MARTIAN CRATER THERMAL INERTIA: A FUNCTION OF DEGRADATION OR RIM MANTLING?

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Introduction: Impact craters are nearly ubiquitous on planetary surfaces. On Mars, analysis of impact craters can provide important constraints on surface age estimates, as well as dating of erosional and depositional events [e.g., 1]. Neighboring martian impact craters that have similar diameters often exhibit notable large variations in thermal inertia, *TI*, observable in Thermal Emission Imaging System (THEMIS)-derived *TI* images (*Figure 1*). However, no explanation for this variation has been previously offered. We investigate two hypotheses for why rims of simple craters exhibit a wide range of *TI* values.

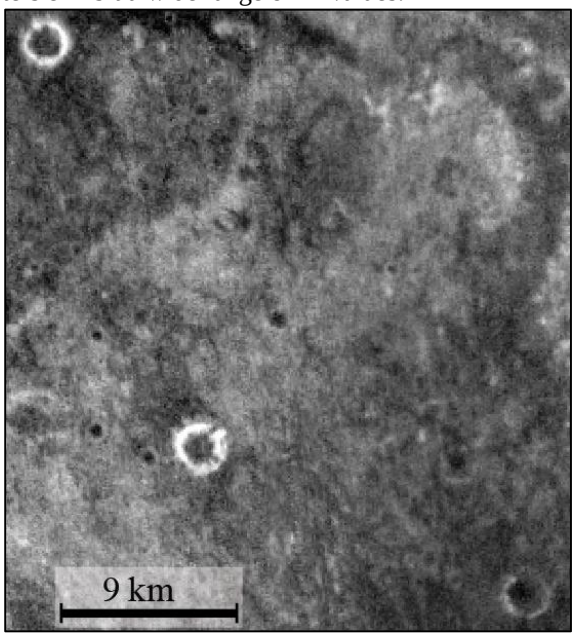

Figure 1: Craters with various rim TI values are visible in THEMIS derived TI images. This image is centered at 44°57'E 6°38'S, near Tisia Valles. Brighter pixels represent higher TI values which range from 150 to 310 J m^{-2} K^{-1} $s^{-1/2}$ in this image.

Hypothesis 1: We investigate the hypothesis that for a homogeneous target surface, impact crater rim *TI* is primarily affected by crater degradation. Degradation would produce finer-grained regolith with time, causing more degraded craters to exhibit lower *TI*. If this hypothesis is supported, then *TI* values may be used to estimate impact crater degradation states, and a relative age dating technique may be developed for craters in close proximity on Mars.

If this hypothesis is true, then craters that are pristine, somewhat degraded, and very degraded, should exhibit a progressive decrease in rim *TI*, all other factors being equal. Because impact crater rims become more irregular with time, there should be a negative correlation between rim *TI* and rim irregularity, and between rim *TI* and maximum-minimum diameter variation.

Hypothesis 2: We also investigate the hypothesis that, for a homogeneous target surface, crater rim *TI* is primarily affected by the presence of mantling regolith on crater rims. This finer-grained mantling regolith, either locally derived or exogenic, would cause crater rims to exhibit lower *TI*. If this hypothesis is supported, and the regolith is exogenic, then impact craters with low *TI* rims could be used to assess the spatial extents of buried regions on Mars. This information could also be used, in conjunction with crater counting techniques, to constrain the ages of burial events.

If this hypothesis is true, then craters with mostly exposed, partially mantled, and mostly mantled rims should exhibit a progressive decrease in rim *TI*. The decrease in *TI* would reflect the presence of fine-grained regolith overlying rocky rim material. There should be a positive correlation between crater rim *TI* and the ratio of a crater's exposed rim length to mantled rim length (*e/b*).

Data Collection: We are conducting our study in the region of Tisia Valles because this area exhibits: 1) little evidence for volatile content [*e.g.*, 2], 2) consistent elevation, and 3) a texturally and geologically homogenous unit [*e.g.*, 3]. The highest resolution Context Camera (CTX) images covering this region were processed and projected.

We determined the number of impact craters, *n*, to be analyzed by using a statistical power analysis. For a regression analysis that can detect at least a medium effect size ($r \geq 0.3$), with 95% confidence, and a power of 95%, n=138. We selected the closest 138 simple impact craters to Tisia Valles that are covered by both CTX and THEMIS derived *TI* images [4], >2 km in diameter, not overprinted by other features, and do not exhibit characteristics of secondary impact craters (*i.e.*, clustered and elliptical in shape).

We calculated the average rim *TI* values using these THEMIS-derived *TI* images [4]. The craters were characterized as being pristine, partially degraded, and mostly degraded, based on visual inspection of their rims, ejecta, and infill within their interiors. The irregularity of each crater's rim was determined by taking the ratio of the crater's rim length to the circumference of a circle of equal area. A crater's diameter variation was taken to be the difference between the maximum and minimum diameter of each crater. We also classified each crater into one of three rim mantling classes

(exposed, partially mantled, or mantled) based on visual inspection of each crater's rim in CTX images. We are in the process of calculating the *e/b* ratios for each crater by visually mapping and measuring the exposed and mantled portions of each crater's rim.

Results: Craters that are pristine, partially degraded, and very degraded do not exhibit progressively lower rim *TI* values at a statistically significant level, based on analysis of variance (ANOVA) test results. Additionally, two regression analysis results show that there is not a correlation between rim *TI* and rim irregularity, or between rim *TI* and diameter variation. These results do not support Hypothesis 1, that crater rim *TI* values are primarily affected by degradation.

However, additional results support Hypothesis 2, that crater rim *TI* values are primarily related to rim mantling. Craters with exposed, partially mantled, and mantled rims exhibit progressively lower rim *TI* values, based on ANOVA test results, at the 99% confidence level. The results of these comparisons are consistent across multiple THEMIS-derived *TI* scenes and within individual scenes (*Figure 2*). Additionally, craters with rims that appear to be more exposed in CTX images exhibit higher *TI* values than those with rims that are partially mantled (*Figure 3)*.

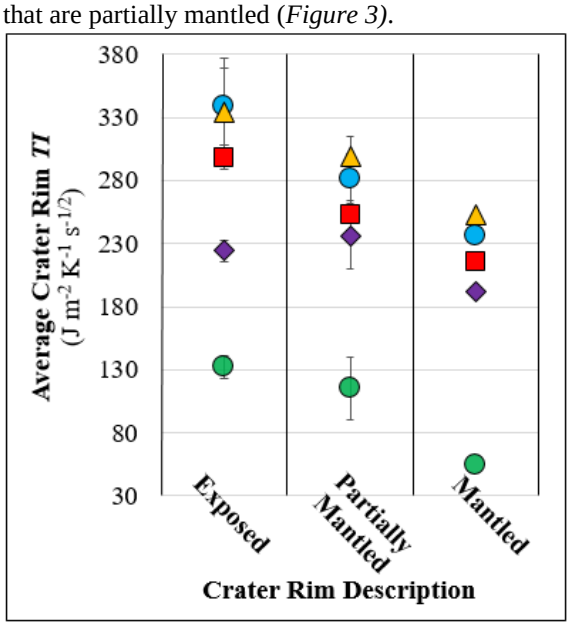

Figure 2: Relationship between average crater rim TI values and rim mantling class for craters compared within five individual THEMIS derived TI scenes [4]. The five different colored symbols represent the different scenes.

Discussion and Future Work: To further investigate Hypothesis 2, that crater rim *TI* values are related to rim mantling, we will conduct a regression analysis to test for a positive correlation between average crater rim *TI* and *e/b* ratios.

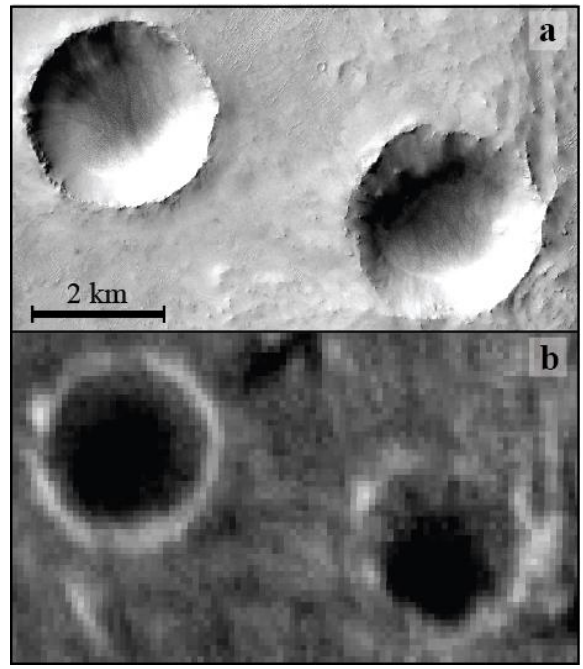

Figure 3: Craters with rims that are mostly exposed (left) and partially mantled (right) are shown in CTX (a) and THEMIS derived TI (b) images. These images are centered at 49°41'E 7°20'S. Brighter pixels represent higher TI values, which range from 108 to 256 J m^{-2} K^{-1} $s^{-1/2}$ in this image.

We will investigate whether the regolith mantling these crater rims is locally derived or exogenic. If the mantling regolith is locally derived, then it should consist of more angular grains than if it is exogenic. This variation in grain shape may be discernable by the topographic slopes of mantled crater rim walls, which should be no greater than the angle of repose. The angle of repose varies for angular (~45°) versus rounded (~25°) grains [e.g., 5, 6], and is likely independent of gravitational acceleration [e.g., 7; c.f. 8].

The slopes of crater walls in the Tisia Valles region will be measured on digital elevation models (DEMs) created using CTX stereo pair images. We will also estimate the amount of regolith present within each crater using these DEMs. The regolith depth can be estimated by comparing crater topography to expected crater depths based on known martian depth-diameter ratios.

References: [1] Buczkowski et al. (2005) *JGR, 110, E03007*. [2] Barlow (2010) *GSA Bul., 122, 644-657*. [3] Greeley and Guest (1987) *U.S. Geol. Surv.* [4] Fergason et al., (2006) *JGR, 111, E12004*. [5] Carrigy (1970) *Sedimentology, 14, 147-158.* [6] Pohlman et al. (2006) *Phys. Rev. E, 73, 031304*. [7] Atwood-Stone and McEwen (2013) *Geophys. Res. Lett, 40, 2929-2934*. [8] Kleinhans et al. (2011) *J. Geophys. Res, 116, E11004.*