AEOLIAN STUDIES FROM HIRISE

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Introduction

The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) has so far returned hundreds of images of the Martian surface. With its sub-meter resolution, high signal-to-noise, and wide field of view [1], HiRISE allows the study of aeolian geology and the monitoring of aeolian processes at a level of detail not provided by previous Mars orbiters and bridges the gap between them and surface landers and rovers. This abstract reports on new aeolian insights and discoveries resulting from images acquired thus far from HiRISE in MRO's Primary Science Orbit. There is insufficient space in this abstract to display all images, so in many cases the image IDs are given. The full resolution images can be viewed on the web at http://marsoweb.nas.nasa.gov/HiRISE/ and http://hiroc.lpl.arizona.edu/.

Observations

Medusae Fossae Formation

The Medusae Fossae Formation (MFF) has been and remains one of the most enigmatic features on Mars [2-4]. The unit is characterized by wind-sculpted landforms, most notably eroded ridges known as yardangs. The composition of the Medusa Fossae is not known, but candidates include indurated volcanic ash [2-4] or remnants of dust-ice mixtures [5]. HiRISE images reveal new details that provide insight and questions on the origin and erosion of the Medusae Fossae:

1. Competent layers: HiRISE images reveal horizontal layers within the MFF. Some of the layers are clearly cliff-formers, indicating a stratigraphy of differential hardness (Figs. 1-2). At the lower slopes of and at the base of the layered materials that contain rocky strata, isolated boulders are seen, suggesting that the cliff-forming layers are actively being destroyed. The dominant mechanism is probably erosion of the less resistant material beneath the rocky layers, resulting in undermining, plucking, and collapse. The rocky layers are also subjected to the wind erosion that affects the softer materials of the MFF, but the rate of erosion by this mechanism alone is probably low. These layers may be wind deposited sediments that have been indurated in the distant past or may be the result of a unique geologic event (s) (volcanic breccia, impact ejecta, etc.) that punctuates an otherwise uniform stratigraphic sequence.

There are also thin resistant layers that cross diagonally across the MFF in some places (Fig. 2). These may be thin dikes or faults that have been indurated by fluids, indicating that the MFF is competent enough, at least in places, for cracks to propagate, even across pre-existing layering.

Despite some bedding, the MFF is fairly massive, with no fine-scale layers or cross-beds. There are no prominent color variations. All of these observations complicate simple models for the origin of the MFF.

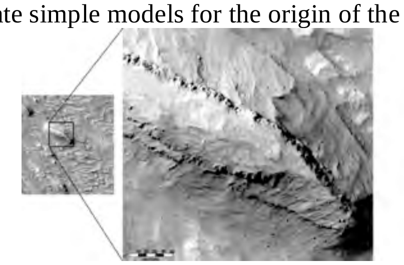

Figure 1: Portion of HiRISE image TRA_000828_1805 of the Medusae Fossae Formation (left) and close-up of region showing rocky layers and boulders (right). Image centered at 0.5°N, 142.1°E (planetographic). Image scale is 27 cm/pixel.

2. Effects of Wind Direction: Based on yardangs on Earth [6], the wind direction that eroded the MFF can be estimated from the orientation of blunt to tapered ends of positive relief landforms. HiRISE images show that wind direction has varied in space or time. Separate yardangs sets are found that differ both in their orientation and elevation above the surface. For example, in Fig. 2, the upper and lower yardangs have shapes indicative of southeasterly and easterly, respectively, wind directions. One hypothesis is that the material composing both sets of yardangs eroded at the same time, in which case the two directions are attributable to topographic effects on wind flow. Another possibility is that the yardangs were eroded at different time periods characterized by distinct regional wind directions. Previous evidence for this has only been documented at a coarser scale from Viking images [4].

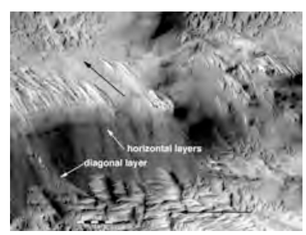

Figure 2: Portion of HiRISE image TRA_000865_1905 of the Medusae Fossae Formation. Black arrows show inferred wind direction based on yardang orientation. Image centered at 10.2°N, 211.5°E. Image scale is 25 cm/pixel.

Dune and Ripple Textures

The texture of dunes and ripples is seen at a detail previously only available from MER [7]. Many dune faces have superposed ripples at orthogonal angles and, upon these, are smaller ripples at orthogonal angles to the 2nd set (therefore, the 3rd order ripples are oriented more or less parallel to the dunes). Examples include dunes in Melas Chasma (Fig. 3) and Wirtz Crater (PSP_001415_1315). Polar dunes

(PSP_001341_2650) show textured surfaces indicative of interaction with ice [8].

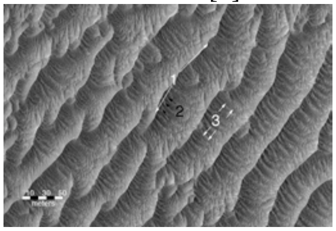

Figure 3: Portion of HiRISE image PSP_001443_1695 in Melas Chasma. Arrows show direction of dune or ripple brinks (so, orthogonal to presumed wind direction), with numbers indicating relative scale, with "1" the largest. Image centered at 10.5°S, 285.7°E.

Sand Migration Pathways

Although the duration over which HiRISE has been observing Mars is too short (so far) to see evidence of ripple and dune movement, sand migration pathways can be discerned in new detail through the orientation, form, and density of bedforms. Clear dune migration pathways are seen in Holden Crater delta (TRA_000861_1530). The barchan dunes have an orientation, with the horns indicating downwind direction, indicating movement uphill. These dunes are commonly within topographic notches, where wind funneling should increase friction speeds, thereby inducing saltation [9-10]. Such areas are expected to have enhanced aeolian abrasion, with high speed sand eroding the notch walls. This might be an area on Mars where there is a positive feedback mechanism between topography driving high speed sand flow that further erodes the landscape.

Small Ripples as a Relative Indicator of Age

Ripples at the decimeter to meter scale provide a method to compare the timing of wind modification relative to other geologic events, although the absolute ages are poorly constrained. Obviously, ripples superposed on a surface indicate that the surface has been subjected to wind processes, most likely saltation-induced creep (which forms ripples on Earth). For example, HiRISE images show details of the dune channels within Russell Crater (PSP_001440_1255). A light and dark banded texture marks the terrain between the channels and, upon looking at full resolution, is seen to extend into at least the upper parts of some channel walls. The bands are probably sand ripples. The channels, although appearing fairly unmodified, at HiRISE resolution contain ripples that post-date channel formation. In contrast, some landslides, such as one in the Kaiser Crater dune field (PSP_001862_1330) have no superposed ripples as seen at full HiRISE resolution, indicating recent slope failure.

Sand generally appears to reside within topographic lows, an observation which pre-dates HiRISE [11]. At the fine scale, dark sand fills polygonal cracks within Melas Chasma (PSP_001443_1695) and in what may be eroded remnants of some megabreccia blocks within Holden Crater (TRA_000861_1530, PSP_001468_1535, PSP_001666_1530). The age of sand filling is not known, but fresh (presumably young) craters, with a high concentration of angular blocks and deep floors, contain a higher concentration of ripples and dunes compared to surrounding craters (PSP_001630_1510, PSP_002006_1730, and especially PSP_001632_2085). This indicates that crater ejecta is a current source for sand and that filling rates are relatively rapid. The surrounding craters may have filled up enough that they do not get buried by migrating sand, which continues across the landscape. Alternatively, the rate of filling may be too slow, with the sand supply largely gone, for much filling to take place. Similar observations have been made from MER [12] and the HiRISE data confirms that analogous processes are occurring elsewhere on Mars. Recently, Malin et al. [13] identified an apparently new crater, just 4-6 years old. A HiRISE image (PSP_002039_1545; Fig. 4) shows ripples within the crater. Either high winds have very recently partially filled or redistributed fine material within the crater or the crater is older than 4-6 years and saltation of fairly fresh sand entrains dust above the crater, creating a darkened spot seen in MOC wide angle images.

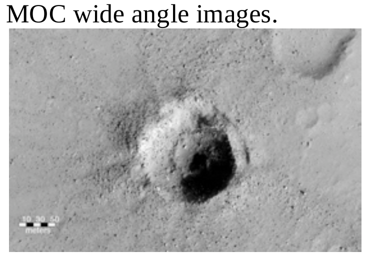

Figure 4: Portion of HiRISE image PSP_002039_1545 of crater identified by Malin et al. as only 4-6 years old. The crater interior contains ripples. Image is centered at 25.7°S, 223.9°E.

Concluding Remarks and Future Plans

HiRISE reveals the aeolian geology of Mars as complex, with evidence for current activity and a variable history. The amount of HiRISE data expected over the next 3 years (through the Primary Science and "Relay" phases of the MRO mission) will substantially exceed that over any previous Mars instrument. Thousands of images of aeolian features are expected and many are currently in the target database. HiRISE should be able to see ripple and dune movement if it occurs at rates at ~1 m, or maybe less, per Mars year.

References

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