NEW OBSERVATIONAL CONSTRAINTS ON THE NATURE OF SLOPE STREAKS ON MARS.
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Introduction: Slope streaks are ubiquitous albedo features in the tropical latitudes of Mars, typically occurring as elongated dark streaks below point sources and with narrow, fan-shaped morphologies [1,2]. Slope streaks represent one of the most active surface processes observed on Mars, with new streaks forming at a rate of up to 7% per Martian year per existing streak [3,4], yet their formation mechanism and their significance in the context of the present day near-surface environment of Mars remain uncertain. The common interpretation for slope streaks is dry mass wasting in the form of 'dust avalanches', e.g., [1,5], although competing hypotheses involving aqueous processes have also been postulated based on the fluvial appearance of some streaks [6], their geomorphic relation with the slopes they occur on [7] and their morphological resemblance with Earth analogs in the form of liquid seepages in Antarctica [8]. In this study we use *HiRISE* [9] images, *HRSC* [10] multispectral data and *CRISM* [11] hyperspectral measurements to test these hypotheses, and to propose a new diagenetic model for slope streak formation on Mars as the precipitated solid residue left behind by short-term seepages of a brine.

Results: *HiRISE* images of dark slope streaks in multiple locations (Fig. 1) reveal adjacent erosional scarps that expose a light-toned substrate beneath an apparently smooth thin dust mantle. These observations are not consistent with an erosional model such as dust avalanching, which would require exposure of a dark-toned rather than light-toned substrate. Furthermore, the *HiRISE* images also reveal that slope streaks crossing terrain boundaries typically maintain constant albedo and textural characteristics (Fig. 1c), which is more consistent with their formation through depositional rather than erosional processes.

HRSC multispectral images show that the dark slope streaks lie outside the spectral mixing volume defined by adjacent unaffected dusty slopes, bedrock outcrops and shadow (Fig. 2), thus indicating that slope streaks represent a compositionally distinct scene element that cannot be explained as a linear mixture of the other scene elements described above. Sub-pixel roughness measurements obtained from *HRSC* stereo data (Fig. 3a) also reveal that dark streaks are rougher at <30-cm scales than their surrounding unaffected slopes. Nonetheless, *HiRISE* images of slope streaks in the shadow of large cliffs (Fig. 3b) reveal a similar albedo contrast between streaks and slope inside and outside the shadowed areas, indicating that the roughness differences between streaks and their surrounding are only a 2nd-order effect and that compositional differences are the primary reason for the observed albedo contrast. The *HRSC* roughness map (Fig. 3a) also suggests that streaks become smoother over time as the albedo contrast with their surrounding is reduced.

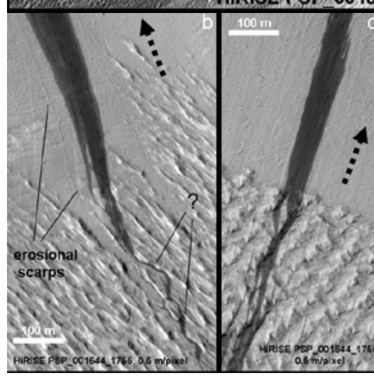

Fig. 1: HiRISE images of dark slope streaks. a) Erosional scarps (<0.5 m high) expose a light-toned substrate beneath a darker mantle of dust and a dark-toned slope streak (~47°E, 7.4°N). b) Light-toned substrate beneath a dark slope streak. Lower right – low-albedo material occurring exclusively within a channel possibly indicating liquid flow (~200.7°E, -8.6°N). c) Dark streak maintains a ~constant albedo and texture as it crosses a clear terrain boundary (~200.7°E, -8.6°N). Dashed arrow indicates down slope direction.

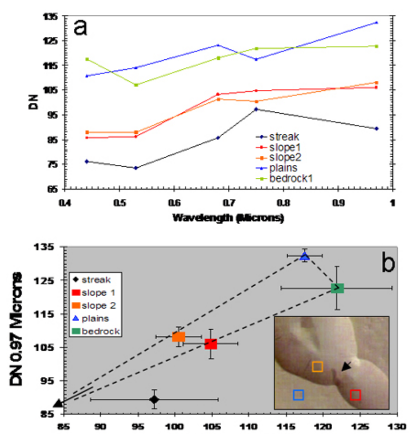

Fig. 2: HRSC spectra for slope streaks and nearby surfaces (218.2°E, 7.1°N). a) Each spectrum is averaged from >20 pixels. Small black arrow in *b* points to sampled streak. Shadow and bedrock sample locations not shown. b) Spectral mixing trends (dotted lines) for bedrock, plains dust and shadow, which lies in the direction of the large black arrow. Slope streaks lie outside these possible mixtures. Error bars are 1 σ.

CRISM hyperspectral measurements (0.4-2.5 μm) of resolved slope streaks (Fig. 4) do not display the indicative spectral features that would be expected if significant amounts of H_2O (liquid or ice) were present in the slope streaks at the time of measurement, and thus suggest that neither water or ice are the cause for the observed albedo contrast between slope streaks and their surroundings.

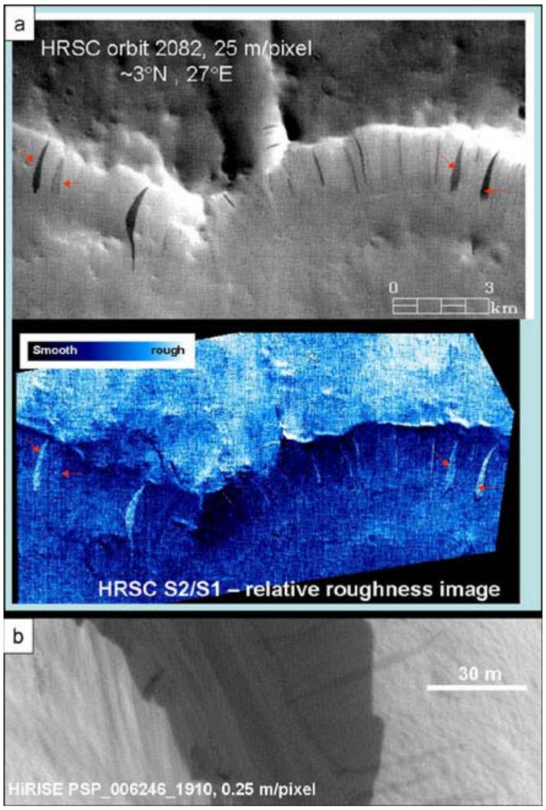

Fig. 3: Roughness of slope streaks. a) HRSC-derived relative roughness map for slope streaks in Arabia Terra produced according to [12]. Streaks are rougher than surrounding slopes and become smoother over time. b) Example of a slope streaks maintaining albedo contrast with their surroundings in a shadow of a cliff (~202.7°E, 11°N).

Discussion: The occurrence of slope streaks primarily in dust-mantled regions [2] offers a strong argument in favor of the dust-avalanche model, e.g., [1,5]. However, geomorphic evidence from *HiRISE* images (Fig. 1) and *HRSC* spectral measurements (Fig. 2) are not consistent with the 'dust avalanche' model for the formation dark slope streaks on Mars. Our observations also suggest that streak formation introduces a new compositional end member onto the local surface (Fig. 2), which is more consistent with a depositional process as also supported by the geomorphic observations (Fig. 1). The typical point-source and fan-like morphology of slope streaks as well as their morphological resemblance to liquid seepages found on slopes in Antarctica [8] suggest the involvement of a liquid phase, yet the *CRISM* spectral data (Fig. 4) rule out long-term presence of significant amounts of water or ice in slope streaks.

Based on the existing observations, we propose a new diagenetic model in which dark slope streaks on Mars result from a residue precipitated from a short-term interstitial seepage of a volatile liquid such as a brine carrying dissolved minerals through the pores of a thin dust mantle. The low thermal inertia of the thin dust layer offers favorably warm summer daytime conditions that prevent the brine from freezing and allow its seepage. As these warm conditions cease, down slope propagation of the brine slows as it freezes and sublimes, leaving behind a residue that roughens and darkens the streaks relative to their surroundings. Subsequent smoothening of dark streaks with time (Fig. 3) can be attributed to continuous deposition of dust, which also accounts for their fading with time, e.g., [3].

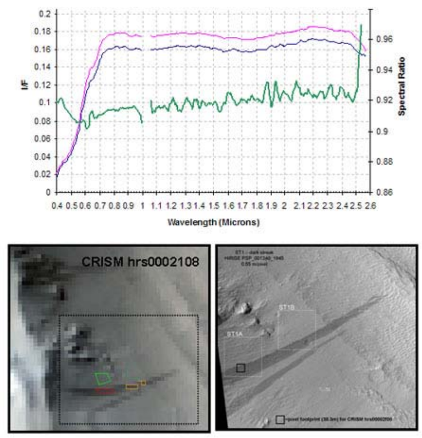

Fig. 4: *CRISM* spectra for slope streaks. Pink – spectra of dusty slope, blue – streak spectra, green – ratio streak / slope. Spectral ratio between streak and unaffected nearby slopes does not reveal H_2O (liquid or ice) absorption features. Lower left - *CRISM* 36 m/pixel image. Boxed area marks *HiRISE* 0.55 m/pixel image in lower right.

The conceptual diagenetic model we present for dark slope streaks is consistent with existing observational data, but differs from previously suggested seepage models in that it requires significantly smaller amounts of liquids and does not require the long-term stability of either liquid or ice on low-latitude surfaces of Mars under present-day conditions. Important elements of this diagenetic model, e.g., the source of the liquids, their composition and the nature of the residue, are the subject of an ongoing experimental study and additional analyses of *CRISM* spectral data.

References: [1] Sullivan et al. (2001) *JGR 106*, 23,607-23,633. [2] Schorghofer et al. (2002) *GRL 29*. [3] Aharonson et al. (2003) JGR 108. [4] Schorghofer et al. (2007) *Icarus 191*, 132-140. [5] Baratoux et al. (2006), *Icarus 183*, 30-45. [6] Ferris et al. (2002), *GRL 29*, [7] Miyamoto et al. (2004), *JGR 109*. [8] Head et al. (2007), *7th Mars*, 3114. [9] High Resolution Imaging Experiment, McEwen et al. (2007), *JGR 112*. [10] High Resolution Stereo Camera, Neukum et al. (2004), *Nature 432*. [11] Compact Reconnaissance Imaging Spectrometer for Mars, Murchie et al. (2007), *JGR 112*. [12] Mushkin and Gillespie (2006), *GRL 33*.