SLOPE ANALYSIS AND ICE STABILITY OF THE MID-LATITUDE DISSECTED TERRAIN ON MARS
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Introduction: Determining the present and past distribution of subsurface ice on Mars is critical for understanding the volatile inventory and climatic history of the planet. An analysis of a latitude-dependent layer of surface material known as the dissected mantle terrain can provide valuable insight into the distribution of ice in the recent past. The dissected mantle terrain is a surface unit that occurs globally in the mid-latitude of Mars (from ~±30 to 45°) and is characterized by a smooth mantle of uniform albedo that has been disaggregated and dissected in places resulting in a hummocky pitted appearance.

In this work we present a new hypothesis for the formation of the dissected mantle terrain based on an analysis of a global subset of HiRISE images (from 0 to -70N and 150 to 180E). We also quantify the occurrence of the dissection pits as a function of slope and latitude. The location of these pits in conjunction with ice stability modeling can provide a global view of the climate and obliquity of Mars at the time these features formed.

Theory: The present theory behind the formation of the dissected terrain is that during period(s) of high obliquity, a uniform mantle of ice-cemented aeolian material accumulates over the mid-latitudes [1]. As near-surface ground ice is not stable at these latitudes under current Martian conditions, devolatilization of this ice reservoir occurs. The dry, friable mantle is then disaggregated by the wind resulting in the observed hummocky, dissected terrain [1]. However, there are a few key observations that are not consistent with this hypothesis.

One striking trend in all of the images analyzed is a distinct slope preference for the formation of the dissected regions (also noted by [2]). Disaggregation of the mantle appears to begin on pole-ward facing slopes. That is, in the southern hemisphere dissection is preferentially seen on the south facing slopes (see Figure 1) and vice versa in the northern hemisphere. If the disaggregation of the mantle is due to desiccation of an ice-rich dust, one would expect the equator-ward slopes to show the first signs of dissection due to more direct solar incidence, particularly at these latitudes (~30-45 degrees). High obliquity is commonly called on to explain melting or sublimation of ground ice on pole-facing slopes [e.g. 3]; however, this is not consistent with the proposed formation of an ice-rich mantle during high obliquity.

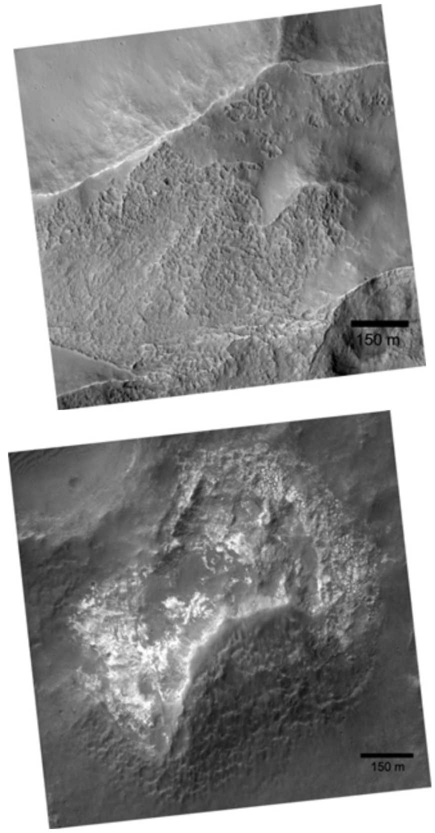

Fig 1. a) Subset of HiRISE image PSP_004059_1410 b) Subset of HiRISE image PSP_005707_1425. North is up in all images.

Dust and soil mantle the surface of Mars; however, at HiRISE resolution, the texture and depositional style of this dusty mantle does not appear to change significantly as one moves from the equator to the mid-latitudes. The mantle does not uniformly coat the surface as one would expect from an ice-cemented aeolian material, but is preferentially located in topographic lows and on shallow slopes (see Fig 1b). Also, the mantle shows complexities such as superimposed craters and partially embedded boulders which one would not expect to see in a recently deposited aeolian mantle.

We present a revised hypothesis for the formation of the mid-latitude dissected terrain. During period(s) of high obliquity, ice becomes stable at lower latitudes [e.g. 4, 5]. Due to lack of direct solar insolation, ice-rich deposits will preferentially accumulate on pole-ward facing slopes first. A mantle of dust and dirt is then deposited on top of these ice-rich deposits. As the obliquity falls and the climate changes, desiccation of the ice leads to collapse of the overlying layer of dust and dirt resulting in a hummocky, pitted surface. In this scenario, ice was only present beneath the hummocky dissected regions and the dusty mantle was relatively ice-free.

This hypothesis is consistent with HiRISE observations which include slope preference, lack of uniform mantle in some regions and the presence of boulders in and on the smooth surface. In addition, experimental studies by Jeff Moore [6] show that sublimation of an ice-rich layer overlain by dust and sand-sized particles under Mars-like conditions can result in a hummocky texture similar to what is seen in the mid-latitude dissected regions.

Slope Analysis: As mentioned above, there is a distinct pole-ward preference of the location of the dissected terrain. Here we quantify the occurrence of the dissection pits as a function of slope and latitude. The resolution of the gridded Mars Orbiter Laser Altimeter (MOLA) product is too coarse to allow for detailed analysis at HiRISE scale (~25cm/pixel); therefore, we have used elevations derived individual MOLA laser shots (footprints) overlaid on top of HiRISE images to determine the slopes where dissection occurs.

Figure 2 shows a subset of HiRISE image PSP_001527_1400 with an overlay of individual MOLA shots with the corresponding elevations shown in red. The slopes between the adjacent MOLA footprints are shown in yellow (pole-facing slopes are in positive degrees and equator-ward slopes are negative). In Figure 3 we show one of the topographic profiles that cuts through Figure 2. The occurrence of dissection is marked on this profile by a dotted line. From these overlays and profiles we can determine the location of dissected regions as a function of slope and latitude. For each HiRISE image within our global subset (0 to -70N and 150 to 180E) we have recorded the minimum slope where dissection can be found as well as the maximum slope with intact mantle.

Ice Stability: Assuming that the location of the dissected regions is a direct indication of the past presence of an ice-rich layer, it is possible to determine the climatic conditions under which the ice would be stable [e.g. 7, 8]. Using the slopes from the previous section, we can use ice-stability models to constrain the obliquity at the time the dissected terrain formed.

Summary: We propose that the mid-latitude dissected terrain results from collapse of a dusty mantle into the void left from desiccation of an underlying ice-rich layer. A study of the global distribution of the mid-latitude dissected terrain can provide invaluable clues towards unlocking the distribution of ice in the recent past. Knowing the distribution of ice in conjunction with ice stability modeling can provide a global view of the climate and orbital history of Mars at the time these features formed.

References: [1] Mustard, J. F., et al. (2001), *Nature*, *412*, 411-413. [2] Milliken, R. E., & J. F. Mustard (2003), *6th Intern'l Conf. on Mars*, #3240. [3] Kreslavsky, M. A., & J. W. Head (2003), *GRL.*, *30*, 1815. [4] Jakosky, B.M. & M.H. Carr (1985) *Nature*, *315*, 559-561. [5] Mischna, M.A. et al. (2003) *JGR, 108 (E6)*, 5062. [6] Moore, J.M. (1990) *PhD Dissertation*, Arizona State U. [7] Aharonson, O & N. Schorghofer (2006), *JGR*, *111*, E11007 [8] Mellon, M.T. & B.M. Jakosky (1995), *JGR*, *100 (E6)*, 11781-11799.

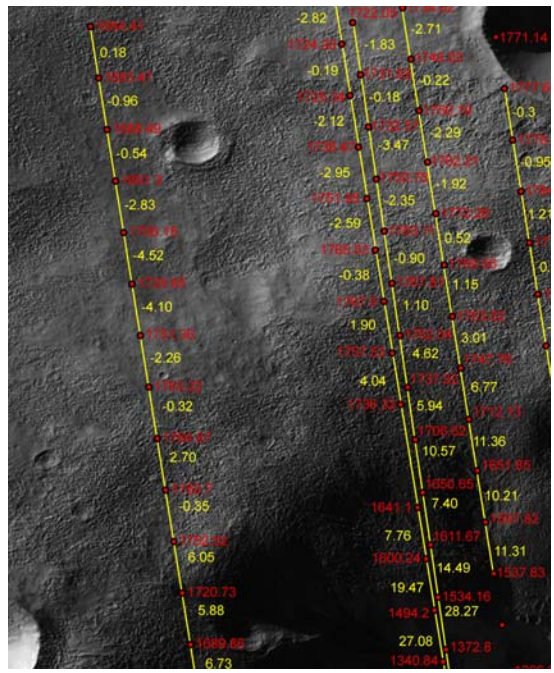

Fig 2. Subset of HiRISE image PSP_001527_1400 with MOLA shots and elevations (m) shown in red. The yellow numbers indicate the slope between adjacent MOLA shots. Image located at (-39.5N, 158.1E).

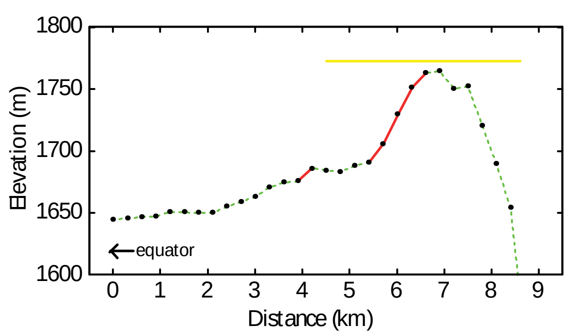

Fig 3. Profile through a portion of HiRISE image PSP_001527_1400. The solid red line indicates regions of intact surface while the dashed line shows regions of dissected terrain. The yellow line shows the region of the profile that corresponds with the leftmost MOLA track from Figure 2.