ANOMALOUS RECURRING SLOPE LINEAE ON MARS. L. Lark[1], C. Huber[1], and J. W. Head[1], [1]Dept. of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI, 02912, USA (laura_lark@brown.edu)

Introduction: Recurring slope lineae (RSL) are dark lines that occur on steep slopes and grow and fade seasonally [1]. They tend to occur in clusters, with tens to thousands of RSL growing on a single slope [2]. RSL appear to originate in bedrock outcrops [1] or on talus slopes near local high points [3, 4]. They generally terminate on fans that are at approximately the angle of repose and appear smooth at the sub-meter scale resolution of HiRISE images [3, 5]. RSL growth is dependent on season and orientation [3, 6], and neighboring RSL tend to follow a similar growth pattern, entering each phase at roughly the same time: fast growth in the early season slowing to a stabilization phase, then gradual fading [6].

The mechanisms by which RSL are initiated, grow, and fade are currently unknown. Both wet and dry theories have been proposed. Wet mechanisms describe RSL as small flows of water or brine that seep through the surface material over an impermeable layer, altering the surface albedo through wicking or grain size change [1, 7]. Various sources of water have been proposed, including an underground aquifer [8], melting ground ice or ice patches [1], and deliquescence [1, 9]. Fading is explained as cessation of the liquid source followed by evaporation or freezing of the streak [1]. Dry mechanisms describe RSL as flows of dust over the surface that change surface albedo through grain size change or by exposing a darker subsurface layer [5]. The flows are triggered by destabilization of grains, possibly involving local volatile activity [10]. Dry RSL are proposed to fade as a result of the settling of a seasonally suspended or wind-borne dust layer, or because of exposure to surface conditions [5].

RSL form in both southern and northern mid-latitudes and equatorially, particularly in Valles Marineris [3]. It is possible that the dominant formation mechanism varies across geographically diverse settings. However, *neighboring RSL*, defined as RSL such that the distance between them is much less than their maximum lengths, should experience similar environmental conditions. That is, if there are no obvious features that might create differing local conditions over large portions of the streak such as large boulders, local landslides, or sudden topographical changes, neighboring RSL should experience similar temperatures, humidity, wind, and dust activity. Soil conditions including chemistry and grain size distribution may vary more locally but should still be quite similar among neighbors. Therefore neighboring RSL should be expressions of the same process.

We can then use variation in behavior between neighboring RSL to constrain possible formation and fading mechanisms. Here we present observations of several types of atypical RSL with typical neighbors.

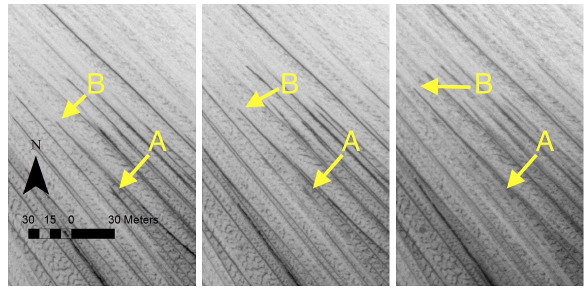

Figure 1: RSL on a fan in Coprates Chasma. RSL A fades as RSL B continues to grow. Downslope is to the northwest. Images from left to right: ESP_032562_1670, ESP_033129_1670, ESP_034408_1670.

Early faders: RSL on a single slope (e.g. a single fan on the wall of a crater) generally fade simultaneously. This usually happens gradually after a period of growth followed by a period of stability [6]. This aligns with proposed general fading mechanisms that are driven by some global change such as lower seasonal temperatures or changing seasonal aeolian activity. However, in rare cases an RSL fades early. In Fig. 1, one RSL (~150m long, termed "early fader") fades while its nearest neighbor (~4m away) and others on the same slope continue to grow. The early fader fades gradually (partially faded after 1 month, fully faded after 4 months), and is no longer visible by the time its neighbors stabilize. Similar behavior has also been noted by [6] in other locations, though there RSL grow and fade much more quickly.

Therefore the mechanism by which RSL fade, though driven globally, must also be responsive to local variation in order to explain the existence of early faders. For wet mechanisms, this implies that the source of just one RSL may be exhausted or disconnected earlier than the sources of its neighbors, and that freezing is an unlikely explanation for fading since freezing conditions should affect neighboring RSL equally. This makes small ice patches a more logical source of liquid for this location than an aquifer, deliquescence, or melting ground ice, since the former allows for individual RSL sources to be exhausted before the patches all freeze at the end of the season whereas the latter would not display such variation in activity. For dry mechanisms, purely global fading mechanisms such as seasonally settling dust are insufficient. It is possible to explain early faders if RSL fading is a response to exposure to surface conditions and early granular current cessation is possible.

Mid-slope RSL: RSL typically begin in rough terrain near the top of ridges (e.g. in Coprates Chasma) or crater walls (e.g. in Garni Crater) [4] or near bedrock outcrops [1]. These RSL then usually continue down onto smooth fans [3]. On rare occasions, however, RSL first become visible mid-slope (Fig. 2). This is similar to downslope specks and discontinuous lines pointed out in [7], but in this case the lines begin in the middle of the fan and then continue to grow to dimensions similar to other RSL on the same slope.

The existence of mid-slope linea constrains possible mechanisms in locations where mid-slope RSL are observed to either those that can initiate RSL in the middle of a fan that is smooth and unbouldered on the 25-cm scale, or form an RSL whose upper portion is not visible at HiRISE resolution but whose lower portion is, despite apparent substrate similarity. In the wet case, mid-slope RSL may indicate locations where the flow is too deep to wick to the surface until the origin of the RSL, either because of thick overlying material or a deep impermeable layer. Alternatively the flow may be too thin to resolve due to a difference in soil permeability. In the dry case, a subtle slope angle change may lead to destabilization of grains mid-slope.

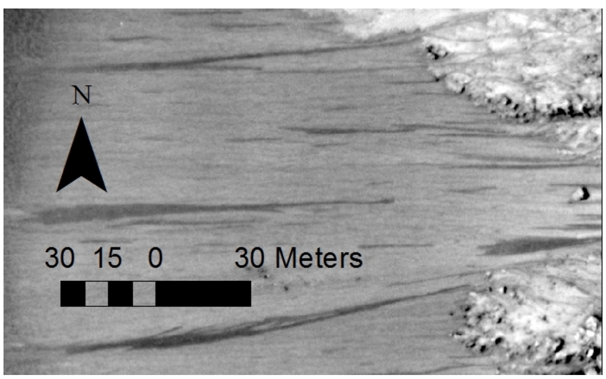

Figure 2: On a fan in Horowitz crater, typical RSL grow from bedrock up-slope, while one anomalous streak begins mid-slope. Image ESP_022678_1475.

Surface disturbances: Typical RSL grow on fans that are smooth at HiRISE resolution, or through rocky fields. These RSL are visibly continuous from beginning to end. However, in several locations, the path of an RSL is interrupted by a surface disturbance. In some cases, the surface disturbance significantly affects the path, though the streak exists both upslope and downslope. In other cases, the streaks appear to continue mostly unchanged through the disturbance (e.g. Fig. 3). These disturbances generally appear to be deposits, though DEM resolution is too coarse to confirm this through topographical measurements and imagery time resolution is too coarse to confirm whether the streaks grow above the disturbance first. If an instance can be confirmed topographically and temporally, this restricts formation mechanisms to those that can explain RSL that continue downslope despite a surface deposit.

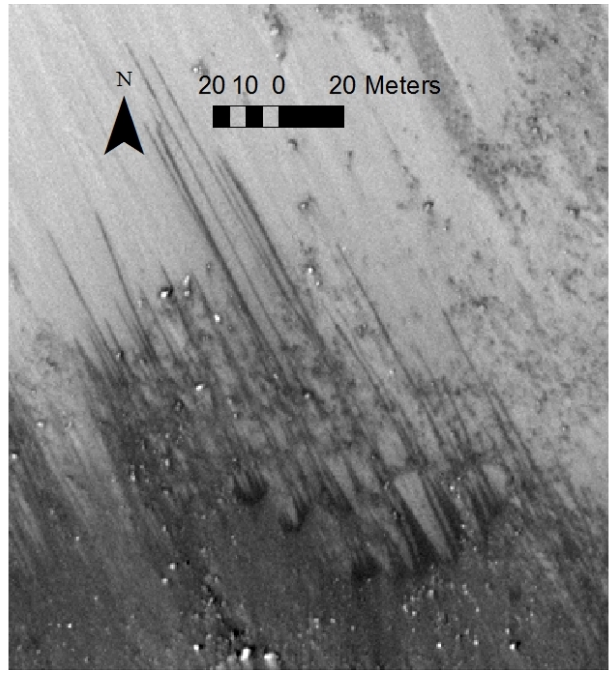

Figure 3: Several RSL continue mostly unchanged despite disappearing at times due to a scattered dark surface layer. In Coprates Chasma. Image ESP_047753_1665.

Conclusions: Anomalous RSL should be considered when evaluating potential formation and fading mechanisms. Specifically, this may be a useful tool in determining whether dry processes could explain RSL as observed, in constraining formation mechanism by considering possible fading mechanisms, and in constraining the wet processes that may be at work during growth and fading. In particular, (1) fading mechanism and RSL source may be required to be more local than previously explored in order to explain early faders, and (2) the depth of proposed mechanisms (e.g. seeping brines through the subsurface vs. flowing grains over the surface) should be considered in the context of mid-slope streaks and RSL on slopes with surface disturbances.

References

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