SPECTRAL CHARACTERISTICS OF DARK SLOPE STREAKS ON MARS: A GLOBAL SURVEY WITH CRISM.

E. S. Amador[1], A. Mushkin[1,2], and A. Gillespie[1]. [1]University of Washington, Department of Earth and Space Sciences, [2]Geological Survey of Israel.

Introduction: The formation and fading of low-albedo slope streaks have been observed across the mid-tropical latitudes of Mars since the Viking orbiters [1]. Two explanations have been established for slope streak formation: dust avalanches [2], and surface "staining" associated with transient brine seeps [3]. The latter formation model was adopted by [4] for a class of slope streak termed recurring slope lineae (RSL) [5]. Spectral data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM; [6]) for RSL suggest in some cases spectrally featureless darkening [7] similar to that found for slope streaks in the Olympus Mons Aureole [3], and most recently, in four instances, CRISM revealed transient spectral signatures consistent with hydrated salts in association with surfaces with active RSL, thus supporting the "wet" formation mechanism [8]. Here, we examine the variability and evolution through time of CRISM spectra of fully resolved slope streaks across Mars and how they may relate to the reported variability of RSL spectra.

We 1) conducted a comprehensive survey of the near-infrared (~1-3.5µm) spectral characteristics of slope streaks across the planet, and 2) examined the spectral changes associated with slope streaks fading over time. Care was taken to specifically look for spectral evidence of hydration (i.e., absorptions at ~ 1.4, 1.9 and 2.9 µm).

Data and Methods: This study relied upon full resolution targeted (FRT; ~ 18 m/pixel) and half-resolution long (HRL; ~40 m/pixel) hyperspectral images from CRISM. The images were atmospherically corrected using standard volcano-scan techniques described in [9] and through additional techniques adapted from the current CRISM Analysis Tool (CAT) v.7.2.1. Spectral indices were produced similar to [10], specifically to look at the BD1900 index for evidence of hydration. CRISM images were spatially coregistered with Context Camera (CTX; ~6m/pixel) and/or High Resolution Imaging Science Experiment (HiRISE; >30 cm/pixel) images in JMARS.

Alltogether, 51 CRISM images were analyzed in the Arabia, Amazonis, Olympus Mons, and northern Terra Sirenum regions (Fig. 1).

Spectral characteristics were determined by spectral ratios, with the dark slope streak as the numerator and an adjacent non-streaked sunlit slope, typically within the same image column, as the denominator.

Results: *Global Survey.* Slope streaks in Arabia tend to be the largest, up to several hundred m across and several km long, but spatially sparse. Slope streaks in Olympus Mons and Terra Sirenum are typically smaller (up to tens of m across) but more frequent [11, 12]. Slope streaks in Amazonis tend to be somewhere in between and more dynamic, recurring and fading within timescales of several years [13].

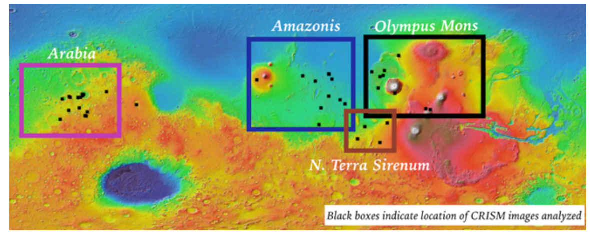

Figure 1. MOLA colorized elevation map, black squares indicate sites where CRISM data were analyzed and colored regional boxes correspond to spectra in Fig. 2.

Regardless of the variability in their size-frequency distribution and activity time-scales, slope streaks in all CRISM images analyzed display flat spectral ratios from ~1.1-2.6 µm (Fig. 2), consistent with previous CRISM analyses of slope streaks in Olympus Mons [3] and RSL at several locations [7]. Observations at longer wavelengths (> 2.7 µm) were more variable and showed low signal:noise, decreasing our confidence in apparent absorptions.

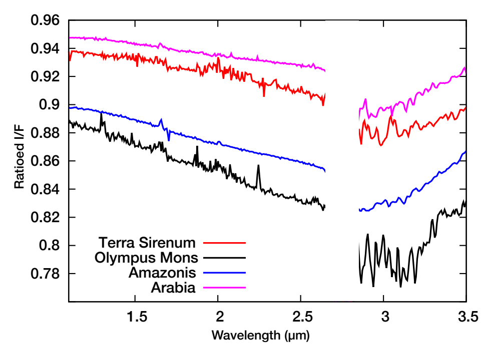

Figure 2. Spectra from the four main geographic regions sampled for this study. Spectra from CRISM images HRL00005D68_07, FRT00010816_07, FRT00005198_07, and HRL00005337_07.

Time series. We found ~25 slope streak sites with multiple CRISM coverage, however it was rare to find a time series that included long-wavelength detector data (~1.-3.5µm). We looked at three such cases in detail. Here we present a time series in Naktong Valles, Arabia, centered around ~36.8 E, 0N (Fig. 3). We focus on three fully resolved slope streaks on the same slope, each on the order of 100 m in width and ~1 km in length

(~ 5x50 CRISM pixels). The streaks characteristic for this scene and remain stable, with no evidence of dynamic change during the 2007-2010 time period.

Fig. 4 demonstrates that while the spectral ratios remain consistently flat/featureless, their offset and slope vary considerably over time. Because these three streaks appear visibly stable during this period, we attribute the variability in spectral offset to atmosphere. Interestingly, the variability in offset, due to atmosphere, for three adjacent streaks in this single location in Arabia, is comparable to the variability found in slope streak spectra across the planet (Fig. 2). Thus, while the offset of the ratio spectra appears to be governed by residual atmospheric effects, the lack of absorption feautres is robust spectral characteristic.

Discussion/Conclusions: The remarkably constant flat/featureless near-IR spectra observed for fully resolved slope streaks across Mars indicate that these rdarkened surfaces are “dry”, having no excess water/hydration in them with respect to their unaffected adjacent slopes. Similarly flat/featureless near-IR spectral ratios were also reported for RSL [7], which in some cases appear to show transient spectral absorptions consistent with hydration, strongly arguing in favor of the brine-seepage formation model [8]. The transient nature of these hydration features and the flat/featureless spectral ratios otherwise observed for RSL [7] suggest that within the seasonal timescale of their persistence, RSL may transition to a “dry” phase, in which they remain dark and are spectrally comparable to slope streaks.

Recognizing the “dry” phase in the post-formation evolution of RSL may have a significant impact on the calculated volumes of liquids involved with RSL. In addition, while some argue that spectral detection of transient surface hydration in RSL implies a genetic distinction from slope streaks, we argue that: 1) The spectral similarity between slope streaks and RSL during their “dry” phase suggests the opposite, and 2) The chances to capture the implied “wet” phase of slope streak formation are significantly lower given their longer annual-decadal timescales for recurrence on a given slope. Amazonis Planitia would likely be a favorable target for CRISM targeting to capture the transient “wet” phase of brine extrusion during slope streak formation, given the relatively short annual timescales of streak activity in that region.

References: [1] Ferguson, H. (1984) *The Planetary Geology Program, NASA Tech. Memo,* 188–190. [2] Sullivan, R. B. (2001) *JGR* 106. [3] Mushkin A. (2010) GRL, 37, L22201. [4] McEwen A., (2014) *Nat. Geo. Sci.*, 7, 53–58. [5] McEwen A. (2011) Science, 333, 740. [6] Murchie S. (2007) *JGR*, 112. [7] Ohja, L. (2013) Geophys. Res. Lett. 40, 5621-5626. [8] Ohja, L. (2015) Nat. Geo. *Sci.,* 8, NGEO2546. [9] McGuire (2009), *PSS*, 57, 809-815. [10] Viviano-Beck, C. (2014) *JGR*, 119, 1403-1431. [11] Bergonio, J. (2013) *Icarus*, 225, 194-199. [12] Mushkin, A. (2014) 8th International Mars Conference. [13] Mushkin, A. (2014) *GSA*, 46, No. 6, p.792.

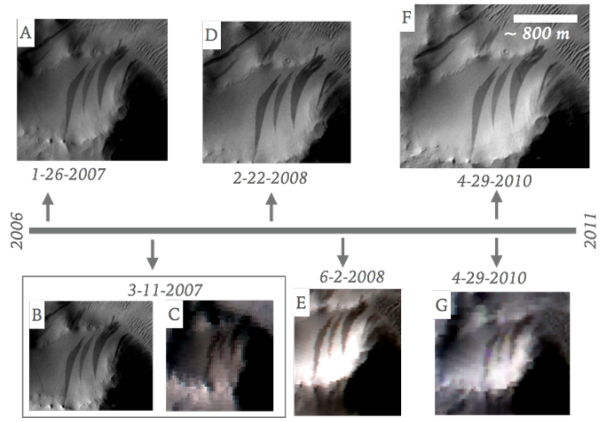

Figure 3. Data timeline for time series in Naktong Valles, Arabia. (A) CTX P03_002349_1804_XI_XN_00N_323W, (B) CTX P05_002916_1802_XI_00N_323W, (C) CRISM HRL00004A85_07, (D) CTX P16_007386_1801_XN_00N323W, (E) CRISM FRT0000AD74_07, (F) CTX B20_017605_1801_XN_00N and (G) CRISM HRL00018612_07.

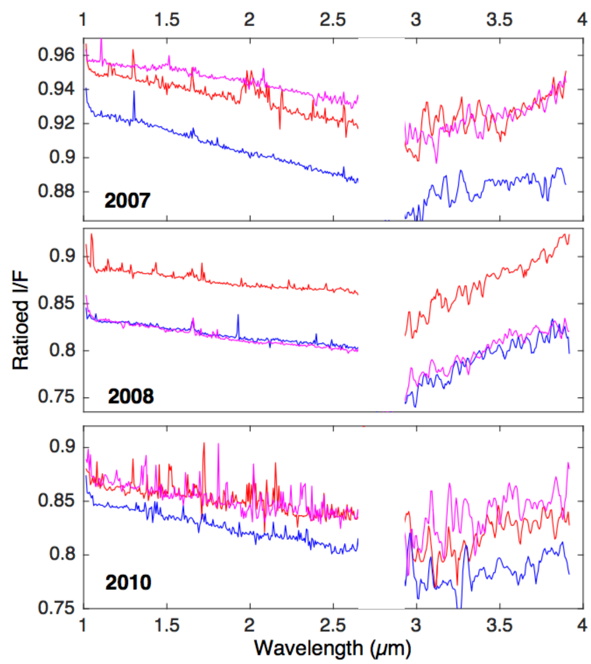

Figure 4. CRISM spectra associated with time series in Naktong Valles. Spectra were collected from three slope streaks as seen in Fig 3. From west to east, the streaks are represented by red, blue, and magenta spectra over the course of three years. Data from 2007, 2008, and 2010 come from image ID HRL00004A85_07, FRT0000AD74_07, and HRL00018612_07, respectively. For spectra from 2010, any apparent deviation from the typical flat (featureless) spectrum is very likely related primarily to noise/atmosphere/illumination and not to something real in the streak.