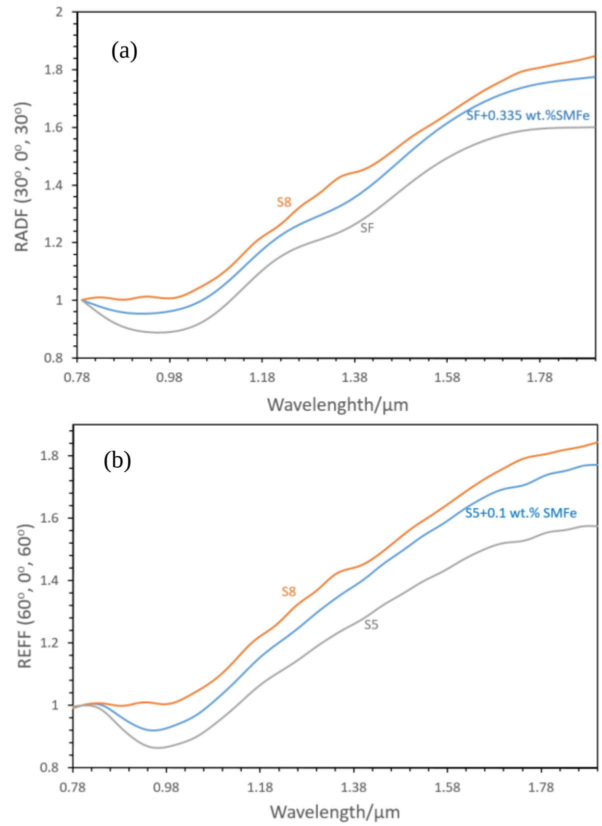

Fig. 3. (a): The original spectra of Site 8 and Site Fresh, with a Hapke model spectrum made by adding 0.335 wt.% $npFe^0$ to Site Fresh. Points and dashed line are the smoothed spectra of Site 8 (S8) and Site Fresh (SF), and the solid line is the best fit for Site 8. (b): The original spectra for Site 5 and Site Fresh, with a model made by adding 0.1 wt.% to Site 5. Points and dash-line are the smoothed spectra of Site 8 (S8) and Site Fresh (SF), and the solid line is the best fit for Site 8. All spectra are scaled to unity at 0.8 μm.