SPECTROPHOTOMETRIC MODELING OF SOILS AND ROCKS AT THE OPPORTUNITY LANDING SITE.

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***Introduction*:** The Panoramic Camera (Pancam) on the Opportunity Mars Exploration Rovers [1] acquired multispectral reflectance observations of outcrop rocks and spherule-rich soils at different incidence, emission, and phase angles (0-155°) that were used for photometric modeling to constrain the albedo and physical properties of the surface materials. Nominal filters covered wavelengths of 432 nm, 601 nm, 753 nm, and 1003 nm, with a stereo filter selected as either 436 nm or 754 nm.

Observations. Pancam acquired four photometry sequences in Eagle Crater: (*1*) on Sol 011 after the rover egressed from the lander; (*2*) on Sols 029-033 of the outcrop and soils above the rocks Guadalupe and McKittrick (Figure 1); (*3*) on Sols 38-39 near Last Chance rock; and (*4*) on Sols 42-45 of the Berrybowl rock area. After exiting Eagle Crater, a comprehensive campaign was conducted south of Fram Crater on Sols 089-091. Two rocks were imaged at multiple times of day within Endurance Crater: Wopmay on Sols 261-262 and Tipuna on Sols 306-307. South of Endurance Crater, a series of extensive campaigns was conducted near the heatshield on Sols 328-329 and 335-336. Measurements of Heatshield Rock (a Fe-Ni meteorite) were acquired during Sols 339-352. A limited sequence was acquired near Alvin Crater on Sol 363, followed by a larger data set nearby during Sols 367-374. Images were acquired of rocks and soils near Valentina at Vostok Crater during Sols 403-404. South of Voyager Crater, observations were acquired during Sols 437-439. Finally, a large campaign was conducted from Purgatory Dune on Sols 449-492.

Analyses. For each Pancam photometry sequence four main tasks were undertaken: (*1*) Analysis of spectral variability within the scenes and selection of regions of interest (ROIs) on endmember rocks and soils, (*2*) Creation of "Photometry QUBs" that included incidence, emission, and phase angle images computed from stereo image disparity maps [2]; (*3*) Application of the sky radiance model of [3] to compensate for the effects of reddened diffuse skylight [2]; and (*4*) Derivation of Hapke scattering parameters at a given wavelength for each endmember using bidirectional reflectance observations corrected for diffuse skylight and incorporating local facet tilts for ROIs. Hapke models were run using Henyey-Greenstein (HG) phase functions to determine the asymmetry parameter (ξ) for a 1-term HG, and the *b* (asymmetry parameter) and *c* (backscattering fraction) parameters for a 2-term HG. All models included the single scattering albedo (*w*) and macroscopic roughness parameter ($\bar{\theta}$). For data sets lacking observations at phase angles < 20° the opposition effect width (*h*) and amplitude (*B0*) were set to zero. A reduced chi-square (χ_v^2) estimate of goodness of fit was also derived. The error on each fitted parameter was estimated by testing how χ_v^2 changed when a particular parameter was purposely varied from its original best-fit value [2,4].

Hapke parameter values were determined for the outcrop and spherule-rich soil units within Eagle Crater, including "bounce mark" soils compressed by the MER airbags. Available phase angles were 20-125° for these data, so *h* and *B0* were not used. Figure 2 shows the modeled *w* values for each unit derived from the 1-term HG models. The lack of visible spherules gave the bounce marks slightly higher albedo except at 443 nm. Figure 3 shows the ξ and *w* values for the soils, outcrop rocks, and the bounce marks. Using the 1-term HG function, the spherule-rich soils were most backscattering, whereas the bounce marks were the least backscattering. Figure 4 shows the *b* vs. *c* plot of these units compared to the values determined by [5] for artificial particle types. Using the 2-term HG function, the bounce marks were the most forward scattering, but the outcrop rocks were the most backscattering. The spherule soils had the highest $\bar{\theta}$ values (26±2°), whereas the bounce marks (20±3°) and outcrop rocks (19±5°) were nearly identical. Ongoing analysis of the other data sets will explore variations in these parameters among units along the Opportunity traverse and provide useful data for interpreting their surface scattering properties.

***References*:** [1] Bell, J.F. III et al., *Science*, 1703-1709, 306, 2004; Squyres, S.W. et al., *Science*, 1698-1703, 306, 2004; [2] Johnson, J.R. et al., *JGR Spirit issue¸in press*, 2006; [3] Lemmon et al., Science, 306, 1753, 2004; [4] Cord, A.M., et al., *Icarus*, 165, 414-427, 2003; [5] McGuire, A., and B. Hapke, *Icarus*, 113, 134-155, 1995.

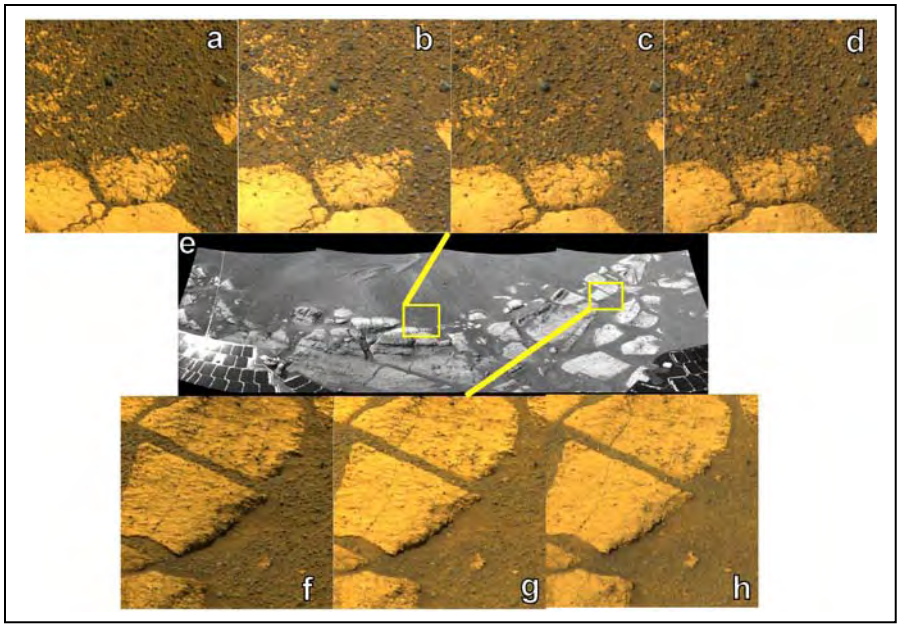

Fig 1. Image sequences acquired above McKittrick and Guadalupe rocks on Sols 29-32 at (*a*) 0921, (*b*) 1151, (*c*) 1319, and (*d*) 1401 Local True Solar Time (LTST), and at Tamanend Park acquired on Sols 32-33 at 0943 (f) , 1204 (*g*) , and 1415 LTST (*h*). Navcam mosaic acquired on Sol 026 shows region locations on outcrop (*e*). All images constructed from *I/F* data using 753 nm (L2), 601 nm (L4), and 432 nm (L7) filters (identical stretches applied to each Pancam band and mosaic: 0.00-0.30).

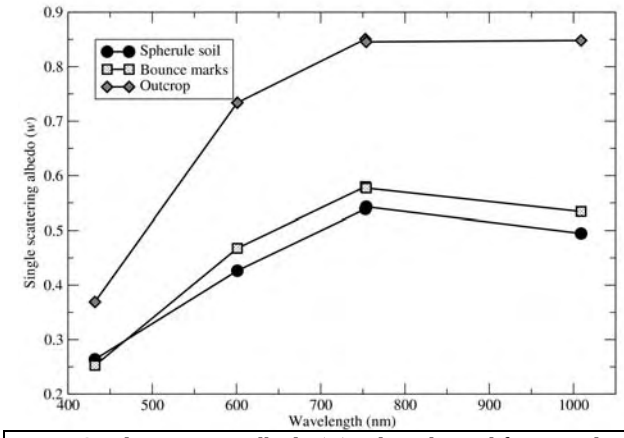

Fig 2. Single scattering albedo (*w*) values derived from single-term HG phase function Hapke model for Eagle Crater units. Spherule soils have slightly higher 443 nm albedos owing to greater presence of spherules.

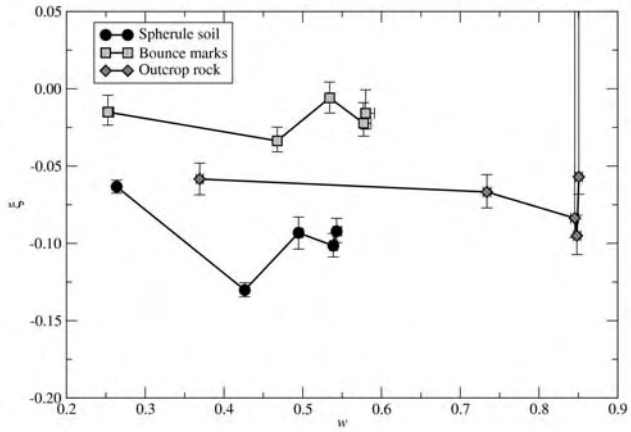

Fig 3. Single-term HG asymmetry parameters (ξ) versus single scattering albedo (*w*) values derived from Hapke models of Eagle Crater units. Spherule soils are most backscattering, and bounce marks are most forward scattering.

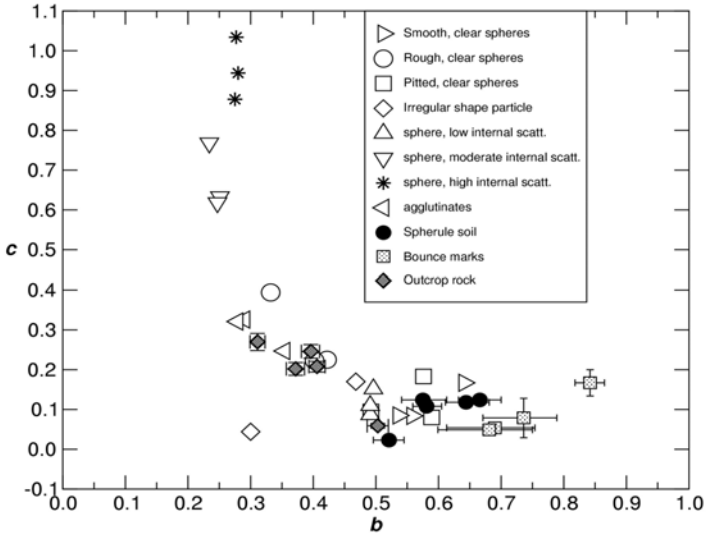

Fig 4. Two-term HG asymmetry parameters (*b*) versus basckscattering fraction parameters (*c*) for Eagle crater units plotted with values derived for synthetic particles (open symbols and stars) from [5]. Outcrop rocks have a broader, more backscattering lobe than the narrower, forward scattering lobe of the bounce marks. Error bars represent one-sigma uncertainty estimates [2].