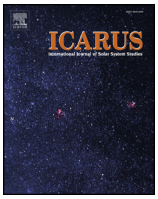
Icarus 314 (2018) 345–363

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus



Investigating crater rim thermal inertia variations on Mars: A case study in Tisia Valles

Chloe B. Beddingfield*, Jeffrey E. Moersch, Harry Y. McSween Jr.

Earth and Planetary Science Department & Planetary Geosciences Institute, University of Tennessee, Knoxville, TN 37996, USA

ARTICLE INFO

Keywords:
Mars
Surface
Cratering
Geological processes
Regoliths
Aeolian processes

ABSTRACT

Impact craters across Mars, that are otherwise similar, commonly exhibit vastly different thermal inertia values on their rims. We focused on the Tisia Valles region because the terrain is mostly flat, and craters of various ages are present within the same target geologic unit. We present an investigation of two hypotheses for why these thermal inertia variations exist. The first hypothesis is that crater rim thermal inertia is affected by crater degradation state, and the second hypothesis is that thermal inertia is affected by the amount of regolith mantling the rims, regardless of degradation state. To investigate the first hypothesis, we used a series of multilevel regression analyses to test for correlations between crater rim thermal inertia and depth-diameter ratio, rim irregularity, and radii variation, which are indicators of crater degradation state. To investigate the second hypothesis, we tested for a correlation between thermal inertia and mantled crater rim percentage, which is indicative of the amount of regolith atop the rims. Our results did not support the first hypothesis but did support the second hypothesis. Therefore, we concluded that regolith rim mantling affects crater rim thermal inertia variations in the Tisia Valles region. Crater degradation may not have an effect on rim thermal inertia because regolith is transported down the crater rim slopes faster than local regolith is produced from erosion in this region. An implication of this work is that the spatial extent of regolith-rich regions near Tisia Valles can be mapped using the spatial extent of proximal craters with low thermal inertia rims. Additionally, the timing of mantling events can be quantified by comparing counts of craters with high thermal inertia rims to those of low thermal inertia rims within a region.

1. Introduction

Impact craters are nearly ubiquitous on Mars and analyses of these craters can provide important constraints on surface processes (e.g., Barlow, 2010; Barlow 2015). Neighboring martian impact craters with similar diameters commonly exhibit notable variations in rim thermal inertia (Mellon et al., 2000). For example, in the crater field shown in Fig. 1, impact craters in a narrow size range (1 to 3 km in diameter) exhibit rim thermal inertia values ranging from 150 to $310\,\mathrm{J\,m^{-2}\,K^{-1}\,s^{-1/2}}$. The perplexing nature of this variation in thermal inertia solicits an interpretation. Because thermal inertia is strongly affected by particle size, these variations could provide clues about important geologic processes, including erosional and/or depositional activity.

We investigated two hypotheses for why impact crater rims on Mars exhibit large variations in thermal inertia within the same host material with otherwise consistent thermophysical properties. These hypotheses are that crater rim thermal inertia is affected by crater degradation (Fig. 2a), and that thermal inertia is affected by regolith mantling the rim (Fig. 2b). Degradation of crater rims would be expected to produce fine-grained regolith over time through comminution. If this regolith is not transported elsewhere, then rim thermal inertia should be negatively correlated with the degree of rim degradation. In this case, crater rim thermal inertia could be used as a quick way to estimate impact crater degradation states by using thermal inertia maps of the surface. Additionally, a relative age dating technique could be developed for similar-sized neighboring martian craters within the same geologic unit, by comparing their rim thermal inertia values.

Although comminution of rim material would produce locally-derived regolith during degradation, regolith may also settle on crater rims from non-local sources via aeolian activity. Because regolith mantling the rim of a crater may be unrelated, in some cases, to degradation of that crater, we also investigated an alternative possibility. Crater rim thermal inertia variations may instead be caused by the presence of regolith mantling the crater rims. This regolith may be derived from the local crater rim and/or deposited atop the rim from a

---

* Corresponding author.
E-mail addresses: chloe.b.beddingfield@nasa.gov, cbeddin1@utk.edu (C.B. Beddingfield).

https://doi.org/10.1016/j.icarus.2018.06.011
Received 15 May 2017; Received in revised form 1 June 2018; Accepted 6 June 2018

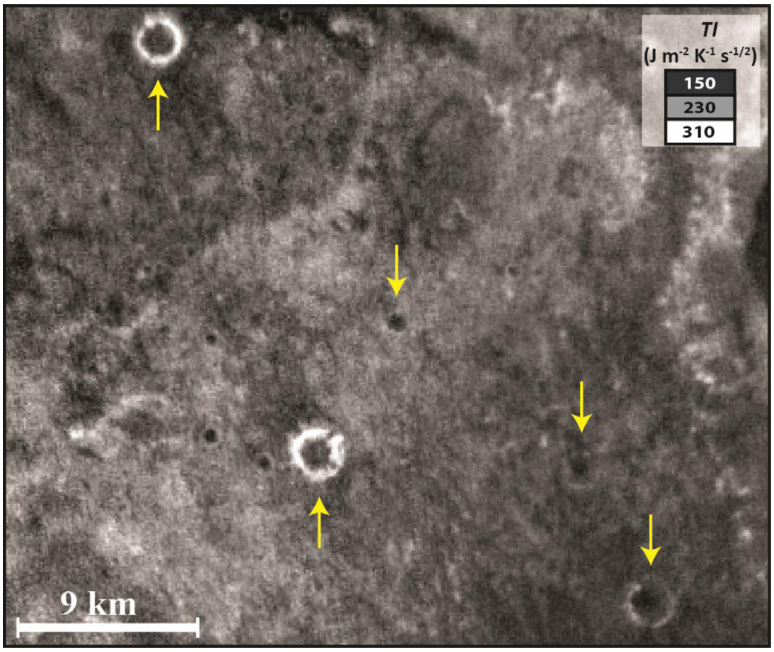


Fig. 1. Craters with various rim thermal inertia values within the same host material. These craters are visible in THEMIS-derived thermal inertia scenes. This scene is centered at 44°57′E 6°38′S, near Tisia Valles, and north is up in this figure. The impact craters shown in this figure are located within the same geologic unit (Fig. 3). Brighter and darker pixels represent higher and lower thermal inertia values, respectively. These values range from 150 to 310 J $\mathrm{m}^{-2}\,\mathrm{K}^{-1}\,\mathrm{s}^{-1/2}$ in this scene. The yellow arrows point to craters with similar diameters that exhibit different rim thermal inertia values than their neighbors. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

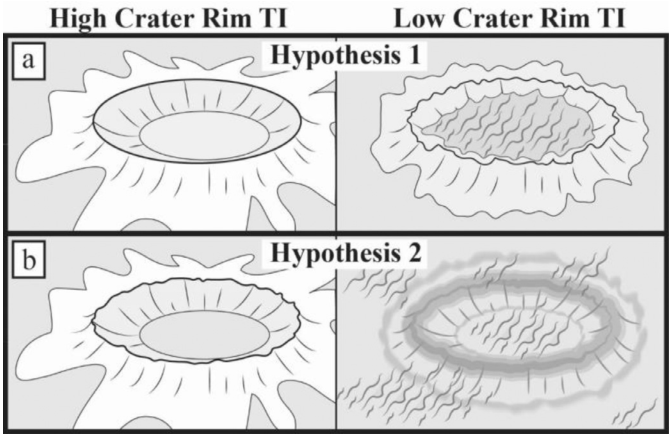


Fig. 2. Hypotheses 1 and 2 illustrations. (a) Hypothesis 1 is that crater degradation affects crater rim thermal inertia. In this scenario, we would expect a fresh crater (left) to exhibit less fine-grained material and a higher thermal inertia than a degraded crater (right). (b) Hypothesis 2 is that crater rim thermal inertia is affected by the presence of a regolith mantle on the crater rims. In this scenario, a crater with a more exposed rim (left) would exhibit a smaller amount of fine grained material and higher thermal inertia than a crater with a more mantled rim (right).

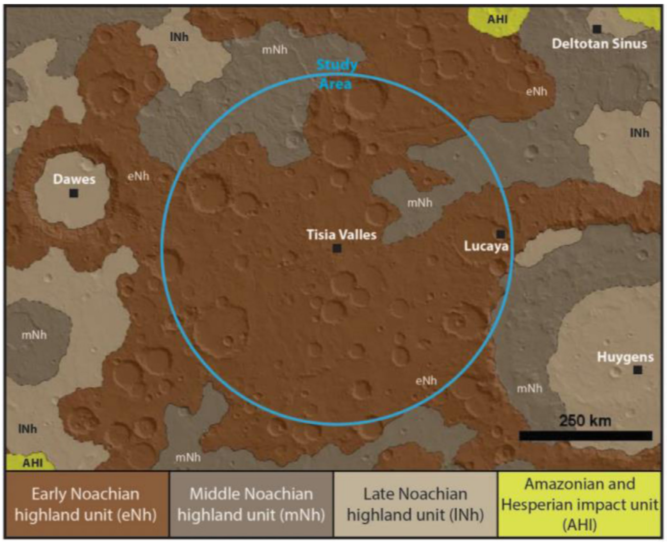


Fig. 3. Study area map. The study area surrounds Tisia Valles (46.7° E, −10.8° N), and is northwest of Huygens crater. North is up in this figure. The study area sits within geologic units that range from early to middle Noachian in age (Tanaka et al., 2014), and is surrounded by some late Noachian units. These units exhibit high abundances of simple impact craters at various stages of degradation, and with various amounts of rim mantling.

nonlocal source. Because a regolith mantle would consist of small particle sizes atop crater rims, we would expect a negative correlation between the percentage of rim circumference that is mantled and thermal inertia. If this is the case, then impact craters with low thermal inertia rims could be used to assess the spatial extent of mantled regions on Mars. This assessment could be performed by mapping the spatial extent of craters with low thermal inertia rims in regions where multiple neighboring craters are mantled. Additionally, this information could be used in conjunction with crater counting to constrain the timing of mantling events. For example, two crater counting assessments could be applied to an area where craters with both high and low thermal inertia rims are present. One assessment would be applied to craters with mantled, low thermal inertia rims, which must have been present before the mantling event. The other assessment would be applied to craters with exposed, high thermal inertia rims in the same region, which likely formed after the mantling event. The two derived ages would bracket the age of the mantling event.

2. Background

2.1. Impact crater degradation

Over time, erosional and/or depositional processes act to modify the morphologies of impact craters on Mars. Significant modification of a crater occurs within the first few minutes following the excavation stage, although further modifications can take place over millions of years (e.g., French, 1998; Osinski and Pierazzo, 2012). Degradation rates were likely higher across Mars in early martian history based on analyses of crater preservation states (Murray et al., 1971; Hartmann, 1973; Chapman, 1974; Jones, 1974; Chapman and Jones, 1977; Barlow,