INVESTIGATING THE POLEWARD TREND OF SOUTHERN DUNE FIELD STABILIZATION ON MARS USING THERMOPHYSICAL OBSERVATIONS.

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Synopsis: Dune fields in the southern Martian hemisphere have morphologies indicating a poleward progression toward stabilization starting at 50-60° S. Separately, a near-surface layer of ground ice is suspected to span the hemisphere from ~50° latitude to the pole. We hypothesize that the southward increase in stabilization may be caused by an ice table that is shallower at higher latitudes, a linkage that would allow dune morphology to be used as a tracer of local climate. Thermal inertia measurements and multi-layer thermal modeling can be used to infer near-surface properties, including ice table depth. We have begun an investigation of the thermal properties of the largest 171 southern dune fields with well-defined characteristics. Our analysis of the first two suggests the uppermost portion of the dunes contains a surface of crust overlying dust, rather than sand overlying ice, indicating there is more to the picture than initially suspected.

Background: Recently, evidence has accumulated for a ubiquitous, high-latitude layer of water ice below the Martian surface. Material excavated by fresh, mid-latitude craters has revealed ice within decimeters of the surface [A]. Neutron spectrometry data from Mars Odyssey indicates deposits of 20–100% water-equivalent hydrogen by mass within a meter of the surface poleward of ±50° latitude [B]. Temporal variations in apparent thermal inertia in the northern polar erg have been shown to be consistent with decimeters of dry sand overlying ice-cemented sand [C].

A mapping of 1190 dune fields poleward of 50° S [D] found that sharp-crested dunes are located almost exclusively north of 60° S, and more rounded dunes are primarily south of this line, progressing to flat sand fields near the pole (Fig. 1). This indicates dunes south of 60° S have experienced increased stabilization and are less reflective of current aeolian activity.

Ice, the Leading Suspect: This southward smoothing of dune fields beginning near 60° S is tantalizingly coincident to the southward rise in Odyssey-detected ice beginning near 50° S. Since it is known that interstitial ice retards bedform migration [E], it has been proposed [D] that the transition in dune morphology is caused by sub-surface ice being closer to the surface in more poleward regions. That is, sand is free to respond to local wind when the ice table is low, but a high ice table cements dunes in place, leaving them subject to non-aeolian erosion and causing their rounded, flattened appearance.

High-resolution images do not reveal any craters on these frozen-in-place dune fields, indicating the dune surfaces are young, perhaps even under 100 years old [F]. This suggests that, if the latitudinal progression in dune stability is caused by a progressively shallower ice table, dune morphology is a direct indicator of current climatic conditions.

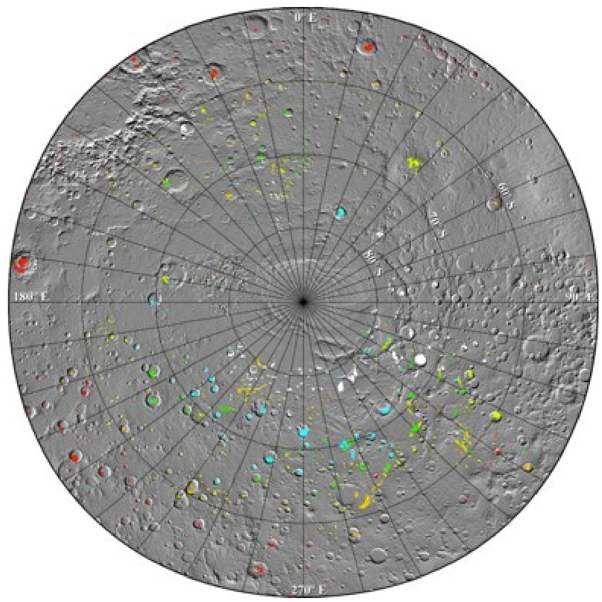

Figure 1. MOLA shaded relief map of the region poleward of 50° S in an oblique equidistant projection. Marked are 1190 dune fields in six morphological classes from [D]. Moving south, sharp-crested dunes (red) give way to rounded dunes (e.g. green) and then to flat sand fields (white).

Investigating with Thermal Inertia: We investigate the ice table depth through comparison of thermal inertia measurements to model results.

Thermal Inertia: Thermal inertia is a bulk material property. For typical materials on the Martian surface, it is dominated by thermal conductivity [G], which is determined by properties such as particle size and porosity, making materials such as dust, sand, and rock easily distinguishable. We determine apparent thermal inertia from individual temperature measurements by the Mars Global Surveyor Thermal Emission Spectrometer (TES) and the Mars Odyssey Thermal Imaging System (THEMIS) using a lookup table which matches temperature to thermal inertia at particular times of day, seasons, latitudes, and atmospheric and surface conditions [H, I].

Thermal Modeling: Once we have determined a dune field's thermal inertia over the course of a year, we compare with predictions from various model surfaces. For a heterogeneous surface, apparent thermal inertia varies with time of day and season [J, K], so observed variations can be matched to a combination of materials (e.g. dust, sand, ice) in a certain configuration (horizontal mixture or vertical layering). Vertical layering is key, as this includes sand layered in some thickness over ice. This technique was used, for instance, to accurately predict sub-surface ice depth at the Phoenix landing site [L] and at the northern polar erg [C].

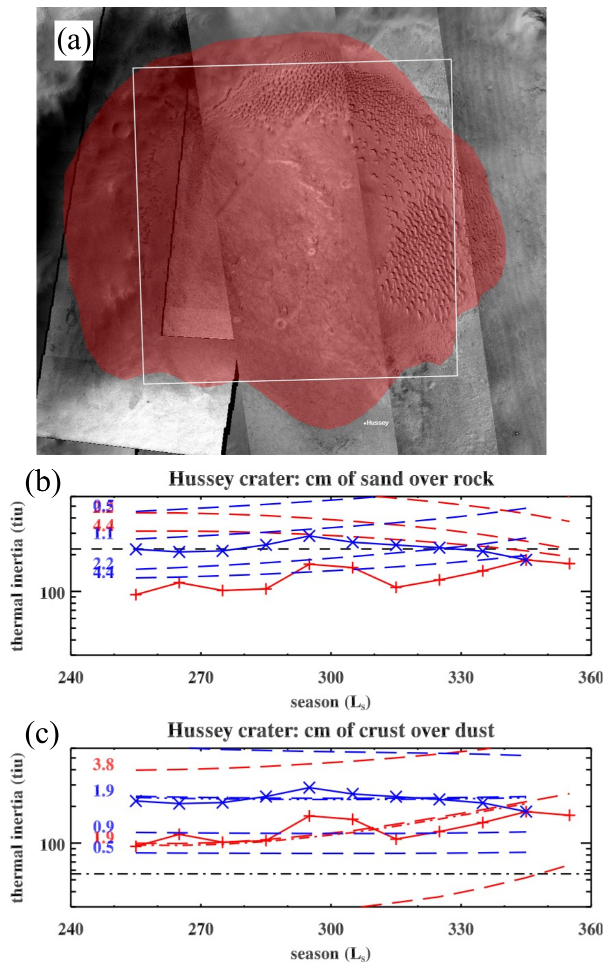

Figure 2. (a) THEMIS visible images showing Hussey crater dune field in red (as defined in [M]), with analysis performed within the white box. (b) and (c) show separate two-layer models (with rock used as thermally equivalent to ice). In each, apparent thermal inertia at 2AM (blue) and 2PM (red) from TES data (symbols connected by solid lines) is compared with that from models (dashed lines) labeled with top-layer thicknesses in cm. Seasons are limited to those when CO2 ice is not present. The data is broadly anti-correlated with the sand (225 tiu)-over-rock (2506 tiu) model, but follows well the crust (889 tiu)-over-dust (56 tiu) lines.

First Looks: We performed an initial analysis on two dune fields, in Hussey crater (233.1° E, 53.1° S) and in the inter-crater plains at 293.7° E, 49.8° S (Fig. 2 & 3). Under the sub-surface ice hypothesis, we might expect thermal inertia measurements at these two sites consistent with a sand-over-rock model (where the model's rock is thermally equivalent to ice). However, both sites are consistent instead with a few centimeters of crust overlying dust. We found similar results in a preliminary analysis of two more poleward, more eroded sites, where shallower ice would be expected. This suggests something more going on, though it does not rule out the presence of deeper ground ice. Of the 1190 dune fields mapped in [D], 171 are larger than 0.25° across (5 pixels in TES data) with a high-confidence morphological classification. We hope analysis of the remaining 167 will help complete this picture.

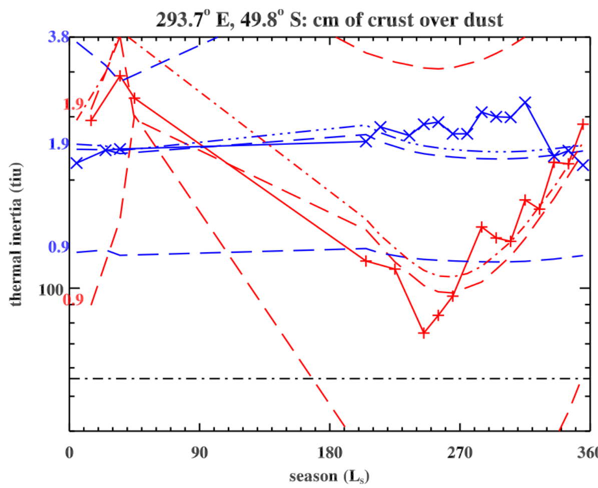

Figure 3. TES thermal inertia and models for the dune field at 293.7° E, 49.8° S, colored and labeled as in Figure 2. As with the Hussey Crater dune field (Fig. 2), a crust-over-dust model provides the best fit whereas a sand-over-ice model (not shown) exhibits an anti-correlated behavior.

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