CONSTRAINING THE THERMAL INERTIA OF MARTIAN BEDROCK EXPOSURES USING OVERLAPPING THEMIS OBSERVATIONS. A. A. Ahern[1] and A.D. Rogers[1], [1]Stony Brook University Department of Geosciences, Earth and Space Science Building, Stony Brook, NY 11794-2100, *alexandra.ahern@stonybrook.edu.*

Motivation: Bedrock exposures on Mars commonly exhibit a range of thermal inertia values (~450 to greater than 1200 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$), derived from single temperature nighttime measurements [1,2]. These values could be consistent with a range of physical scenarios, including weakly lithified and/or porous rocks, to dense rocks overlain by a few cm of unconsolidated sediment. Having constraints on the physical nature of Martian bedrock can provide greater understanding of the origin of these outcrops and the prevalence of sedimentary, effusive volcanic, or pyroclastic processes that operated on Mars' surface in the past. In this study, we use orbital thermal data from the Mars Odyssey Thermal Emission Imaging System (THEMIS), acquired over different local times and seasons on Mars to distinguish between different physical scenarios that give rise to the high (but not extremely high) nighttime thermal inertia values for bedrock. The use of multiple observations spanning diurnal and seasonal curves allows for determination of the thermal inertia and physical characteristics of these outcrops.

Background: THEMIS currently provides the highest resolution thermal information of the surface of Mars at 100 m/pixel [3]. Single point, nighttime surface temperature measurements have been commonly used to derive apparent thermal inertias of surface materials. However, the diurnal and seasonal thermal response of the near surface on Mars can be affected by heterogeneity of near-surface materials. This heterogeneity can take the form of vertical layering (i.e. thin sediment cover over bedrock, induration or weathering of upper few cm) or lateral mixing (i.e. differential dust or sand cover of bedrock, or small dune fields in local lows) [4].

It is likely that thermal measurements of many outcrop surfaces on Mars are affected by near-surface heterogeneity, and this can obscure the thermal properties of the bedrock [4,5]. In order to separate thermal effects from different materials, we use repeating THEMIS observations of areas of interest throughout both Martian days and seasons and compare that data to modeled heterogeneous scenarios to find configurations of best fit.

Methods: We have selected areas of interest based on locations where we see physically or spectrally distinctive bedrock that have overlapping THEMIS IR observations. Within these regions, we create sampling polygons maximizing lateral homogeneity using higher-resolution CTX and HiRISE imagery. Next we obtain THEMIS IR projected brightness temperatures (PBTs, processing version 2.1) from within the polygons at ~3-5:30 AM and ~6-7:30 PM local time to reduce the effect of albedo in our thermal data. Additionally, surface temperatures at these times show the greatest difference in heterogeneous scenarios, thus making these local times the best for distinguishing between homogenous and heterogeneous surfaces. We then combine these surface temperatures, the corresponding dust opacities for each observed year [5], THEMIS VIS albedos, and the appropriate temporal and location data into the KRC thermal model [6] to obtain apparent thermal inertias for each THEMIS observation from within our selected polygons.

The apparent thermal inertias provide an indication of whether the surfaces we have selected are vertically or laterally homogenous or heterogeneous. Since thermal inertia is an intrinsic property of a material, the thermal inertia should remain constant during a Martian day, even as the surface temperature fluctuates with the rising and setting of the sun. If apparent thermal inertia appears to change between 5 AM and ~7 PM, it is likely that the differential thermal responses of multiple materials affect the overall apparent thermal inertia of the surface in that location (Fig. 1) [4].

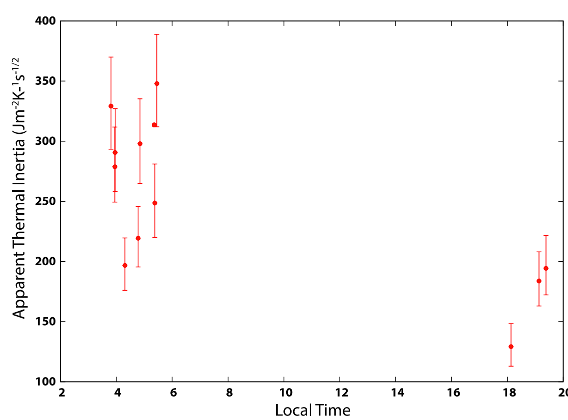

Figure 1: Apparent thermal inertias derived from within a sampling polygon on the Cerberus Fossae lavas, converted from THEMIS surface temperature observations. The difference in apparent thermal inertias in the AM and PM times suggest surface heterogeneity.

If we determine that a surface appears heterogeneous, we then use the KRC thermal model to generate various layering and lateral mixing scenarios.

These scenarios are summarized in Fig. 2 and are run for the corresponding times of day and year to our THEMIS observations. They incorporate dust, sand, and bedrock in a variety of vertically layered configurations, as well as lateral mixes of these materials in different proportions. We then compare the apparent thermal inertias derived from THEMIS observations to the modeled scenarios at those same local times and days derived from the KRC thermal model and find the heterogeneous configuration that best fits our data.

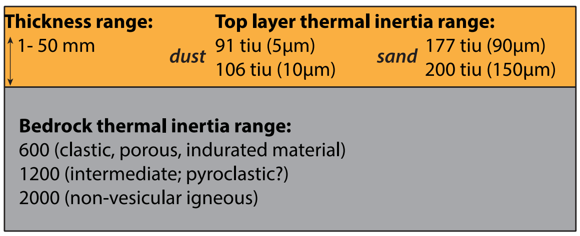

Figure 2: Model parameters for vertical layering scenarios tested against observed data in this study. Lateral mix models assume no vertical heterogeneity, but 25-75 and 50-50 mixes of all combinations of the same materials above within the surface area of each polygon.

Results: Preliminary results for our selected areas of interest are summarized in Table 1.

Table 1: Best fit scenarios for areas of interest

	Bedrock TI (tiu)	Top Layer TI (tiu)	Top Layer Grain Size	Top Layer Thickness
Cerberus lava flows	2000	91	5 µm	20 mm
Meridiani Planum chlorides	600	177	90 µm	25 mm
Nili Patera feldspathic rock	1200	200	150 µm	20 mm
Nili Patera silica-rich rock	600	177	90 µm	40 mm
Noachis Terra feldspathic rock	1200	200	150 µm	15 mm
Noachis Terra olivine-rich rock	1200	200	150 µm	15 mm

Basaltic rocks at the Cerberus Fossae site are consistent with high thermal inertia (~2000 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$), effusive volcanic rocks. However, thermal observations also support a model of thin dust cover over these flows (Fig. 3). This corroborates earlier work that states that the lava here is relatively young [7], in that thermally it appears to be competent, intact rock.

Other results from this study indicate that, unsurprisingly, bedrock properties on Mars vary. For instance, chloride-rich deposits in Meridiani Planum are consistent with models of moderate thermal inertia bedrock (~600 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$). This suggests bedrock here is indurated or weakly cemented, likely by evaporites. We also detect a fine-sand layer atop the bedrock.

We also see variation in thermal inertia within basaltic outcrops which likely arises due to different modes of emplacement (e.g. effusive vs. pyroclastic processes) or weathering or alteration of outcrops at the surface. Approaching study of outcrops on Mars from a thermal standpoint can provide greater insight into properties, and thus processes of formation, of these rocks.

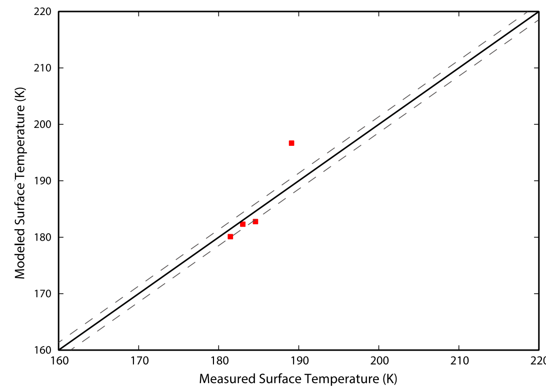

Figure 3: Modeled vs. measured surface temperatures for within one of the sampling polygons near Cerberus Fossae. This uses the model of best fit, which incorporates 7.5 mm of dust cover (91 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$) over high thermal inertia bedrock (2000 $J \cdot m^{-2} \cdot K^{-1} \cdot s^{-1/2}$). The black line shows equivalency between measured and modeled temperatures, and the gray dashed lines indicate ±2 K, which is THEMIS instrumental error.

Future work: Work is ongoing in the selection and characterization of important areas of interest, including future landing sites and spectrally distinct outcrops.

Laboratory measurements of thermal inertia and thermal conductivity of various rock types, as well as lithified cements with varying degrees of cementation and porosity, are part of our plans for the upcoming year. Measurements will be carried out using a commercial instrument and under Mars pressures. This will provide us with better constraints on model scenario parameters when testing against orbital observations. It will also help us to understand heat transfer within different materials as it happens on Mars.

References: [1] Fergason, R.L. et al. (2006a) *JGR, 111, E12004.* [2] Edwards, C. et al. (2009) *JGR: Planets, 114, E11001*. [3] Christensen, P. et al. (2004) *Space Sci Rev 110,* 85-130. [4] Audouard, J. et al. (2014) *Icarus*, *233*, 194-213. [5] Putzig, N. And Mellon, M. (2007) *Icarus, 191*, 68-94. [6] Kieffer, H.H. (2013) *JGR:Planets, 118,* 451-470. [7] Hartmann, W. and Berman, D. (2000) *JGR, 105,* 15011-15025.

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