A BRINE EXTRUSION MODEL FOR RECURRING SLOPE LINEAE. A. Mushkin[1,2], A. R. Gillespie[1], D. R. Montgomery[1], C. A. Hibbitts[3] and B. C. Schreiber[1], [1]University of Washington, Seattle, WA 98195, [2]Geological Survey of Israel, Jerusalem, Israel 95501, [3]John Hopkins University Applied Physics laboratory, Laurel, MD 20723

Introduction: Low-albedo streaks that appear during warm seasons and fade during cold seasons in the mid- and tropical latitudes of Mars have been identified by McEwen et al. [1,2] and named 'Recurring Slope Lineae' (RSL). McEwen et al. [1,2] pointed towards brine seepage as the formation mechanism most consistent with the dynamic nature of RSL, a genetic model previously suggested by Mushkin et al. [3] for recently formed low-albedo slope streaks (LASS) in the Olympus Mons Aureole (OMA). Here, we re-examine McEwen et al.'s [1] taxonomic distinction between slope streaks and RSL in order to understand the relation between these dynamic surface features and their possible genetic association better.

Slope streaks and RSL: Slope streaks are elongated low-albedo surface features that form downslope within sub-annual time scales in the high-albedo ("dusty") regions of equatorial Mars [4] and gradually fade and disappear over longer time periods of several decades [5,6]. Two explanations have been established for the formation of low-albedo slope streaks: dust avalanches [4] and surface 'staining' associated with transient brine seeps [3]. The latter formation model was adopted by [1] for RSL displaying striking similarities in appearance and scale to recently formed slope streaks at OMA (Fig. 1). Slope streaks and RSL both originate on rocky slopes and continue down-slope onto local accumulations of fine-grained material while displaying typical localized-source flow-like patterns that follow local topography, have common mid-slope digitate terminations and lack streak–background topographic relief.

Possible formation mechanisms for OMA slope streaks and RSL were tested by [3] and [1], respectively, using similar approaches and orbital data, which led to similar conclusions. Both studies eliminated exposure of a darker substrate and a mass-wasting 'avalanche' origin because of the lack of streak–background topographic relief and inconsistencies with HiRISE color analysis. Both utilized CRISM hyperspectral data to detect spectral absorption features within slope streaks/RSL and arrived at the conclusion that these features are dry at the time of observation, as their spectra lack the distinctive water and/or ice absorption bands. At OMA, [3] used CRISM spectra of resolved streaks to characterize a spectrally unique class of slope streaks for which an effective enrichment in FeO_x absorption was constrained to be the primary surface darkening agent. A brine-extrusion model for this class of slope streaks was proposed as the explanation most consistent with the orbital observations [3].

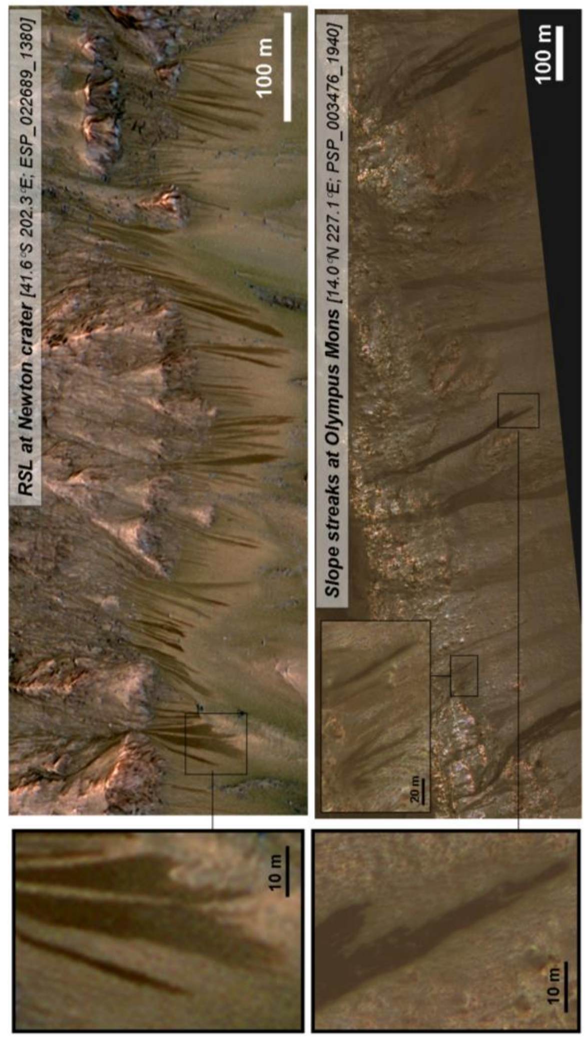

Figure 1. HiRISE color images (0.25 m/pixel) demonstrating the geomorphic resemblance between RSL and slope streaks. Insets highlight the overlap in streak size and morphology at the two sites. Left image from [1 – SOM], right image from [3]. Colors in both images were similarly stretched.

Nonetheless, McEwen et al. [1] proposed that differences in the settings and properties of slope streaks vs. RSL imply a genetic distinction between these features. Here, we examine possible ambiguities in these distinction criteria. Lower *slope albedo* and *dust index*, higher *thermal inertia* and *variable regional mineralo-*

gy for regions where RSL occur relative to those where slope streaks were raised by [1]. However, as these attributes are all derived from coarse-resolution (>100 m/pixel) orbital data the purpoted values separating RSL and slope streak regions are readily explained by sub-pixel mixing with bedrock outcrops that typically surround the fine-grained material on which RSL occur (Fig. 1a). A higher maximum *albedo contrast* between streaks and their respective surrounding slopes was also invoked as a criterion seprating RSL and slope streaks. However, both slope streak and RSL populations typically display a range of albedo contrasts, with the freshest slope streaks/RSL in a given image being the darkest (Fig. 1). Thus, the higher maximum albedo contrast for RSL may simply reflect differences in stages of post-formation fading. *Association* of RSL with *channels* and *rocks* was also proposed to distinguish them from slope streaks. As not all RSL occur within channels (Fig. 1a) and slope streaks also form in rocky terrain (Fig. 1b) these criteria appear to provide ambiguous genetic distinctions. [1] argue that RSL occurrence is limited to the mid-latitudes whereas slope streaks occur primarily in the tropical latitudes – but recently, McEwen etal. [2] idenitifed RSL in the tropical latitidudes as well.

The maximum *size* of RSL vs. slope streaks (width: < 5 m vs. <200 m) and their *abundance on slopes* were also presented by [1] as distinctive criteria. However, feature size and abundance may simply reflect differences in seepage characteristics such as volume, rate and duration, which [3] and [1] agree remain unknown.

Seasonal versus annual-decadal *fading time scales* for RSL versus slope streaks, remains as a robust distinction criterion. Gradual aeolian deposition of dust proposed for slope-streak fading [5] does not appear to be a likely mechanism for the fading of RSL within a single season and thus a different fading mechanism is likely involved. Figure 2 suggests that at least in some cases slope-streak fading too cannot be attributed to aeolian dust deposition. Furthermore, slope streak populations are known to have survived global dust storms largely unaffected. Thus, other fading mechanisms such as meta-stability of the streak-darkening agent are likely involved and may explain the differences in the fading time-scales between slope streaks and RSL.

Thus, we find that ambiguities in the interpretation and meaning of the criteria proposed by [1] for genetically distinguishing between slope streaks and RSL do not support their idea of different origins. Instead, we find that the above commonalities between RSL and the OMA slope streaks argue for a common brine-seep genesis [3].

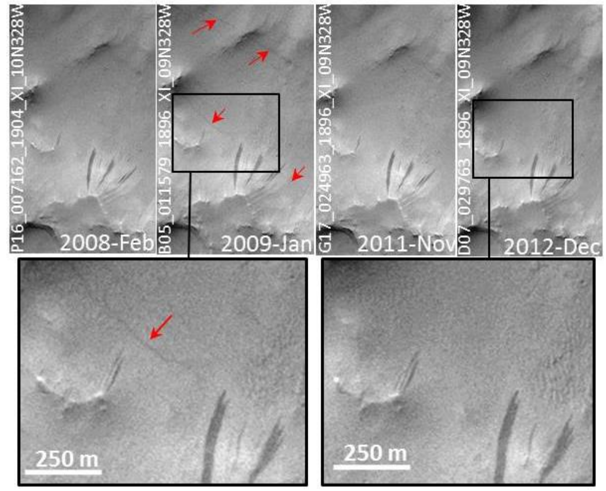

Figure 2. CTX images from Arabia demonstrate fading of wind streaks (red arrows) formed between 2008-2009 within several years while nearby slope streaks remain unaffected.

Conclusions: The study of surface and near-surface brines on Mars benefits from complementary cross-discipline research efforts that include theoretical modeling of liquid-phase flow and stability [7-8], laboratory experiments [9], Earth analogs [10], photo-interpretation of high-resolution images [11,2], environmental characterization [12] and orbital color and spectral observations [3,1] as these are progressively released. We find that commonalities in the geomorphic, spectral, environmental and dynamic characteristics of slope streaks and RSL exceed the differences between them. We propose that these differences, which are primarily manifested as a smaller maximum size and a shorter fading time scale for RSL, place slope streaks and RSL on a continuum of active surface features best-explained as byproducts from transient extrusions of brine onto the Martian surface under present-day conditions. We therefore propose that the brine extrusion model previously established for slope streaks at OMA [3] is also applicable to RSL.

References: [1] McEwen, A. S. et al. (2011), *Science 333*. [2] McEwen, A. S. et al., (2014) *Nat.Geo.Sci*. 7, doi: 10.1038. [3] Mushkin, A. et al. (2010) *GRL 37* L22201. [4] Sullivan, R. B. et al. (2001) *JGR 106*. [5] Aharonson, O. et al., (2003) *JGR 108(E12)*. [6] Bergonio, J. R. et al., (2013) *Icarus*, *225*, 194-199. [7] Miyamoto, H. et al. (2004) *JGR* E06008. [8] Fairen A. G. et al. (2009) *Nature*, *459*, 401-404. [9] Chevrier, V. F. and Rivera-Valentin, G. (2012) *GRL 39* L21202. [10] Head, J. W. et al. (2007) *LPSC. 38*, #1935. [11] Ferris, J. C. et al. (2002) *GRL*, 29(10). [12] Schorghofer, N. et al. (2002) *GRL 29(23)*.