SURFACE PHOTOMETRIC PROPERTIES ALONG THE MARS EXPLORATION ROVERS' TRAVERSES: SOLS 500-1525. J.R. Johnson[1] W.M. Grundy[2] M.E. Lemmon[3] J.F. Bell III[4] R.G. Deen[5], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, jeffrey.r.johnson@jhuapl.edu, [2]Lowell Observatory, Flagstaff, AZ, [3]Texas A&M University, College Station, TX, [4]Arizona State University, Tempe, AZ, [5]Jet Propulsiton Laboratory, Pasadena, CA.

Introduction: Pancam multispectral visible/near-infrared images (432-1009 nm) acquired along the Mars Exploration Rover (MER) Spirit and Opportunity traverses have enabled mapping of surface textures, morphology, and mineralogy vital in constraining the geologic processes that formed and modified these field sites. Photometric properties of the rocks and soils observed by Pancam were quantified for both rovers using multispectral observations acquired under variable illumination and viewing geometries up to Sol 475 by [1]. Additional Pancam photometric observations were acquired at multiple wavelengths between Sols 500 and 1525 that augment previous Pancam analyses. Spirit data were acquired from the summit region of Husband Hill down to the areas around the eastern margin of Home Plate, and Opportunity data obtained from north of Erebus crater to the rim of Victoria crater (Table 1, Figure 1). These data sets sampled previously unobserved rock and soil types, such as high-silica deposits, ferric-sulfate soils, volcaniclastic materials, and dark basaltic sands, as well as new exposures of ferric soils and dusts, hematite spherule-rich soils, sulfate-rich sandstones, and basaltic rocks.

Method. We used a Hapke radiative transfer model in combination with corrections for diffuse sky illumination and local surface facet orientations derived from Pancam stereo image models, following the methodology presented by [1]. We modeled Hapke parameters of rock and soil units including the single scattering albedo (*w*), 1-term and 2-term Henyey-Greenstein (HG) phase function parameters, macroscopic roughness ($\bar{\theta}$), and opposition effect widths (*h*, when low phase angle coverage was available). Comparison of Hapke parameters among the units observed by both rovers, parameters modeled from other landing site data sets, and laboratory-based analyses [2,3] allowed for interpretations of physical properties of the geologic materials (Figure 2).

Spirit results. For data sets with sufficient phase angle coverage, typical "gray" rocks (i.e., those with comparatively less dust or soil contamination) tended to be the most forward scattering in 2-term HG models (particularly Torquas rocks, cf. Figure 2), whereas soils were more backscattering. Conversely, the basaltic sand ripples of El Dorado were very forward scattering at all wavelengths but 432 nm, similar to Viking orbital observations of dark sands [5]. Ferric sulfate-rich soils exhibited the largest *w* values as well as very forward-scattering behavior in 2-term HG models, but were the most backscattering in 1-term HG models. This contradictory result likely arose from the limited ability of the phase angle coverage (~5-60°) to constrain the scattering behavior and requires further study. Silica nodules and silica-rich soils exhibited some of the most backscattering behaviors, although progressively less backscattering with increasing wavelength. This behavior may result from greater absorption/lesser penetration (i.e., less multiple scattering) of photons at longer wavelengths. Values of *h* were better constrained using 1-term HG models, and on average ranged from ~0.07 to ~0.21, albeit with little consistency among units at the different rover locations.

Opportunity results. Spherule-rich soils in the Meridiani data sets were often the most backscattering materials, although soils without spherules and rover tracks were more forward scattering (consistent with lab studies [2]), and dusty soils were less backscattering (Figure 2). Soils inside the dark wind streak on the northern rim of Victoria crater were somewhat less backscattering that those outside the streak [4]. These dark streak sands exhibited larger *h* values (~0.095) and lower $\bar{\theta}$ values than the dustier soils outside the streak, consistent with their greater proportion of basaltic sands of more uniform grain size. Outcrop rocks exhibited the highest *w* values, more intermediate backscattering behaviors, and *h* values similar to soils.

Discussion. Ongoing modeling work will refine these results, in particular issues related to high values of atmospheric opacity (Sols 1240-1245A) or the Sol 1250B dust storm. The latter resulted in all units exhibiting similar photometric properties owing to dust that temporarily contaminated the Pancam window.

References: [1] Johnson, J.R., et al. J. Geophys. Res., 111, E02S14, doi:10.1029/2005JE002494, 2006; Johnson, J.R., et al. J. Geophys. Res., 111, E12S16, 2006JE002762, 2006; [2] Johnson, J.R. et al., Icarus, 223, 383-406, 2013; [3] McGuire, A. and B. Hapke, Icarus, 113, 134-155, 1995; [4] Geissler, P.E., et al., JGR, 113, E12S31, 2008; [5] Geissler, P. E. and Singer, R. B. LPSC 23, p. 403, 1992.

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Table 1. Spirit (A) and Opportunity (B) photometric sequences: Sols 500-1525.

Area	Sols	Incidence (°)	Emission (°)	Phase (°)	No. of images
Voltaire	564A	10-21	55-85	45-104	60
Cliffhanger	606-610A	9-81	57-74	5-147	140
El Dorado	708-710A	10-81	67-81	32-150	60
McMurdo	930-935A	40-83	52-81	9-152	60
Torquas	1142-1148A	7-78	51-82	15-137	115
Eileen Dean	1240-1245A	11-77	65-80	13-151	240
N Erebus	573-575B	23-77	37-75	1-151	180
Olympia	665-703B	3-76	54-85	5-161	378
Overgaard	716-717B	11-64	40	16-103	8
Bellemont	736-739B	8-84	54-70	12-153	144
Victoria Annulus	920-925B	27-77	65-82	4-157	146
Outside Streak	1134-1136B	11-74	55-80	7-144	120
Inside Streak	1138-1141B	12-74	55-80	5-144	80
Duck Bay	1510-1522B	24-62	76-97	32-152	175

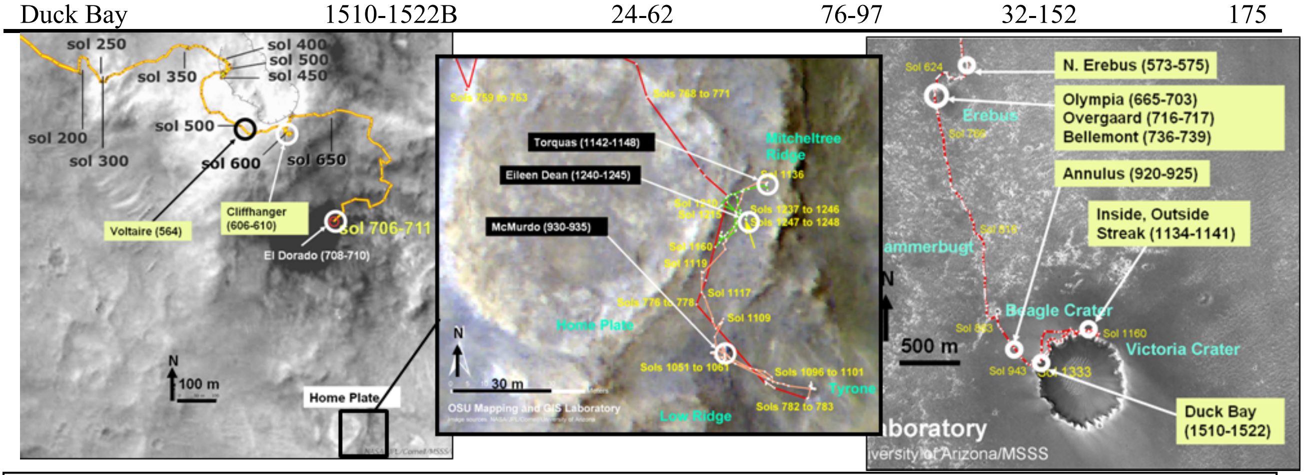

Figure 1. Locator maps for Spirit (*left, center*) and Opportunity (*right*) sequences shown in Table 1. Basemaps cropped from images at http://marsrovers.jpl.nasa.gov.

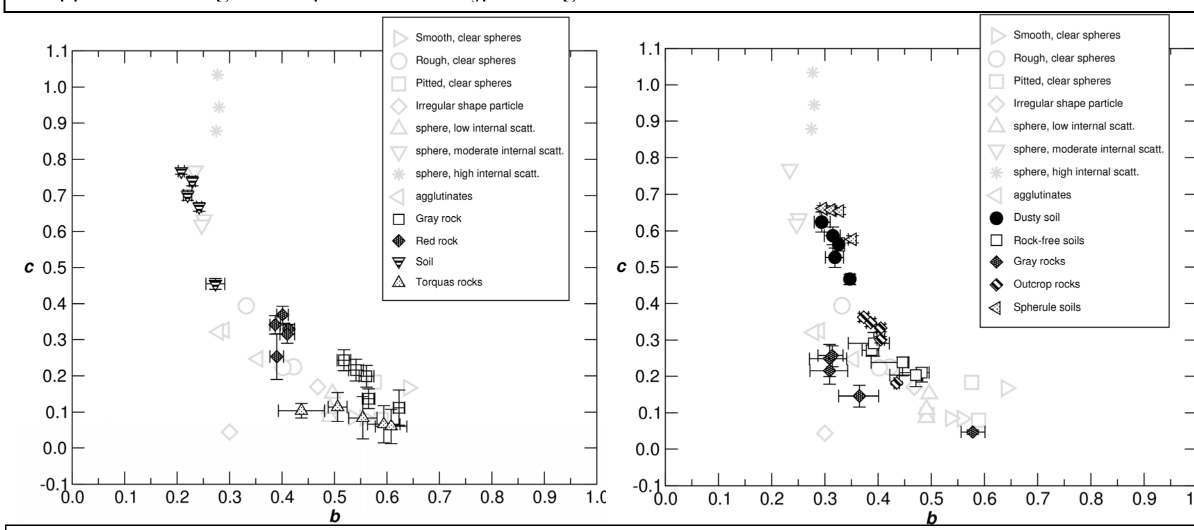

Figure 2. Example asymmetry parameters (*b*) versus backward scattering fraction parameters (*c*) for (*left*) Spirit, Sols 1142-1148 (Torquas), and (*right*) Opportunity, Sols 665-703 (Olympia) from 2-term HG models, plotted with values for lab data (gray points) from [3]. High *c*/low *b* values represent materials with broad backscattering lobes.