

**SLOPE STREAK EMPLACEMENT IN THE DISRUPTED TERRAIN OF OLYMPUS MONS AUREOLES.**

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**Introduction:** Variable-resolution imaging and topographic datasets have revealed new detail on the Martian surface [1,2], raising questions about active geomorphic processes. Evidence for slope streak emplacement between repeat MOC and HiRSIE images indicate that processes responsible for their formation operate in the current environmental conditions. They are therefore some of the youngest geomorphic features on Mars and their signature is thought to fade over time [3]. However, like gullies [4], the emplacement of these streaks has never been observed, and their origin remains controversial. Proposed emplacement mechanisms include dry dust avalanches [5, 6, 7, 8], wet debris flow [9, 10], liquid water flow and liquid CO<sub>2</sub> flow [12].

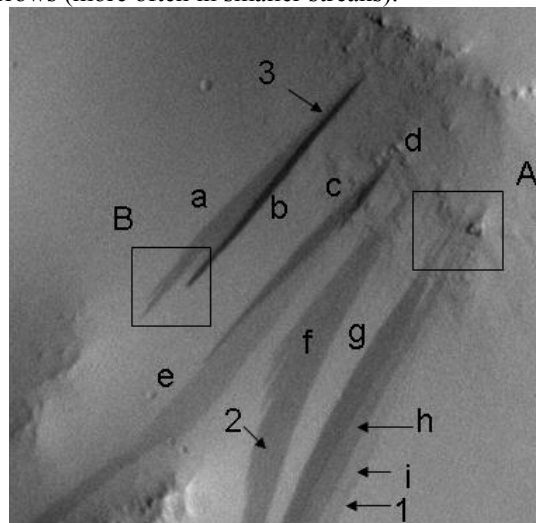
The aureoles that surround Olympus Mons contain one of the two major global concentrations of slope streaks. Image and topography datasets of the aureoles from the last decade of Mars missions have been combined into a common projection and co-ordinate system. These constitute the products for the creation of a new geomorphic map. Aureole units show topographic variability suggestive of either multiple deposits resulting from the same failure or that there were multiple failures each of which can be considered to be a separate event. Slope streaks occur on all aureole units suggesting either that they are all relatively recent or that their emplacement can be related to time since the individual aureole events were emplaced. The properties of slope streaks within aureoles have been quantified and used to determine if they differ from those reported on escarpments, impact craters and alos to test models for streak emplacement.

**Approach:** Data from MOLA, MOC, THEMIS, HRSC and HiRISE have been used to 1) determine the extent of slope streaks in aureole units, 2) characterize the dimensions of slope streaks, 3) determine topographic variability, and 4) describe the geomorphology of the area. From these an improved characterization of streaks in aureoles is being obtained. This in turn, enables comparison with those reported on escarpments, impact craters and other geographic locations.

Topography and image data were related in a geographic information system (GIS) environment. For MOLA topography a cylindrical equal area projection was assigned along with a user defined datum derived from the gridded 128 pixels/degree data. Derivative products created included shaded relief, slope gradient

maps, contours and profiles. THEMIS visible images were mosaiced and assigned the same datum and projection as the MOLA DEM. These datasets were used to map the geomorphology of the aureole units.

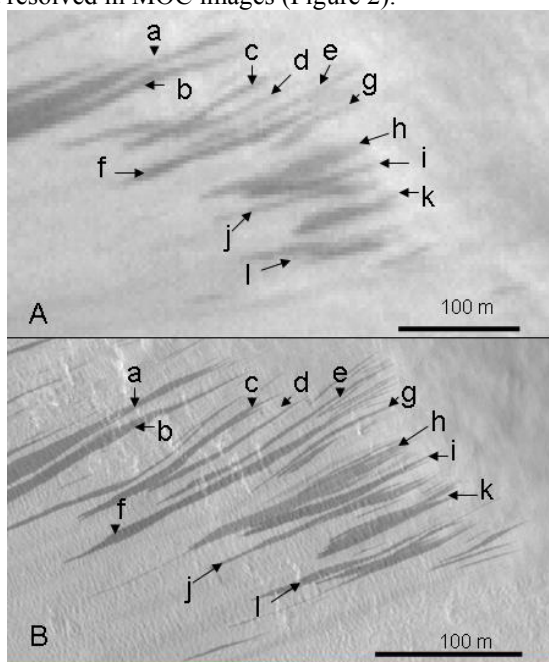
**Streak Characteristics:** The morphologies and morphometrics of over 300 streaks were examined in MOC (~1.4 m/pixel) and HiRISE (~30 cm/pixel) images plus MOLA topography. Slope streaks have dark to bright albedo features on Martian slopes (Figure 1). Each streak was assigned an albedo ranking of 1-3, with 3 being the darkest. It was found that if two streaks ranked 1 overlap they become briefly indistinguishable while in situations where streaks ranked either 2 or 3 overlap, 3 overlays 2. Morphologically, a streak was described as 'complex' if it has more than one flow source, or overlaps with another (e.g. a, b in Fig 1). Streaks that are not complex are described as 'simple' (e.g. f in Fig. 1). In their distal regions (Box B in Fig 1) streak were found to be: 1) wide, usually digitate (more often in larger streaks), and 2) narrow where beyond a point of maximum width the deposit narrows (more often in smaller streaks).



**Figure 1.** Examples of albedo variations 1-3, complex and simple streaks, source areas (box A) and digitate plus lobate distal margins (Box B). From MOC2-1621-b.

Lengths and widths measurements were conducted in ArcMap and also in NIH Image software. The length was measured along the center of a streak's width. For digitate streaks, length was measured to the that which

extended furthest downslope. Width measurements were made on streaks wider than  $\sim 5$  pixels. Streaks commonly start and end only 1 pixel wide. For smaller streaks (and for complex streaks where width measurements are difficult), one representative width measurement was obtained at the widest part. In MOC images, determining true versus pixel width is difficult. Areas of sufficiently large 'simple' streaks were measured. Where possible, the angle of spread from proximal to the distal zone was also measured. Analysis of HiRISE images reveals that the size class with the greatest percentage of streaks is  $<100$  m in length and  $<10$  m in width, compared with the 100-200 m in length and 10-20 m in width noted from MOC images [14]. Many small streaks visible in HiRISE images are not resolved in MOC images (Figure 2).



**Figure 2.** Two views of a slope in Acheron Fossae. A. MOC S13-01131. B. HiRISE PSP\_001656-2175.

Slope angles and heights were calculated from MOLA data using 1) raw PEDR files but with elevation profile paths limited to MOLA orbit tracks, 2) MEGDRs in which elevation profiles can be taken along any path but data are interpolated. Streaks tend to occur on slopes with gradients of  $10\text{-}24^\circ$  and ranging from  $\sim 100$  m to  $\sim 1100$  m in height. It is anticipated that HRSC DEM's will refine these measurements.

**Discussion:** Dimensional analysis of over 150 streaks at sites on escarpments, craters and aureole units reveals no evidence that those in aureole units can be distinguished from those found elsewhere (Figure 3). Streaks in aureole units can therefore be used to test models of emplacement [5-11]. The aureoles are con-

sidered to have originated from Olympus Mons as a result of flank failure [12]. Streaks are found oriented in all cardinal directions on aureole blocks. The disrupted nature of the aureoles with bedding planes at multiple angles is problematic to emplacement models that invoke aquifers, a perched water table or seepage along bedding [e.g. 7]. This suggests that the factors contributing to streak formation appear not to be unique. Can the ubiquitous presence of dust, sand, wind, and gravity along with time explain slope streaks?

Data for Martian streaks are similar to dimensional and morphologic characteristics of naturally occurring gravity and wind-driven dry granular flows on terrestrial sand dunes. The term flow is used to describe a mass of clasts moving downslope in a coherent manner with individual clasts sliding, rolling and saltating. On sand faces, wind has been observed to preferentially deposit sand in hollows on the slope resulting in periodic failing of piles. Resulting flows (lobes or sheets) can form channels near the proximal zone, maintain relatively uniform widths, have a darker albedo than the surroundings that fades with time, can block each other and overlay older flows, can be triggered mid-slope, follow local topography and can anastomize or digitate in the distal region. Multiple flows can form a single larger aprons. Rocks of pebble size and larger can trigger flows and can be 'rafted' on them. Flow speeds ( $\sim 10$  cm/sec) are likely less than for gravity-driven dry granular flows on Mars (possibly 1-10 m/sec). Critical to mobility is the size, sphericity and angularity of individual clasts. Analysis of the size distribution of sands observed to flow naturally shows they have the highest weight percent in the  $2\Phi$  (medium) and  $3\Phi$  (fine) class [13]. Those that flow are distinguished from those that do not by having a high proportion of clasts subrounded to well rounded and with high sphericity. This occurs as a result of physical and chemical weathering. This result indicates that if streaks on Mars are formed by gravity and wind-driven dry granular flows then individual clasts are likely to be rounded with high sphericity. The key factor for clasts on Mars may be the tens to hundreds of million years they are exposed to physical and chemical weathering. This can be tested in the future by in-situ sampling of Martian streaks to examine size, sphericity and angularity.

**References:** [1] Malin and Edgett, 2001. [2] Smith *et al.*, 1998. [3] Schorghofer *et al.*, 2007. [4] Malin *et al.*, 1998. [5] Sullivan *et al.*, 2001. [6] Treiman and Louge, 2004. [7] Baratoux *et al.*, 2006. [8] Chuang *et al.*, 2007. [9] Ferguson and Lucchitta, 1984. [10] Williams, 1991. [11] Ferris *et al.*, 2002. [12] McGovern *et al.*, 2004. [13] Bulmer *et al.*, 2007.