The Earlier Mars Odyssey Orbit Time Reveals Aqueous Mineralogy in Mid-IR Data A. M. Baldridge[1], M. D. Lane[1] and J. J. Wray[2] [1]Planetary Science Institute 1700 East Fort Lowell, Suite 106 Tucson, AZ 85719-2395, abaldridge@psi.edu [2]425 Space Sciences Building, Cornell University, Ithaca, NY 14853 jwray@astro.cornell.edu.

Introduction: The Thermal Emission Imaging System (THEMIS) has been in orbit at Mars since early 2002 [1]. A primary objective of the THEMIS experiment is to identify minerals associated with hydrothermal and subaqueous environments including carbonates, clays, chlorides, silica and sulfates. Of these, THEMIS data have thus far supported the presence of clays[2], silica-rich deposits [3, 4] and chlorides [5], but have not provided evidence for the presence of sulfates[6]. Given extensive morphological evidence for aqueous surface processes on Mars and the long-standing expectation that sulfates should be a dominant alteration product at the Martian surface [7, 8], this null result is surprising. It is especially puzzling given the detection of sulfates in the visible/near-infrared (VNIR) by the Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activite´ (OMEGA) and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [9-13] and surface detections by the Miniature Thermal Emission Spectrometer (mini-TES) [14, 15] and Mössbauer Spectrometer [16].

Evaporite minerals may be present, but below the detection limits for THEMIS or buried by dust or other rocks. The extended mission proposal for THEMIS on Mars Odyssey suggests that the detection of all minerals may be enhanced by improvements to the THEMIS signal-to-noise ratio (SNR) that would be achieved by acquiring additional data at earlier local times and thus at warmer temperatures.

Mars Odyssey is in a near-polar Sun-synchronous orbit. To obtain high-quality daytime infrared (IR) measurements, the THEMIS instrument needs local true solar times (LTST) earlier than 5:00 PM, achieving best imaging nearer to 3:00 PM. However, to keep the Sun out of the Gamma Sensor cooler field of view, a LTST of 4:00 PM is the earliest time that can be accommodated. The LTST has oscillated ~±40 minutes around 5:15 PM, the local mean solar time (LMST) that was designed as a compromise between the constraints of the two instruments. To enhance surface observations the THEMIS team proposed that the orbit be moved to 3:45 LMST. The maneuver that brought Odyssey to this orbit began in early 2009 and allowed for a period during summer 2009 with LMST of ~3PM and surface temperatures 20 degrees warmer than previously observed.

Here we examine sites on Mars in which VNIR data have revealed aqueous minerals including sulfates and THEMIS data were collected when the earlier orbit time coincided with the Martian local summer resulting in warm surface temperatures. These sites include Columbus crater [9] and Cross crater [10] in Terra Sirenum and Aram Chaos [11].

Methods: THEMIS daytime IR decorrelation stretch (DCS) images were used as the primary means for detecting unique surface compositions. The data used in this study represent both warm (240-290K) and cool (<240K) average surface temperatures. The THEMIS images used in this study were corrected for atmospheric effects using methods described by[17]. Average spectra for unique spectral units were collected from the emissivity images and compared to THEMIS convolved library spectra [18, 19]. Detections in IR data will be compared with those in the VNIR to confirm and constrain mineralogy.

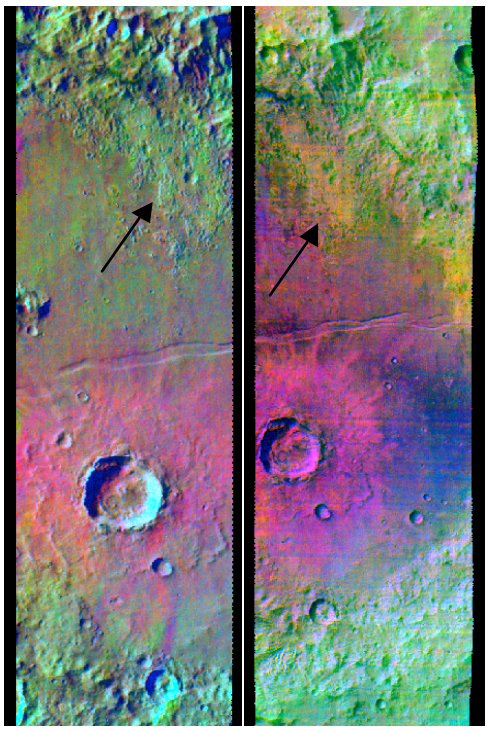

Figure 1. THEMIS bands 9-6-4 DCS images, Columbus crater. Left: I18329003, LST: 16.29, Average surface temperature: 238.8K. Right: I34488006, LST: 14.64 Average surface temperature: 268.5K. Sulfate/phyllosilicate deposits appear yellow in the warmer data (right) but do not distinguished in the cooler data (left).

Results and Discussion: The newer THEMIS data appear to more clearly indicate the presence of low spectral contrast minerals such as sulfates and clays (e.g. Figure 1). However, high-silica phases and sulfate minerals are difficult to distinguish at the spectral resolution of THEMIS (Figure 2); they are known to occur in close proximity within Figure 1 and are indistinguishable at the spatial resolution of TES. A narrow

absorption present in the TES data at 22 μm is characteristic of clays but the yellow units in the THEMIS concentration maps are better fit with sulfates rather than phyllosilicates. Regardless, the presence of both sulfates and phyllosilicates is consistent with the VNIR data [9]. In some cases, the sulfates and phyllosilicates appear to be interbedded and are therefore indistinguishable at even THEMIS spectral resolution. Indeed, on Earth, clays and sulfates often occur together or in close proximity in aqueous environments [20].

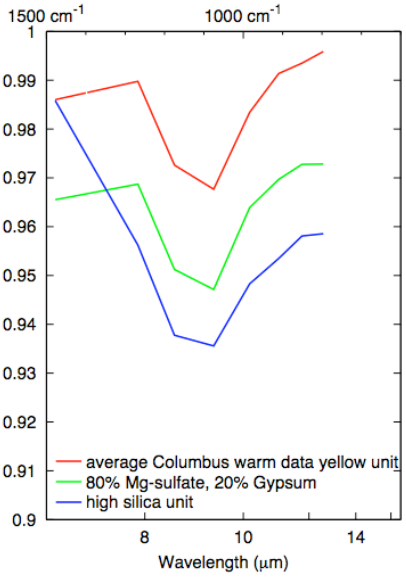

Figure 2. Average THEMIS warm image spectra of yellow unit (red) compared to mixture of gypsum and hexahydrite (green) and Hellas Basin high-silica unit [3].

Many regions on Mars where VNIR detects aqueous mineralogy have not yet been imaged by THEMIS at the new earlier time of day. Therefore, we are unable to compare the IR and VNIR observations. However, Columbus crater has complete coverage both before and after the change in orbit time. Although the aqueous deposits only appear distinct in a few of the warm images, this may indicate that several factors affecting surface temperature (and therefore SNR) must coincide for these low spectral contrast units to be detected with THEMIS:

- The average surface temperature for the images in which the aqueous deposits are detected is 270K. This is ~20 degrees warmer than most images taken prior to the orbit change.
- Warmer surface temperatures are related to the time of year that images are acquired. The THEMIS observations in which the aqueous deposits are detected in Columbus crater occur during the late southern summer (Ls~ 270-360). Unfortunately, southern summer is also a common time for Martian dust storms. Therefore, ideal observation conditions, when dust opacity is low and surface temperature high, occur in the late summer, when dust storm activity is reduced.
- The warmest surface temperatures on Mars lag noon by ~3 hours before the surface begins to cool again. Therefore, to optimize SNR, it is ideal to observe the surface at this time before the cooling begins. Beginning with the 4th extended mission, Odyssey is currently in a 15:45 LMST orbit compared to 17:15 LMST in earlier phases of the mission.

Conclusions: Earlier time of day and proper seasonal observations combine to provide warm surface temperatures and ideal conditions for the observation of low spectral contrast aqueous minerals at the surface of Mars. It is fortuitous that these conditions occurred over Columbus crater where several aqueous minerals have been detected in the VNIR and that the presence of these minerals could be confirmed by THEMIS. The VNIR and thermal IR spectral regions can provide independent constraints on sulfate compositions and hydration states. Several other sites on Mars where aqueous minerals have been detected in the VNIR (e.g. Northern Meridiani, Juventae Chasma, Gale crater) will be targeted while Odyssey's orbit remains in the early afternoon; these observations may reveal additional evidence for aqueously formed minerals.

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