Understanding the role of aeolian processes and physical sorting on Martian surface compositions through analysis of spectrally and thermophysically heterogeneous dune fields.
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Introduction: Dark aeolian dunes are widespread on the Martian surface [1] and well identified from high-resolution images [2; 3]. Previous studies of martian sand dunes have focused on the distribution, morphology, physical properties, modeling of transport modes and wind regimes, and sand sources[eg. 4; 5; 6; 7; 8; 9; 10]. However, compositional variations within dunefields have received little attention. On Earth, spatial variations of chemical composition were observed in volcanic sands in Iceland, such that sands showed enrichments in olivine compared to the source rock [11]. Here, we show that some dune fields on Mars exhibit clear spatial variations in composition and thermal inertia, providing an excellent opportunity to study the effects of aeolian sorting on bulk mineral compositions measured from orbit.

Data and Methods: To date, we have used Thermal Emission Imaging System (THEMIS) images to examine composition and thermal inertia, and high resolution visible images (CTX, HiRISE) to study dune morphology. Future work will incorporate CRISM/OMEGA data.

Decorrelation stretch (DCS) images covering sand dunes on the floor of impact craters were first used to locate compositionally heterogeneous dune fields (indicated by color variations within the stretch). Next, these compositional variations were mapped quantitatively by fitting a polynomial to each THEMIS spectrum and mapping the wavelength position of the fit minimum (similar to the methods of [12]). Silicate minerals are characterized by broad emissivity minimums (reststrahlen bands) in the 8 to 12 µm region due to different Si-O bonding structures. The minimum emissivity in this region tends to shift to shorter wavelengths as silicate content increases [eg. 13]. High abundance of sulfate minerals will also shift the minimum to shorter wavelengths. Therefore, the emissivity minimums are indicators for compositional differences between surfaces. The cubic polynomial fit is used to determine the emissivity minimum of each spectrum here. It fits a nonlinear relationship between the value of x (THEMIS wavelength) and the corresponding conditional mean of y (emissivity). An iterative nonlinear least-squares algorithm was used to determine the parameters and minimum of the curve for each average unit spectrum.

$$y=p_1x^3+p_2x^2+p_3x+p_4$$

Last, THEMIS spectral averages were extracted from compositionally distinct areas within the dune field. Thermal inertia is the measurement of material's resistance to changes in temperature, and can be related to the average particle size of a surface [14-15]. THEMIS thermal inertia images [16] were used to extract thermal inertia values for compositionally distinct regions within the field.

Results: A sand dune located at 150°E, 9.48°N is shown here for example. THEMIS bands 8(~11.8µm)-7(~11µm)-5(~9.4µm) as red-green-blue in the DCS mosaic indicates color variations of orange (unit "A") and purple (unit "B") (**Figure** 1). A map of the wavelength position of the minimum emissivity (from a cubic polynomial fit to the THEMIS spectra) (**Figure 4**) shows that most of unit A has emissivity minima at shorter wavelengths while unit B has emissivity minima positioned at longer wavelengths, suggesting an increase in abundance of olivine in unit B. THEMIS spectra from each unit show the overall spectral character of each unit (**Figure 2**). The average thermal inertia of unit B is 363 +/- 12 $Jm^{-2}s^{-0.5}K^{-1}$, whereas the Unit A average is 317 +/- 10 $Jm^{-2}s^{-0.5}K^{-1}$ suggesting a decrease of particle size in Unit A relative to B. From CTX imagery (**Figure 3**), we observe a greater areal coverage of ripples in Unit B, whereas Unit A is smooth and featureless, suggesting particle size differences within the dune field.

Discussion and Future Work: Our preliminary results suggest compositional differences within a dune field also exhibit thermal inertia differences. The high thermal inertia (larger particle size) portion of the dune exhibits higher olivine abundance and and distinct ripple forms, while the lower thermal inertia portion of the dune field is relatively olivine poor and morphologically smooth. This work suggests that aeolian activity has preferentially concentrated olivine into the coarser fraction of sand. Interesingly, this trend is opposite of what was observed by [11] in Iceland. One possible explanation for the trend is preferential comminution of plagioclase and pyroxene relative to olivine during grain saltation. Future work will explore alternative explanations and will apply these methods to sand dunes with various mineral compositions.

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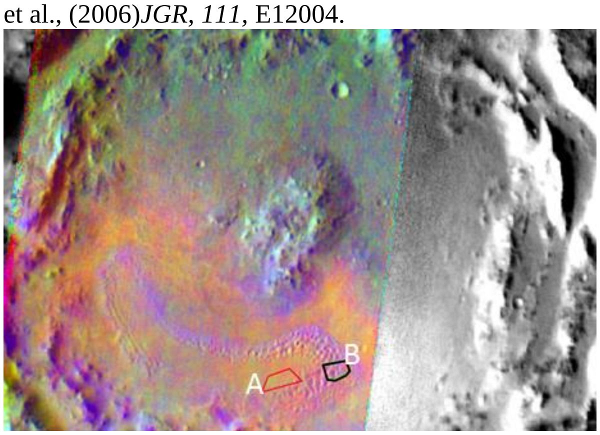


Figure 1. THEMIS color variation within an intra-crater dune field located at 150°E, 9.48°N. THEMIS bands 8(~11.8µm)-7(~11µm)-5(~9.4µm) are displayed as red-green-blue in the DCS mosaic.Polygons indicate regions of interest from Units A (orange) and B (purple).

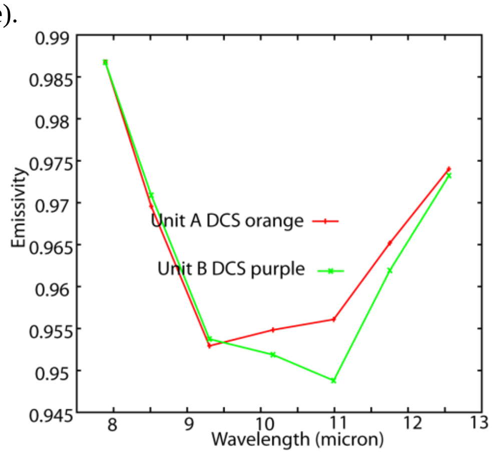


Figure 2. THEMIS spectra of red (DCS orange) and black polygons (DCS purple) from Figure 1.

Figure 4. Stretch map of the wavelength position of the minimum emissivity of the sand dune (A) and corresponding thermal inertia (B). Red and black polygons regions of interest from Figure 1. Purple polygon is

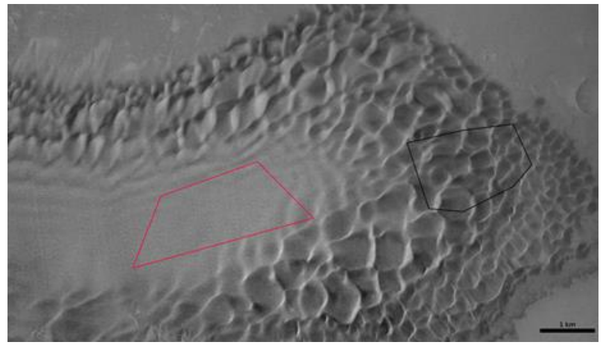
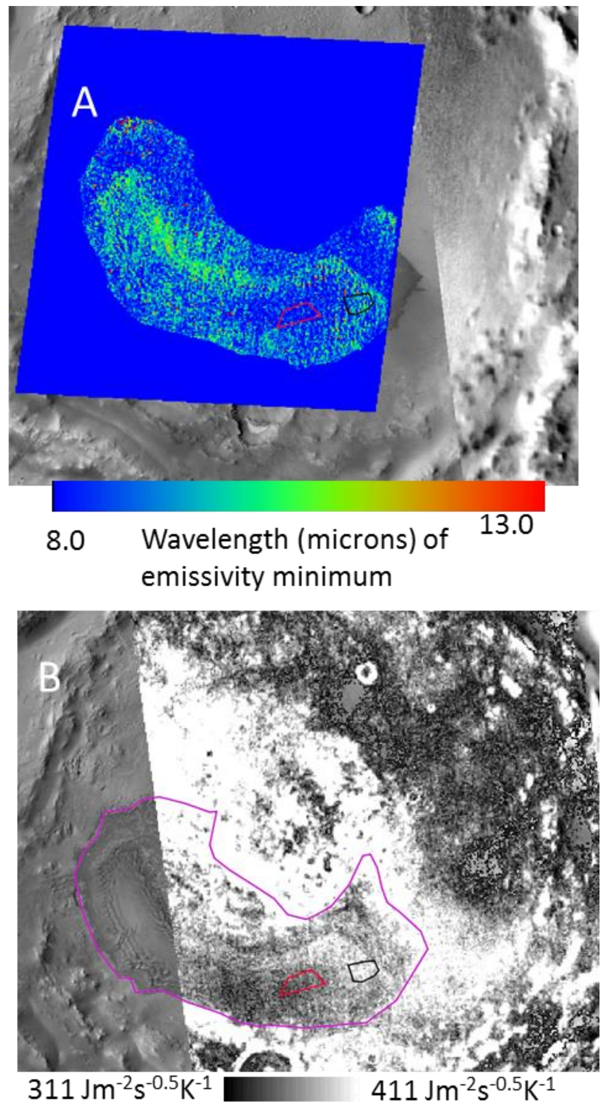


Figure 3. CTX image of the sand dune in Figure 1. Polygons indicate areas of interest from Units A and B.



dune boundary. Most of the Unit A has shorter minimum emissivity wavelength, while Unit B exhibits longer wavelength minima.