MODIFICATION OF MARTIAN SLOPE STREAKS. F.C. Chuang[1] and R.A. Beyer[2], [1]Planetary Science Institute, 1700 E. Fort Lowell Rd., Suite 106, Tucson, AZ 85719 (e-mail: chuang@psi.edu), [2]Carl Sagan Center at the SETI Institute/NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: Slope streaks, commonly dark features in the high albedo, low thermal inertia, dust-rich equatorial regions of Mars, have been observed in images from all orbiting spacecraft since Mariner 9 [1-9] and are thought to fade or brighten over time due to mantling of dust [2,3,8]. Recent studies using images from the High Resolution Imaging Science Experiment (HiRISE) camera [10] have shown that under conditions of low sun illumination, highest possible spatial scale, sufficiently thick dust deposits, and slopes facing away from the sun, slope streaks do have relief on the order of a meter or less [9]. This study focuses on features that were not identified or were uncommon in previous studies including ridge-like structures, terminal deposits, and mantle deposits [11].

Data and Methods: Approximately 2,346 HiRISE images from orbits 1300 to 4700 were studied, including a repeat of images up to orbit 3600 by [9]. Some individual HiRISE images beyond orbit 4700 were also studied, but they were not systematically evaluated like those up to orbit 4700. The images have spatial scales of 25-100 cm/pixel with a total of 135 unique sites (~6%) having slope streaks. Photoclinometry, or shape-from-shading, was used to estimate the heights and/or depths of surface features in HiRISE images. In this study, profiling photoclinometry was applied in which slope information from individual pixels are modeled along a down-sun line, producing a profile of heights [12,13].

Slope Streak Features: Three features are observed that were previously unapparent or unresolved in MOC and HiRISE images: ridge-like structures, terminal deposits, and mantle deposits. Approximately 32% (44/135) of images with slope streaks have ridge-like structures and 8% (11/135) have terminal deposits. The percentage of slope streak images with mantle deposits is more difficult to ascertain and only a few images have unambiguous examples.

Ridge-like structures. These features are typically a series of ridges along the bed of a streak. The number of ridges varies depending on the width and length of the streak, but are typically in the tens to hundreds for any given streak. The ridge axes are often, but not always transverse to the downslope direction of the streak and cover most of the bed. In some cases, the entire length of the bed is covered by ridges. Ridge morphology varies from linear to slightly arcuate, sometimes sinuous segments. The ridges are generally solitary, but their ends may sometimes merge with an adjacent ridge or the margin of the streak. The crest-to-crest spacings, or wavelengths, of 163 ridge crests in 9 streaks were measured from 2 HiRISE images at 25 cm/pixel. Ridge wavelengths are consistently regular within a range of 1.1-4.5 m with a mean and standard deviation of 2.5±0.6 m. Ridge heights, or amplitudes, from 14 photoclinometry profiles of 96 ridges in 5 streaks are approximately 0.1-0.5 m with a standard deviation of ±0.2 m.

The wavelengths and amplitudes of ridge-like structures fall within the range of values for coarse-grained ripples on Earth (up to 20 m wavelength and tens of cm amplitude) [14] and are comparable to ripples measured at two sites on Mars, Gusev Crater by the Spirit rover (2-3 m wavelength, 0.3 m amplitude) [15,16] and Utopia Planitia by Viking Lander 2 (0.5-1.5 m wavelength, 0.05-0.15 m amplitude) [14]. The regular spacing and transverse orientation of the ridge-like structures relative to the streak suggests that they are ripples formed by eolian activity with grains having been and/or are continuing to be saltated by winds.

Terminal deposits. These features appear as a large accumulation of material at the termini of slope streaks with an irregular surface in no preferred orientation. They are common along the slopes of volcanoes or other positive-relief structures in volcanic regions where a thick layer of dusty materials was excavated in order to form the slope streak and the resulting deposit. The terminal deposits support previous interpretations that slope streaks are formed by dry avalanches of dusty surface materials [2,5-7,9]. Their sizeable volumes from shadows along the deposit margins suggests that at least a portion of the avalanche was sufficiently cohesive and dense to avoid complete loss to the atmosphere as suspended particulates.

Mantle deposits. In addition to bedforms and terminal deposits, there is also evidence that the streak bed is mantled. Figure 1 shows a streak where ripples in the upper half of the bed are partially obscured, with only the uppermost sections up to the crest remaining visible. Ripples in the lower half of the bed are no longer visible and the relief has decreased compared to the upper half. Mantle material appears to fill in the low areas between ripples until they are completely buried, at which point there is no relief and the bed appears flat. These observations indicate that slope streak beds gradually shallow over time by addition of new material. The streak bed is neither darker nor brighter than the adjacent surface, suggesting that both the area within and outside the streak are mantled by the same material, likely airfall dust.

Discussion: Our study leads us to hypothesize a slope streak formation and modification cycle that occurs in the following sequence: (1) formation of the slope streak by a dust avalanche that leaves a bed topographically lower than the adjacent un-disturbed surface; (2) grains exposed on the bed after the initial avalanche, and possibly dust aggregates, are mobilized by winds swept across the bed; (3) saltation of the finer grains by eolian activity initiates the formation of ripples within the streak bed; (4) during or between periods of ripple growth and migration, dust-sized fallout from atmospheric suspension mantles the streak bed and surroundings; (5) continued dust deposition raises the floor in the streak bed and decreases the apparent ripple amplitude; (6) dust infill reaches near the ripple crests and continued deposition eventually buries the ripples, but streak relief may still be present; (7) smaller ripples like those that form on the non-streaked surface via multidirectional winds may begin to form on the slope streak bed, possibly forming reticulate bedforms [17]; (8) continued dust deposition mutes the local topography and the level of the slope streak bed reaches the level of the adjacent surface such that relief is no longer evident. This cycle is hypothesized for slope streaks where topographic relief can be observed.

Our modification cycle predicts that newly formed streaks should not have ripple trains in their beds. Both MOC and HiRISE have observed newly formed slope streaks (i.e., observed a surface without a streak and then observed it again later with new streaks visible) over timescales on the order of years and they appear to have smooth surfaces that are darker than their surroundings [11, fig. 8]. Our hypothesized cycle also predicts that if there is a combination of older and more recently-formed streaks on a slope, the older streaks should be more infilled and shallower than younger streaks. To test this prediction, we draw upon previous work by [8] in the Olympus Mons aureole deposits where some dark streaks observed by Viking Orbiter are no longer dark in MOC, along with others that still have an albedo contrast.

HiRISE targeted this same location (7564_2080) in the aureole deposits and we have identified the same streaks that are no longer dark in MOC by the presence of ripples along the slope [11, fig. 9]. Some streaks that were dark in MOC are also dark in HiRISE. The HiRISE image also shows other nearby streaks that are not dark, but have ripples that were not seen in Viking or MOC due to their coarser spatial scale. These ripples are much less numerous than those in streaks that are no longer dark. Thus, we interpret the streaks observed only in HiRISE to be the oldest, the streaks observed by [8] which faded between Viking and MOC observations to be of intermediate age, and those that retain an albedo contrast across Viking, MOC, and HiRISE to be the youngest. Based on these assumptions, the streaks that are no longer seen in MOC should have greater ripple amplitudes than the oldest streaks (i.e., they are younger and have had less time to be infilled). This prediction is confirmed from our observations in HiRISE covering the same aureole deposits [11, fig. 10].

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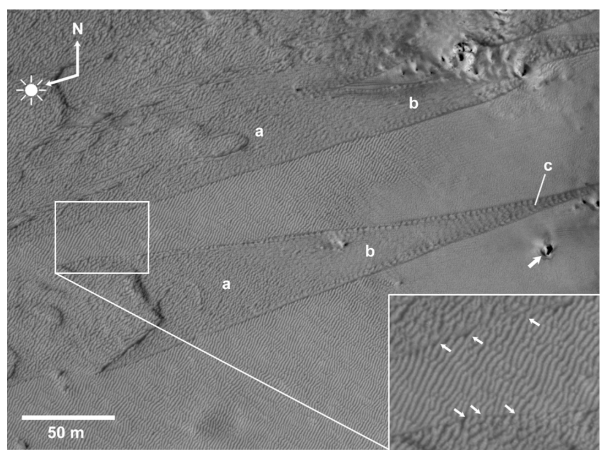

Figure 1. Mantle deposits covering portions of two slope streaks along the caldera wall of Jovis Tholus. (a) Mid-lower portion: deposits have completely filled the streak bed and the ripples on the un-streaked surface have reformed on this surface (see magnified view). (b) Mid-upper portion: mantle deposits have filled low areas between ridge-like structures, interpreted to be eolian ripples. (c) Uppermost portion: ripples have yet to be mantled. A moat along the face of a large boulder (large arrow) indicates a SW-NE wind direction oriented sub-parallel to the streaks, possibly saltating materials up the streak bed. Portion of HiRISE image PSP_002737_1985 (center: 18.4 N, 242.6 E).