Directional Emissivity Effects on the Meridiani Plains. W. M. Calvin[1], T. D. Glotch[2], R. E. Arvidson[3], S. Wiseman[3], J. R. Johnson[4], S. W. Ruff [5], A. T. Knudson [5], and P. R. Christensen[5] [1]Geological Sciences, University of Nevada, Reno, wcalvin@unr.edu, [2]Geological and Planetary Sciences, Caltech; [3]Earth and Planetary Sciences, Washington University; [4]U. S. Geological Survey, [5]Geological Sciences, Arizona State University.

Introduction: Upon landing at Meridaini Planum, the Mars Exploration Rover Opportunity, soon found that the spectral signature of bulk hematite that had been identified from orbit was caused by a lag deposit of spherical concretions. Both the Miniature-Thermal Emission Spectrometer (Mini-TES) and the Mössbauer Spectrometer (MB) confirmed the dominant signature of hematite in these small "blueberries" [1-4]. It was noted that in Mini-TES observations, the distinctive hematite spectral signature was stronger outside Eagle crater and was initially attributed to projected area and viewing geometry effects [1]. Over the course of nearly two Earth years and several kilometers of traverse a series of observations have been acquired that allow more systematic exploration of the emission angle dependence of the hematite signature across the Meridiani plains and on dune slope faces.

Methods and Observations: Plains scans were obtained in several groupings associated with other rover activities. The first was inside Eagle crater, where Opportunity was below the local plains level. Upon egress from Eagle a series of vertical scans were performed. A series of detailed Pancam visible/near-infrared photometry observations have been made [5,6] and several Mini-TES scans in support of these observations were obtained. The next major plains scans occurred in the vicinity of the Heatshield, south of Endurance, and a series of dune face observations were made beginning with Purgatory, the ripple in which Opportunity got stuck in June 2005. We have also acquired 8 rasters of the plains with more widely-spaced observations so that both lateral as well as vertical dependence can be explored. In addition, approximately 40 systematic foreground observations (low pointed closely-spaced rasters) were made between sols 70 and 609, allowing comparison of distant emission variations with local scale changes in soil signatures.

For this analysis we concentrate on those plains scans occurring outside Eagle crater (sols 57-72), and in the vicinity of the heatshield (sols 354-372). In both cases the rover was on fairly level terrain so that the instrument elevation angle can be used to determine an approximate surface emission angle through simple geometry. A number of observations in the vicinity of Eagle crater are extremely noisy as these scans only acquired 2 individual scans (icks) in each position. These noisy observations and those which exhibit a rover tilt of more than 5 degrees have been excluded from the current analysis.

An example of spectral variability with elevation in one of the vertical scans is shown in Figure 1. The increase in the strength of the hematite feature with increasing distance (emission angle) onto the plains is obvious. The band strength of the hematite feature near 550cm^{-1} has been determined and compared with elevation angle in Figure 2. Relative band depth is determined using (Ec – Eb), the emissivity of the continuum – band in atmospherically uncorrected spectra. This difference approach accounts for variation in the continuum level that occurs due to time of day and pathlength variations between observations and allows for occasional continuum emissivity values that are greater than unity in the raw calibration. The hematite bands are in an area relatively unaffected by atmospheric contributions so this simple measure is appropriate. The presence of hematite will affect the shoulder of the spectrum near 600 cm^{-1} so the continuum value is derived near 745 cm^{-1} on the opposite side of the strong atmospheric CO_2 absorption feature.

Hematite signature variability: Figure 2 shows that there is a strong and consistent pattern of increasing band strength with larger emission angles (smaller instrument elevation angle) on the plains. Observations from different sols and locations all show the same elevation angle dependence. Small deviations throughout can be accounted for by heterogeneity in berry cover, varying dune face geometry, noise levels in the early, low-ick scans and the extreme distances involved in the smallest elevation angle observations. The increase in projected area of the Mini-TES spot size is predicted to follow a $(1/\cos(\theta))^3$ curve, where θ is the complement of the elevation angle. This approximate fit is shown as the dashed line. While this measure works well nearest the rover, the observations deviate from this simple geometrical relationship at elevations above -15 degrees. The approximate elevation where this occurs projected on the Meridiani plains is shown in Figure 3.

The lowest elevation angles of the vertical scan data are consistent with the same hematite index for the systematic near field observations. The latter show no distinct pattern. These foreground observations are acquired between –35 and –50 elevation angles with band depths ranging from zero to a maximum of 0.048 with an average of 0.033. Strong variability at the same elevation is attributed to local and widely varying coverage by spherules and other cobbles, but these observations also cluster along the same trend as the vertical scans at these lowest elevations.

Implications: The lack of a feature at 390 cm^{-1} in the spectra from TES in orbit and Mini-TES on the surface suggests that the emission is dominated by a single crystal axis (c-face), as can occur if the crystal grains are oriented (laminated or platy structure) [7]. Recent work by Glotch et al. [8] models spectra from spherules using Fresnel refelctance theory and notes that either random thin plates or interior concentric laminations could account for the observed spectra. To date, Opportunity Rock Abration Tool has ground through 17 fully-formed berries and another dozen or so smaller features and blebs associated with aqueous mineral redistribution in outcrop. None of these show structure at the scale of Microscopic Imager (MI) images. We note that in all of the Fresnel models band center shifts and relative changes in band strength are observed at emission angles of 75 degrees – the same point at which the directional emissivity variation deviates from a simple geometric curve. Future work will concentrate on understanding these directional effects and their implications for spherule composition and formation.

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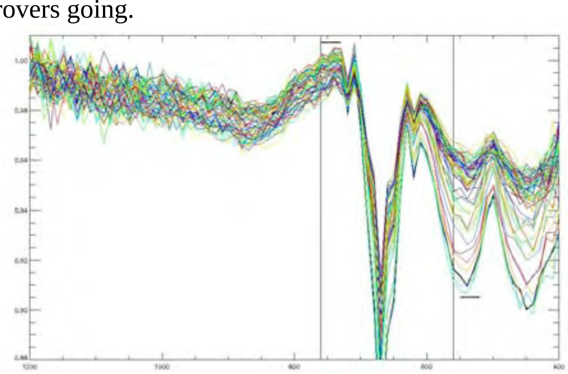

Figure 1: Vertical scan acquired on Sol 72. Vertical black lines note region generally obscured by atmospheric absorption. Horizontal black lines note regions used to determine continuum and band depth of the hematite feature. Stronger absorption is associated with increasing distance on the plains.

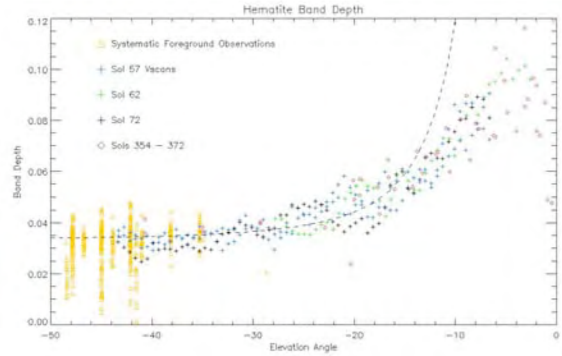

Figure 2: Hematite band strength vs elevation angle for various vertical scans on the plains and from the systematic foreground observations. Predicted projected area function does not match the observed far-field behavior.

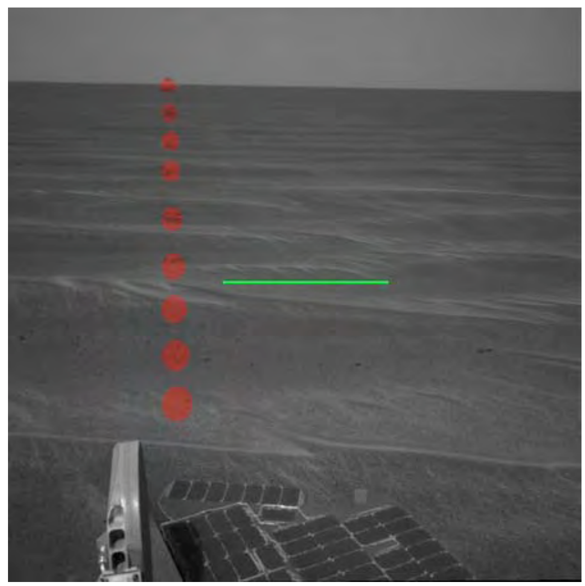

Figure 3: MTES spots for the Sol 371 vertical scans are shown in red. An elevation of roughly –15 degrees is shown in green. At elevations above the green line hematite band strength diverges from the predicted projected area increase.

References: [1]Christensen, P. R. et al., (2004) *Science*, *306*, 1733-1739. [2]Soderblom, L. A. et al. (2004) *Science*, *306*, 1723-1726. [3]Klingelhöffer, et al., (2004) *Science*, *306*, 1740-1745. [4]McLennan et al. (2005) *EPSL*, *240*, 95-121. [5]Johnson, J. R. et al. (2005) LPSC XXXVI, #1815. [6]Seelos, F. P. et al. (2005) LPSC XXXVI, #2054. [7] Lane et al. (2002) JGR, 107, 5126 doi:10.1029/2001JE001832. [8]Glotch et al. Icarus, in press.