MID-LATITUDE DISSECTED MANTLE TERRAIN AS VIEWED FROM HIRISE.
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Introduction: Early Viking and Mariner images of Mars show evidence for a latitude-dependent layer of surface material [e.g. *Squyres and Carr*, 1986]. Based on MOC images, Mustard et al. [2001] described this unit as a dissected mantle terrain (DMT). DMT is characterized by a smooth mantle of uniform thickness and albedo that is draped over the existing topography. This smooth mantle is disaggregated and dissected in places resulting in a hummocky pitted appearance.

The leading theory behind the formation of the DMT is that during period(s) of high obliquity, a mantle of ice-cemented aeolian material forms. As near-surface ground ice is not stable at these locations under current Martian conditions, devolatilization of the surface and the loss of cohesive ice leads to the observed hummocky, dissected terrain [*Mustard, et al.*, 2001]. In this work, we examine the small scale morphology of the dissected mantle terrain (DMT) to test the plausibility of this hypothesis.

Global distribution of images analyzed: A major advantage of HiRISE (High Resolution Imaging Science Experiment) is the ability to determine small scale morphology on the order of 25 to 32 cm/pixel [*McEwen, et al.*, 2006]. We have analyzed over 500 high resolution HiRISE images cataloging the occurrence and morphology of the dissected mantle terrain. Shown in Figure 1 is the global distribution of the images analyzed to date. The red dots represent images where dissected mantle terrain is observed while the black dots lack evidence of a dissected mantle. As expected, this mid-latitude distribution of DMT mimics that observed using lower-resolution MOC images [*Mustard, et al.*, 2001].

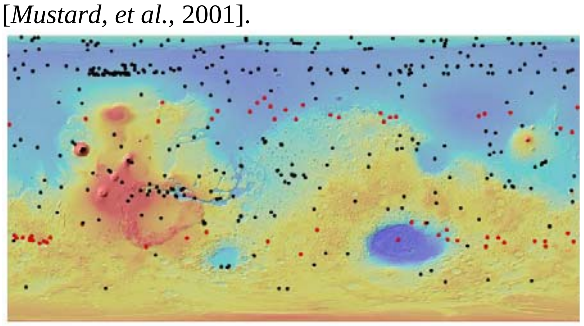

Figure 1. Global distribution of HiRISE images analyzed. The red circles denote images containing dissected mantle terrain, while the images denoted by the black dots do not show this terrain.

Observations:

General Morphology: In prior analysis of DMT, the mantle is described as young and smooth [*Mustard, et al.*, 2001]. With the higher resolution of HiRISE, the mantle demonstrates more variety. In some of the images (see Figure 2 for example) the mantle is beginning to show small indentions which can be interpreted to be the initial stage of pit formation. A wider range in dissection pit sizes can also be observed. In some areas a gradation from small to large pits can be seen.

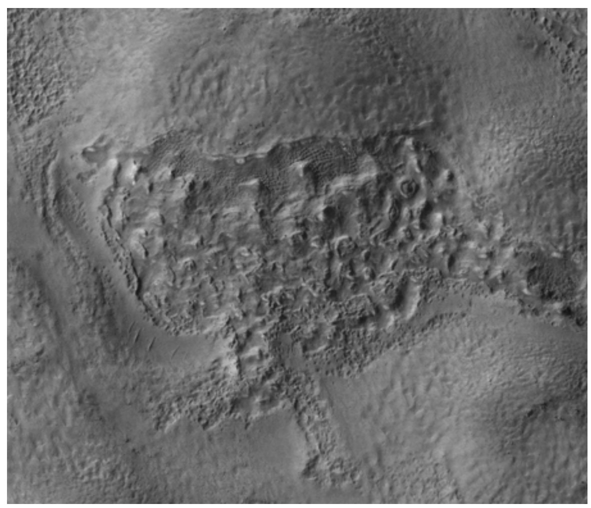

Figure 2. At MOC resolution, the mantle appears relatively smooth with a uniform albedo (see MOC image FHA01450 at this location); however, in this HiRISE image, the mantle shows more complexity and small intermediate dissection pits are seen. This image is a subset of PSP_001911_1370 located at 42.5381°S, 120.836°E. North is up.

There are also indications that the ‘young’ mantle may be older than was previously assumed. Sub-meter to meter scale boulders and small craters litter the surface in some regions. A more detailed analysis of the crater distribution is needed to determine the approximate age of this terrain. In Figure 3, fractures can also be seen cutting through both the mantled and dissected regions. This could be an indication that the DMT is an older feature and not currently undergoing modification.

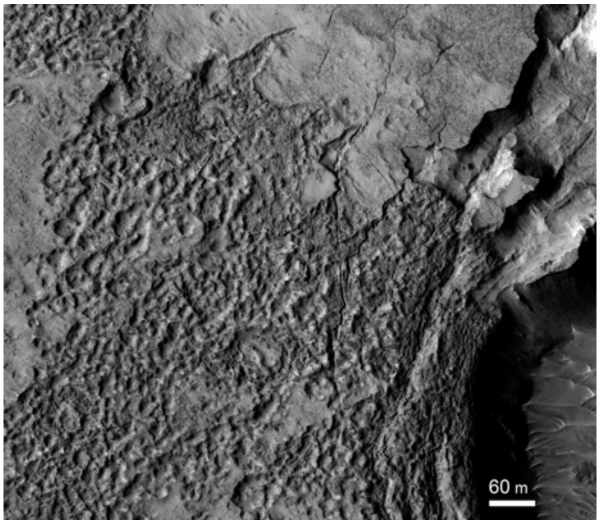

Figure 3. Subsection of HiRISE image PSP_001440_2175 showing a fault cutting through the smooth mantle and dissected region (center right). Image is located at 37.0797N, 1.48785E.

Slope Preference: One striking trend in all of the images analyzed is a distinct slope preference for the formation of the dissected regions (also noted by Milliken and Mustard [2003]). Disaggregation of the mantle appears to begin on the poleward facing slopes. That is, in the southern hemisphere dissection is preferently seen on the south facing slopes (see Figure 2) and vice versa in the northern hemisphere (see Figure 4). While dissection is extensively observed on a number of level surfaces, on small knobs and the exterior and interior of small crater rims as well as on larger valley walls and larger craters, the dissection often occurs on the poleward facing side with intact mantle persisting on the equatorward facing side.

Rock Distribution: One important advantage that HiRISE can lend to the study of DMT is the ability to resolve sub-meter scale boulders. In general, relatively few boulders are seen in the DMT. In images where boulders are found, they tend to be relatively small (1-2 m) and distributed roughly equally on the surface of both the mantled and dissected regions. This distribution indicates that the mantle material itself is relatively boulder free. This is supported by the lack of inbedded rocks observed in cross-sections where the exposed edge of the mantle can be seen.

Aeolian features and bedrock: Although Mustard et. al. [2001] noted the absence of dunes associated with DMT; small aeolian bedforms are seen in a large majority of the HiRISE images examined. The most common type of aeolian features seen are transverse dunes residing in low lying regions and within larger dissection pits. In many images faint bedforms can be detected at the limit of resolution within smaller hummocks. In general, dust appears to be collecting at the bottom of the dissection pits. This is consistent with a thermophysical analysis by Mustard [2003] indicating that DMT is not distinct from dust/soil.

Initial examination shows that, in most cases, the dissected areas do not entirely excavate the mantle to reveal the underlying unit. Part of this observation is explained by the presence of loose dust and dunes which would mask any bedrock. It is also possible that the underlying unit is not spectrally distinct from the mantle in the red wavelengths.

Polygons: Although the formation of polygonal patterned ground in ice-rich soils on Mars is a common occurance [e.g. *Mangold*, 2004]; evidence for polygonal ground is absent in the DMT, in both the intact mantle and dissected units.

Changes in morphology with time: Is the dissected mantle terrain currently undergoing disaggregation? A large majority of the images surveyed containing DMT have overlapping coverage with MOC narrow angle images. A visual comparison of the HiRISE and MOC datasets was made in order to determine if the terrain has been altered in the time between images. Due to resolution differences between the cameras it is not possible to determine if small sub-meter scale changes have taken place, however, this comparison allows us to look for changes in morphology that occur at MOC resolution. The results thus far indicate that the DMT is not undergoing modification on the length scale or timescales observed.

Other viscous flow features: In the process of cataloging images with dissected mantle terrain, we have also made note of the association of DMT with latitude dependent viscous flow features such as concentric crater fill, lineated valley fill, and lobate debris aprons (see also Milliken et al. [2003]). All images containing concentric crater fill also show DMT, and the majority of images surveyed with lineated valley fill and lobate debris aprons also contain DMT.

It has been suggested that these features are genetically linked [e.g. *Carr*, 2001; *Chuang and Crown*, 2005; *Milliken, et al.*, 2003]. At HiRISE resolution, the similarities seen in the morphologies of these features support this hypothesis (see Figure 4). Both the DMT and flow features show similar boulder distributions. The flow features are relatively boulder free and a change in boulder distribution from mantle to hummocky/lineated areas is not seen, suggesting the mantle and flow features consisted of ice-rich fine-grained material. The range of sizes of pits and hummocks within the DMT and flow features is consistent within a region. In places the hummocks of the DMT appear to grade into the more directional textures seen in the viscous flow features.

Discussion: In this work, a detailed morphologic analysis of the mid-latitude mantled terrain using high-resolution HiRISE images was performed. On the whole, many of the observations are consistent with desiccation and disaggregation of an ice-rich mantle deposited during period(s) of high obliquity. An analysis of boulder distributions indicate that the bulk of the mantle is free of meter-scale rocks. The texture of the mantle and the presence of intermediate sized pits grading into larger scale hummocks supports desiccation and removal of friable material. The presence of aeolian bedforms and dust within the pits indicate that not all of the friable material is stripped away. However, the presence of bedforms also indicates that not all the friable material consists of dust. Although active erosion/dissagregation of the mantle was not observed, the length scales and/or timescales measured may not be sufficient to see evidence of disaggregation.

The pole-facing slope preference for the formation of the dissection is puzzling. If the disaggregation of the mantle is due to dessication 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. *Kreslavsky and Head*, 2003]; however, this is not consistent with the proposed formation of an ice-rich mantle during high obliquity, nor is it consistent with the latitudinal distribution of DMT. It could be that these areas are more ice rich when formed and thus more easily disaggregated upon changing the climate.

The lack of evidence of polygon formation in the mantle is enigmatic. If the mantle was composed of ice-cemented dust, one would expect polygons to form on the surface during times of higher obliquity when ground-ice is stable in these mid-latitude regions. Why are these features not observed? There are several possible answers to this question. The period of ice-stability may not have been of a suffient length of time to allow polygons to grow to a detectable size. The mantle may not have been ice-rich or the ice was too deep for the formation of polygons (too deep to expeience sufficient seasonal cooling stress). Subsequent reworking of the surface could also provide a plausible explanation for the lack of polygons.

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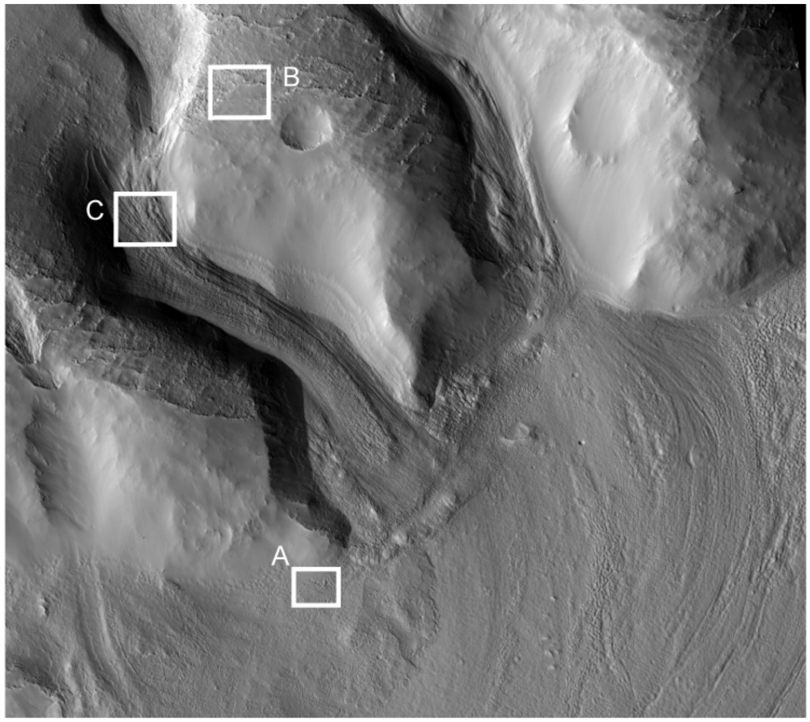

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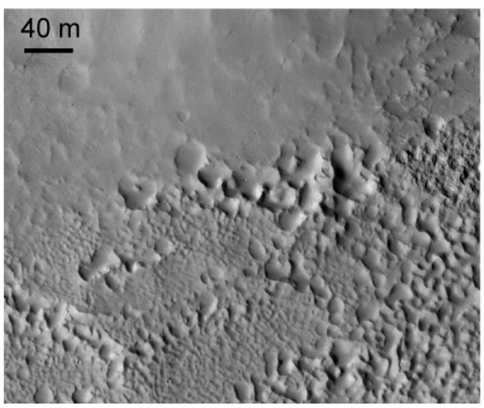

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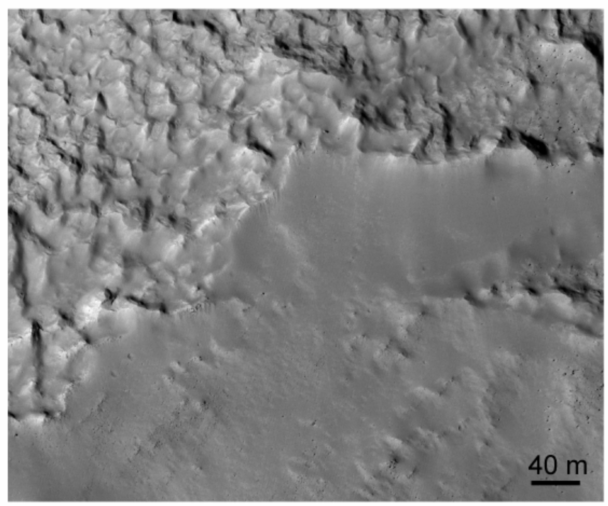

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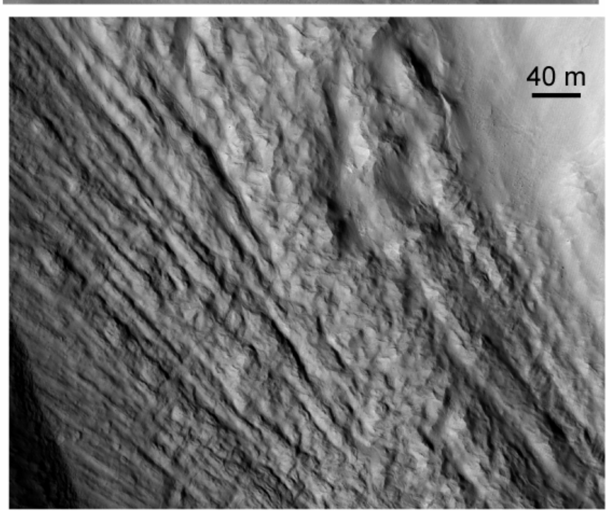

Figure 4. Top image is a subset of HiRISE image PSP_001834_2215 showing DMT and lineated valley fill. The boxes show the locations of the remaining figures. Image is located at 41.0042N, 54.6257E.