A TALE OF TWO SPECTRA: ISOLATING THE COMPOSITION OF BEDROCK AND REGOLITH SURFACE COMPONENTS USING MARS ODYSSEY THEMIS AFTERNOON AND EVENING SPECTRA. J. C. Cowart[1] and A. D. Rogers[1], [1]Department of Geosciences, Stony Brook University, Stony Brook, NY (justin.cowart@stonybrook.edu).

Introduction: Several previous studies have shown a correspondence between VNIR or TIR olivine detections and areally extensive exposures of bedrock ('bedrock plains') in the Martian cratered highlands [e.g. 1, 2, 3]. More recently, Cowart et al. [4] modeled thermal emissivity spectra of these regions from Mars Odyssey Thermal Emission Imaging System (THEMIS) data to determine the amount of olivine present in these locations. They found bedrock plains are typically associated with moderate olivine enrichments (≤ ~10%) relative to the surrounding materials. Higher levels of olivine enrichment are roughly correlated with well-developed erosional features, and bedrock plains with the greatest olivine enrichments also tend to have large, well-developed bedform fields [4].

Olivine enrichments observed in association with bedrock plains may at least partially arise from olivine-enriched sediments (sand ripples or regolith) or patchy lag deposits, rather than solely from bedrock [4, 5]. Regolith materials may be further enriched in olivine by preferential comminution and transport of less dense / fine grained minerals within regoliths. The strong VNIR detections of olivine in association with bedrock plains support this suggestion, because the 1µm olivine absorption band is maximized within sand-sized particles compared to solid materials [6].

We test this hypothesis using new data from the Mars Odyssey THEMIS instrument. In 2016, Odyssey's sun-synchronous orbit was adjusted from ~3 pm to ~6-7 pm local time data collection. This change enables comparisons between surface emissivity spectra collected at different times of day. Heterogeneity in surface thermophysical properties below THEMIS 100 m/px imaging scale may cause diurnal changes in the surface emissivity spectrum.

Thermal spectral radiance from a mixed-component surface is dominated by the warmest components in the scene. Observations taken during Odyssey's 3pm orbit measure the surface when sediments are the warmest component in the scene, and dominate the radiance observations compared to rock. Thus, THEMIS mid-afternoon spectra may be biased towards the spectral signal of warm, low thermal inertia materials (e.g. dust and fine regolith components).

Conversely, spectra collected near or after sunset will show a stronger contribution from higher thermal inertia materials (e.g. blocky regolith and bedrock). These materials approach or exceed the temperature of low thermal inertia materials in the early evening hours. Thus, spectral trends between daytime and evening local times may isolate compositional differences between regolith and consolidated surface materials.

Methods: We identified overlapping THEMIS multispectral images of selected regions of the Martian surface. Images from the ~3 pm orbit were constrained to surface temperatures > 270 K; images from the ~6 pm orbit were constrained to > 235 K. Images were map-projected and georeferenced with one another. Atmospheric corrections were performed using TES spectra with footprints located in high-emissivity surfaces surrounding bedrock plains [7]. An assumption inherent to this correction is that the low thermal inertia of the surrounding materials indicates a relatively homogenous regolith, which should not show changes in spectral shape at different times of day. Spectra are then collected from the highest thermal inertia locations from both images.

Bedrock plain spectra: We tested the hypothesis that olivine-enriched spectral signatures associated with bedrock plains arise from predominantly from surficial unconsolidated materials. Olivine-rich basaltic materials show a broad, U-shaped spectrum centered around 11 µm. Olivine-poor basaltic bedrock materials show a more V-shaped absorption centered ~9-10 µm. If olivine is primarily present in fine-grained regolith components, evening spectra should shift towards shorter wavelengths as the regolith cools and olivine-poor bedrock becomes more spectrally dominant.

Bedrock Plain [4]	Lat.	Long.	Evening Spectral Trend
SB09	-24.3	30.4	Olivine-enriched
SB21 – Unit 1	-22.5	43.6	No change
SB21 – Unit 2	-22.4	43.6	Olivine-enriched
SB22 – Unit 1	-24.1	44.7	No change
SB22 – Unit 2	-24.4	44.7	Olivine-depleted
SB25	-22.8	47.5	Olivine-enriched
SB26	-19.4	48.1	Olivine-depleted
SB31	-23.1	55.9	Olivine-enriched

Table 1. Bedrock plains with multiple time-of-day spectral observations.

However, in 4 of 6 bedrock plains we have measured, we observe the opposite (**Table 1**, **Figure 1a, b**). Evening spectra of bedrock surfaces suggest that (1) overlying patchy sediments do not contribute significantly to the olivine signature and that (2) these sediments suppress an even stronger olivine absorption intrinsic to the bedrock than previously realized. This has important implications for the origin of these clastic bedrock materials, and may support a pyroclastic origin [4, 5].

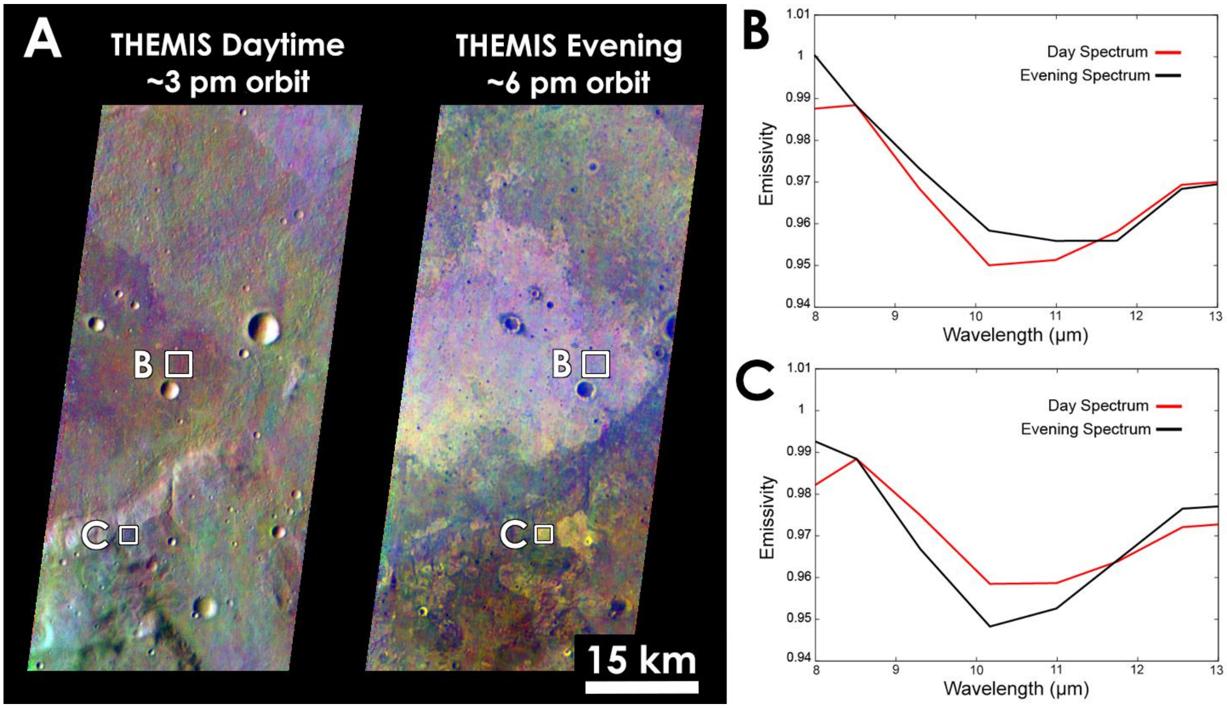

Figure 1. Spectral variations related to imaging at different times of day. A) THEMIS band 8-7-5 decorrelation stretch using images taken at two different times of day. Increased color variation in the evening image may represent decreased spectral contributions from homogenized, fine-grained regolith components. B) Spectra collected from a bedrock plain (SB031 mapped by [Cowart]). Evening spectra are shifted towards longer wavelengths, consistent with a larger contribution from an olivine-rich surface component. C) Spectra collected from a spectral unit that is only visible in evening imagery. This unit shows an evening spectrum consistent with a larger contribution from a more silica-rich component.

Previously unidentified spectral units: In several regions, evening multispectral imagery shows spectral diversity not visible in afternoon imagery (**Figure 1a, c**). These typically occur in low-emissivity, low thermal inertia materials that appear to have a regolith mantle in CTX imagery. The newly identified spectral units may represent patchy bedrock exposures exposed within a pervasive homogenized regolith cover. The example shown in **Figure 1c** corresponds to small exposures of erosionally-resistant materials. Daytime spectra of these materials show a moderately olivine-rich spectrum. Evening spectra are narrower and shifted towards shorter wavelengths, which suggests the bedrock component of the surface spectrum is more silica rich or that olivine is confined to a fine-grained regolith fraction.

Conclusion: Analysis of early evening spectra will be a powerful new tool in understanding the compositional diversity of Martian surfaces. These comparisons may be particularly useful where analyzing suspected clastic deposits, as the spectral properties of these surfaces be strongly affected by post-depositional modification and regolith processes. In addition, evening thermal imagery has also identified previously unseen spectral units. These spectral units may represent intact surface deposits with only small exposed outcrop areas in a regolith-heavy region. These previously unidentified spectral units may contribute to a better understanding of crustal processes in the Martian cratered highlands, as highlands montane surfaces have mostly homogeneous spectral appearances in mid-afternoon imagery.

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References: [1] Ody A. et al. (2013), *JGR: Planets*, 118, 234-262. [2] Rogers A. D. et al. (2009), *Icarus*, 200, 446-462. [3] Edwards C.S. et al. (2014), *Icarus*, 228, 149-166. [4] Cowart J.C. et al. (2019), *JGR: Planets*, 124. [5] Rogers, A.D. (2018), *GRL*, 45, 1767-1777. [6] Poulet F. et al. (2007), *JGR: Planets*, 112, E8. [7] Bandfield, J. L. et al. (2004), *JGR: Planets*, 109, E10.