CHARACTERISTICS AND POSSIBLE GENETIC LINK BETWEEN DUST AGGREGATE BEDFORMS AND YARDANGS AS SEEN BY THE HIRISE CAMERA

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Introduction: The High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter (MRO) has documented "reticulate" ridges in low thermal inertia areas that are interpreted as saltation bedforms [1,2]. Previous reports were overviews of a limited number of images. Now, at the conclusion of MRO's Primary Science Phase, we have completed an analysis of all images on and near the Tharsis Montes and integrated other data and saltation theory into the analysis. We propose that the bedforms are dust aggregates. These may eventually lithify into abradable yardangs and indurated surfaces, a "duststone" that appears to be a common Martian rock with no known terrestrial analog.

Background: Dust is abundant on Mars, with local and global dust storms observable from orbiters and even Earth-based telescopes. Among the dustiest areas are the classic bright terrains of Tharsis, Elysium, and Arabia, with predicted dust thicknesses in excess of 0.1 – 2 m [3]. HiRISE images of the Martian volcanoes show an intricate suite of ridges that have been interpreted as bedforms [1], with some features possibly erosional scars in a weakly indurated mantle [4]. The integrated, commonly polygonal, reticulate pattern at the meter scale has been noted on all the major volcanoes, regardless of elevation [1]. It has also been observed that some yardangs have a "polygonal" texture similar to the bedforms, leading to speculation that there could be a genetic relationship.

Methods: A total of 367 HiRISE images of the Tharsis Montes and nearby plains were examined and then color-coded based on ridge texture (honeycomb, accordion, linear, or mixed) presence of yardangs, lack of any reticulate ridges or yardangs, or unusable because of haze. We used a modification of Google Earth whereby various Martian base maps were overlaid on the terrestrial sphere, effectively producing a virtual Mars in the Google Earth client [5,6]. These included THEMIS VIS and daytime and nighttime IR mosaics, MOLA topography, thermal inertia, and albedo. KML files containing the corner coordinates of HiRISE and other released image products were used to locate the position of the footprints on the basemaps. This allowed us to compare images to more regional morphology and thermophysical properties. Thermal inertia models available in the literature were used to constrain the physical properties on the Tharsis Montes [7,8].

Results:

Reticulate Bedforms: Reticulate bedforms are distinct from other dunes and ripples on Mars based on their morphology and size. Three types are identified: 1) Honeycombs are composed of interlocking, azimuthally-symmetric sets of ridges. They mantle structural, volcanic, and crater topography (Fig. 1). The honeycomb sets occur in a diversity of settings. The bedforms within the volcano calderas are almost exclusively honeycomb. Honeycombs are also found within smaller craters on the volcano flanks. They are found in some plains near the volcanoes. 2) Linear bedforms exhibit dominant curvilinear sets a few meters apart and up to several kilometers long. They are located on the flanks and edges of the volcanoes, with some examples in the surrounding plains. On the volcanoes, they are oriented perpendicular to the local slope (i.e., circumferential to the caldera). 3) Accordion bedforms contain two linked ridge sets and have attributes of the linear and honeycomb morphology.

There is commonly an association with local topography, in which honeycombs within depressions transition to honeycomb and linear forms on the surrounding plains. In addition to Tharsis, reticulate bedforms have been identified in numerous other locations across the planet, including Elysium [1,4] draping deposits in Vallis Marineris [4] and in Daedalia Planum [9]. We have also recently found similar examples in the North Polar Layered Terrain, in some crater wind streaks, as bright superposed ridges on the surfaces of dunes in Lyot Crater, and east of Schiaparelli.

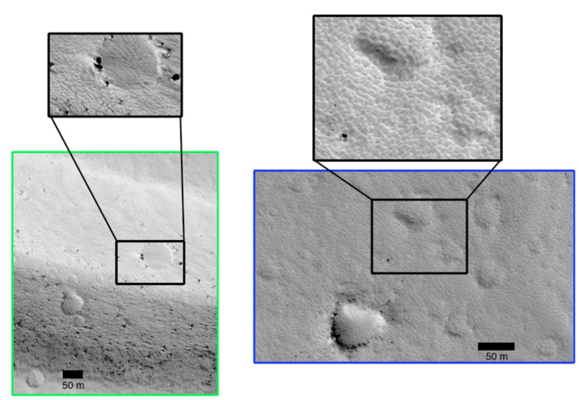

Figure 1: Honeycomb bedforms within the Olympus Mons caldera. Note that the bedforms superpose underlying topography. Black boxes within main frames show outline of 2x, stretched enlargements above (PSP_004966_1985).

Yardangs: Yardangs are common along the mid to lower flanks of the Tharsis Montes (Fig. 2). Some are also found on the nearby plains. On the flanks, yardang tapered edges and wind tails point radially away from the calderas. In some cases, it is difficult to determine if point-shaped features downslope of blunt edges represent wind tails or are the downwind portion of yardangs. Some yardangs on the volcanoes have a honeycomb-like texture of dark, elevated ridges similar to that seen in the honeycomb reticulate ridges described above [1]. Reticulate texture on indurated surfaces is not limited to Tharsis. For example, "White Rock" in Pollack Crater, has honeycomb-like ridges of similar scale and shape.

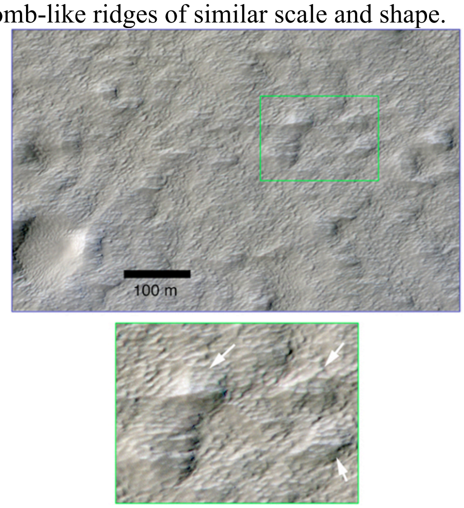

Figure 2: Details of yardangs on the western flank of Olympus Mons in HiRISE image PSP_008816_1985. Note the blunt to tapered edge of most yardangs (white arrows).

Discussion: The co-location of reticulate bedforms in regions of low thermal inertia, high albedo, high dust index, and dust deposition indicates that they cannot be made of traditional sand or granules like other dunes and ripples on Mars. Rather, they must be mostly or completely composed of dust or some dust-like material. Their location at the highest elevations of Tharsis indicates that saltation occurs even at very low atmospheric densities.

The particle size and density of the reticulate bedform grains can be constrained by a consideration of the saltation threshold curve and the saltation/suspension boundary. The former defines the friction speed as a function of particle size needed to initiate particle motion. Superposing threshold [10] and saltation/suspension boundary curves illustrates the theoretical behavior of particles as a function of friction speed and size.

Our working hypothesis is that many reticulate ridges are saltation bedforms consisting of dust aggregates. Initially, dust is suspended in the Martian atmosphere (Fig 3). It settles in quiescent periods (orange arrow), when the magnitude or duration of surface friction speeds are insufficient to re-suspend more dust than is being deposited from the atmosphere. When friction speeds increase again, the dust is re-suspended. At times when dust is on the surface, it aggregates with nearby settled particles, initially due to electrostatic forces and later possibly from chemical cementation (blue arrow). The aggregates may become suspended again in high wind events, with some broken back down into smaller particles. However, a certain fraction will continue to grow over time, eventually reaching a size, as seen at the MER landing sites [11-13], of a few hundred microns (green arrows). Subsequent winds above threshold will saltate, rather than suspend, these materials, forming bedforms.

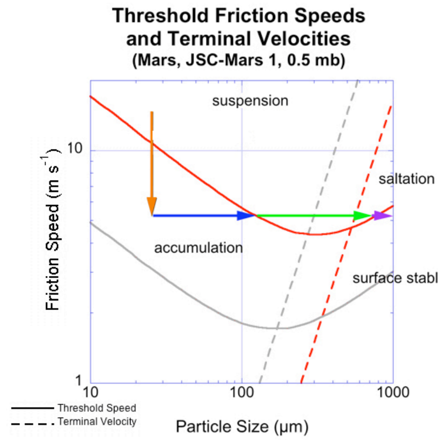

Figure 3: Schematic diagram of the proposed sequence of events for dust evolution discussed in the text. Red curves show JSC-Mars 1 at 0.5 mb and gray curve is basalt at 6.1 mb. Curves computed using the parameterization of [10]. The lines represent the saltation/suspension boundary. Labels define four zones of particle behavior defined by the intersection of the threshold curve and saltation/suspension boundary.

More conjecturally, we hypothesize that, over time, some aggregates continue to grow, such that they again fall below the threshold curve (purple arrow). This may initially occur via electrostatic charging, but, over time, cohesion could increase due to natural geochemical processes on Mars, such as cementation by sulfur- and chlorine-rich salts, as indicated by the high S and Cl contents of cohesive soils on the planet [14]. Aggregation will most likely occur for honeycomb materials, which are trapped within depressions not subject to dramatic slope winds that occur on the volcano flanks. These will eventually harden into low-density bedrock that preserves the original honeycomb texture. Subsequent wind abrasion may accentuate this texture while also liberating particles that can be re-suspended. Such "duststone" may therefore be a common rock on the Martian surface and serve as both a sink and possible source for dust.

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