TESTING A TECHNIQUE FOR IDENTIFYING OLIVINE COMPOSITION FROM REMOTE SENSING DATA: AWAITING GROUND TRUTH FROM GALE CRATER, MARS. Melissa D. Lane, Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719 (*lane@psi.edu*).

Introduction: The successful landing of the Mars Science Laboratory *Curiosity* rover on the surface of Mars presents a rare opportunity for validation of a spectral index developed for determining olivine chemistry (Fo#) from orbital mid-infrared remote-sensing data, e.g., from the Mars Global Surveyor Thermal Emission Spectrometer (TES). Previously, a suite of 13 synthetic Mg-Fe olivine samples ranging in composition from forsterite to fayalite were studied using thermal emission spectroscopy [1]. Here a spectral index is defined, using these emissivity spectra, for determining the chemical composition of the olivine. Utilizing this spectral index, a prediction of olivine composition is made for a large NE-SW trending olivine-rich basaltic sand dune field [2,3] in Gale Crater at the base of a ~5 km high sediment stack (Aeolis Mons/Mount Sharp) that can be seen in orbital images near the landing zone of the *Curiosity* rover and in the surface images from *Curiosity* (Figures 1, 2).

This dark dune field will be crossed before the rover can reach the main areas of orbitally detected clays and sulfates and ascend the crater's 5-km high central mound that will be studied in detail later in the mission. The *Curiosity* rover can use its instrument suite (e.g., ChemMin, ChemCam and APXS) to verify or refute the Mg-Fe olivine chemistry prediction presented here when it reaches the dunes. The ability to test the developed olivine spectral index using the rover's ground-truth instruments and verify the olivine composition predictions will strengthen future planet-wide compositional mapping of the olivine chemistry across the Martian surface using this index.

Figure 1. Gale in 3D projection showing the MSL landing ellipse. Image credit: NASA/JPL-Caltech/ESA/DLR/FU Berlin/MSSS.

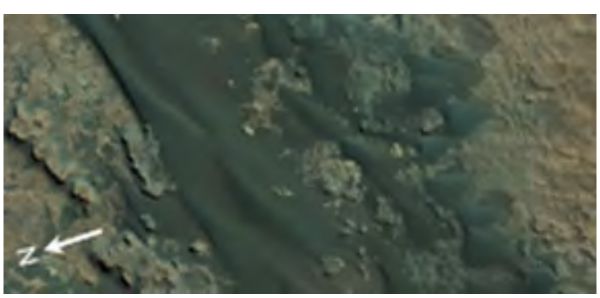

Figure 2. HiRISE image of dune field (ESP_18854_1755_RGB). Image credit: NASA/JPL-CaltecUA.

Dune Characteristics: The dune field offers a unique opportunity to study a geologic unit of approximately uniform composition at a scale that is able to be studied using the large spatial resolution of the TES data. The dunes appear to be a constant lithology because many of its properties are uniform across them, including low albedo, high thermal inertia (530-740 J m^{-2} K^{-1} $s^{-1/2}$), and general elevation (i.e., all are trapped at the lowest part of the crater [4]). These dunes also appear to be active [5] and self-cleaning (TES Dust Cover Index in JMARS [6,7]), thus having a low amount of fine dust cover (in an otherwise high-dust area [2]) that enables the dune's spectral characteristics to be studied from orbit. THEMIS decorrelation-stretched (DCS) images also show the dunes as a uniform false-color, indicating mineralogic uniformity (Figure 3).

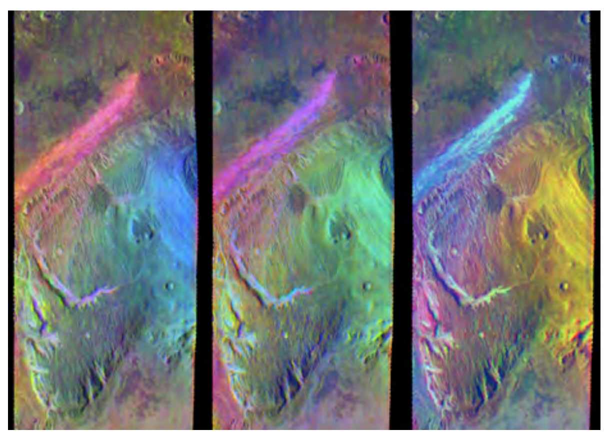

Figure 3. THEMIS DCS images, where RGB = 875, 964, 642, respectively.

Data from the Mars Reconnaissance Orbiter Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument identified the dunes to be mafic in composition, containing olivine and high-Ca pyroxene [3,5]. The lithologies of the Gale Crater units using Mars Odyssey Thermal Emission Imaging System (THEMIS) and Mars Global Surveyor Thermal Emission Spectrometer (TES) data were assessed by [2] who found the dune field to be similar to "Surface

Type 1" [8] that is basaltic; however, the THEMIS band at ~11 μm was deeper, related to an additional olivine component.

Olivine Spectral Index: Synthetic olivine samples (powders pressed into pellets) ranging in composition from forsterite to fayalite (also including $Fo_{89.5}$, Fo_{80}, Fo_{75}, Fo_{70}, Fo_{65}, Fo_{60}, Fo_{55}, Fo_{50}, Fo_{40}, Fo_{30}, Fo_{20}, and Fo_{10}) were analyzed using thermal emission spectroscopy (mid-infrared) to study the spectral effects of Mg-Fe solid solution [1]. The Fo_{60} pellet was too small to obtain a good spectrum. In that study it was observed that olivine fundamental spectral bands gradually change in position and strength from Mg_2SiO_4 at larger wavenumbers to Fe_2SiO_4 at smaller wavenumbers, as historically known; however, the systematic shifting of an additional feature in the olivine spectra, i.e., a local emissivity maximum (a convex-upward bend called the flection position) that occurs between two fundamental bands was identified (details in [1]). The shifting of this flection position, farther-shifting than any of the fundamental bands, is utilized here for identifying olivine composition from remote sensing data.

A spectral index based on the flection position was determined from the full-resolution laboratory data and follows the general formula of:

$$\text{Index value} = \varepsilon_{fp} / (\varepsilon_{\text{Band 9}} + \varepsilon_{\text{Band 12}}), \qquad \text{Eqn. (1)}$$

where ε_{fp} is the emissivity value at the flection position, $\varepsilon_{\text{Band\#}}$ is the emissivity value at the defined Band 9 and Band 12 positions (and the band number is identified and detailed in [1]). Because the positions of Bands 9 and 12 shift for each olivine composition, there is a different specific formula for each Fo#, but they all follow the general formula. Higher index values represent higher abundances of a given Fo#.

Mapping Olivine Composition: In order to apply the developed spectral index to interpreting the TES data from Mars, the laboratory spectra (at ~2 cm^{-1} spectral resolution) were degraded to the ~10 cm^{-1} TES spectral resolution [9] to identify correct TES bands for the index formulae. Because of the coarseness of the TES spectral resolution, some Fo#s are represented by an equation identical to a neighboring Fo#. This was the case for $Fo_{50\&55}$ as well as $Fo_{70\&75}$, indicating a minimum error in compositional determination of 5 Fo#. Using JMARS software [7], TES data were analyzed by applying the olivine indices, and results are shown in Figure 4.

Results and Limitations: Figure 4 shows that the $Fo_{50/55}$ analysis returned the most warm-colored pixels indicating larger olivine index values for that composition than for any other from forsterite to fayalite (the Fo_{60} sample was not able to be used). Neighboring index results for Fo_{45} and Fo_{65} also are shown in Figure 4 for comparison. This index analysis assumes the olivine is Mg-Fe and has not accounted for other minerals in the basalt *per se*; however, this index strategy has been applied successfully to the prediction of the correct Fo# (± 5 at lab resolution) of some meteorite samples whose whole-rock emissivity spectra were measured (e.g., LAP 04840, Y984028, NWA2737). Further work will be conducted to test further the rigor of this analysis.

Final Comment: Mapping the olivine composition with the MSL instrument suite will support or refute these findings and help establish the accuracy and limitations of using the spectral index. If supported, then this olivine spectral index may be applied robustly to the global Mars TES data set.

References: [1] Lane M. D. et al. (2011) *JGR, 116,* E08010. [2] Rogers A. D. and J. L. Bandfield (2009) *Icar.,* 437–453. [3] Milliken R. E. et al. (2010) *GRL, 37,* L04201. [4] Pelkey S. M. et al. (2004) *Icar., 167,* 244-270. [5] Silvestro S. et al. (2012) *LPS XLIII,* Abstract #1804. [6] Ruff S. W. and P. R. Christensen (2002) *JGR, 107,* E12, 5127. [7] Christensen P. R. et al. (2009) *AGU,* Abstract #IN22A-06. [8] Bandfield J. L. et al. (2000) *Science, 287,* 1626-1630. [9] Christensen P. R. et al. (2001) *JGR, 106,* 23823-23871.

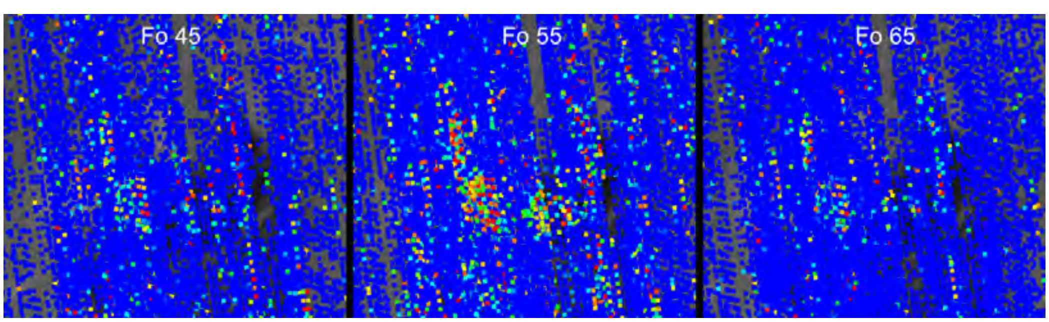

Figure 4. Spectral index of olivine for Fo_{45}, $Fo_{50/55}$, and Fo_{65}. More intense colors appear for the $Fo_{50/55}$ index, suggesting the olivine in the Gale Crater basalt dunes is more similar to this composition than to Fo_{45} or Fo_{65}. This compositional prediction can be tested by the MSL *Curiosity* instrument suite when it reaches the dunes.