ANALYSIS OF THERMAL INERTIA TO UNDERSTAND THE NEAR-SURFACE PROPERTIES OF LAYERED EJECTA CRATERS AND SOUTHERN HEMISPHERE DUNES ON MARS. R. H. Hoover[1]⌘, S. J. Robbins[1], N. E. Putzig[2], S. Courville[2,3], and L. K. Fenton[4]. [1]Southwest Research Institute, Boulder, CO; [2]Planetary Science Institute, Lakewood, CO; [3]Colorado School of Mines, Golden, CO; [4]SETI Institute, Mountain View, CA. ⌘RHoover@Boulder.SwRI.edu

Synopsis: Analysis of thermal inertia and other thermophysical properties informs the geologic, erosional and depositional history of an area. The research presented here focuses on application of thermal inertia analysis to constrain the formation and geologic history of layered ejecta craters and southern hemisphere dunes on Mars. Currently, 171 dune fields and 35 layered ejecta craters have been investigated and classified through the analysis of derived thermal inertia values and comparisons to two-layer thermal models. Multiple datasets and analyses are employed to characterize near-surface properties and identify subsurface volatiles.

Background: Thermal inertia, a composite thermophysical property of a material, can be used to infer grain size, induration, rock abundance and percentage of exposed bedrock [1]. Thermal inertia derived from individual temperature observations of the Martian surface typically exhibits diurnal and seasonal variations that has been attributed to heterogeneity within the field of view of the observations [2,3]. An important component of our work on two different projects is to analyze thermal inertia to provide insight into formation mechanisms of layered ejecta craters and understand the geologic processes affecting southern hemisphere dunes.

Layered Ejecta Craters: Two primary hypotheses exist to explain the formation of layered ejecta craters. The first hypothesis introduces the "fluidized model" in which an impactor strikes a volatile-rich surface resulting in the melting or vaporization of volatiles [4]. The volatiles become entrained in the ejecta causing it to flow and act like a fluid [4]. The second hypothesis introduces the "atmospheric model" in which the ejecta of a crater interacts with the atmosphere [5]. Each model has implications for the geology and environment of the impacted area. For example, the fluidized model would indicate the presence of subsurface volatiles which could let layered ejecta craters be used to track subsurface water or other volatiles.

Southern Hemisphere Dunes: The stabilization and activation of dunes represent shifts in local and regional climates as dunes are influenced by the presence of volatiles. Previous research has identified a trend from active to stabilized dunes as one moves poleward from the equator, establishing eight unique dune classes based on the erosion state of the dune [6]. Furthermore, a 20% increase in hydrogen concentrations detected by the Mars Odyssey Neutron Spectrometer indicates the likely presence of subsurface water ice poleward of ~60°S [7]. Some researchers have suggested that the decrease in aeolian activity is directly related to the increased presences of subsurface volatiles [6]. Others have also identified water ice in the subsurface of dunes that potentially influences the stabilization of the north polar erg [8]. An investigation of the thermophysical properties of southern hemisphere dunes could provide insight into the location of subsurface volatiles and consequently the recent climate shifts on Mars [1].

Methods: Features of interest are mapped using ArcGIS and JMARS [9] software. Apparent thermal inertia (ATI) of a surface is derived from individual brightness temperatures obtained by the Mars Global Surveyor Thermal Emission Spectrometer (TES) and the Mars Odyssey Thermal Imaging System (THEMIS). Derivation employs a lookup table of model temperatures for a broad range of season, time of day, latitude, albedo, surface pressure, dust opacity, and thermal inertia [1]. Values derived from TES, with a 3 km/pixel scale, are used to identify large-scale heterogeneities by examining their diurnal and seasonal variations and comparing them to values calculated for two-component heterogeneity models created for a variety of materials (e.g., dust, sand, rock/ice, duricrust) with either horizontal mixing or vertical layering representing the top few cm of the surface [1]. We use the results of these comparisons to classify the physical characteristics of the dunes or crater ejecta. Values derived from THEMIS data, with 100 m/pixel scale, are used to identify trends and variations within dune fields and crater ejecta to further clarify the near-surface materials at finer lateral resolution. Useful THEMIS images for thermal analysis are largely limited to nighttime observations because the majority of daytime observations are too close to dusk to provide accurate thermal inertia results.

Results: Of the 171 dune fields for which we evaluated TES variations in ATI, approximately half did not match the current set of models. Dune fields that did match heterogeneity models dominantly matched models of 'crust over dust' (Fig. 1), 'dust over crust' or 'dust over sand' [3]. Dunes identified in image data as the least degraded [6] had the closest matches to the 'crust over dust' models. In only six dune fields, we identified a possible thermal signature of water ice; however, this result does not eliminate the possibility of water ice being present in the remaining dune fields. Of the 35 layered ejecta craters investigated so far, approximately half did not match the TES heterogeneity models. For the models that did match, the majority are 'crust over dust', 'dust over rock' or a 'dust-rock mix'. The model thermal inertia for rock is identical to that of water ice and therefore reveals the potential for the existence of water ice in the upper few centimeters of the ejecta blankets.

THEMIS analysis reveals varying patterns within dune fields and layered ejecta craters. We established three categories of dune fields based on the observed patterns of thermal inertia [10]. Type 1 dune fields have exposed bedrock in the interdunes and lower ATI compared to the surrounding material. Type 2 dune fields have higher ATI along the crests than in the troughs. Type 3 dune fields do not have interdunes and have consistent ATI values across the dune field. Layered ejecta craters are revealed to have different characteristics; however we have not yet established categories since each ejecta blanket may display more than one characteristic. Characteristics we consider include: (a) presence of rays of high thermal inertia, (b) thermal inertia of the ejecta blanket lower than the surrounding terrain, (c) thermal inertia of the ejecta blanket higher than the surrounding terrain, (d) edge of an ejecta blanket exhibiting a distinct thermal inertia value compared to the surrounding materials (Fig. 2), and (e) lack of a distinct pattern observed in the thermal inertia (equivalent to background).

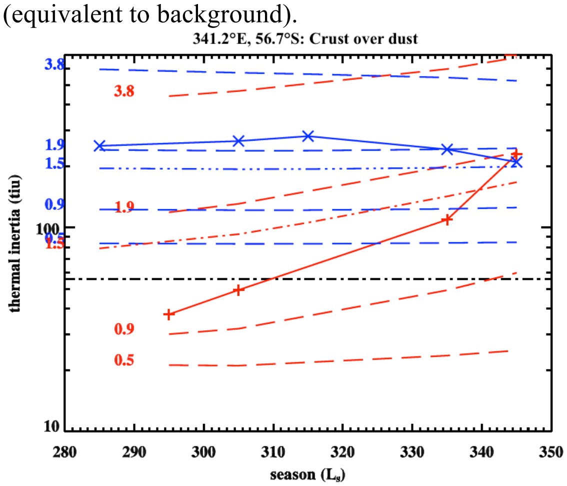

Figure 1: Seasonal apparent thermal inertia for a dune field located at 341.2°E, 56.7°S. TES measurements (symbols and solid lines) are compared with modeled values (dashed lines) for 2AM (blue) and 2PM (red) TES observation times. Colored labels on the left axis indicate upper-layer thickness in centimeters. The data correlate best with a model of 1.5 cm crust over dust (dot-dashed lines).

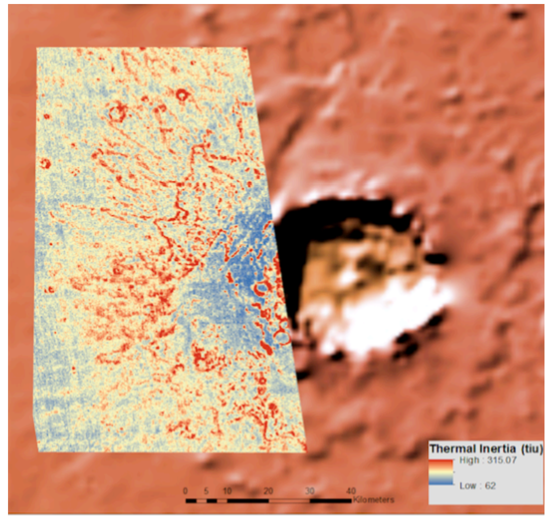

Figure 2: A MOLA basemap of multi-layer ejecta crater, located at 236.4°E, 27.7°S, overlain by an image of apparent thermal inertia derived from a THEMIS. The edges of the ejecta blankets display a distinct, higher thermal inertia, compared to surrounding material, indicating the edges are either more consolidated or have larger grain sizes than elsewhere in the ejecta blanket.

Benefits: Using TES in conjunction with THEMIS provides a clearer picture of the thermophysical properties and behaviors of near-surface materials. TES heterogeneity models are useful for identifying large-scale variations and classifying vertical and horizontal mixtures. Currently, 3+ layer models are in development which will provide more insight into subsurface layering and identification of subsurface ice. THEMIS is important for identifying small-scale heterogeneities and trends and is advantageous for investigating sparse features that reveal underlying surface material.

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