Anomalous Recurring Slope Lineae on Mars

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1. Introduction

Recurring slope lineae (RSL) are dark lines that occur on steep slopes and grow and fade seasonally.[1,2,3,4] Mechanisms for RSL growth and fading are unknown. Proposed mechanisms are summarized in Table 1.

While dominant growth and fading mechanisms may vary across the geographically diverse settings in which RSL are found, neighboring RSL should experience similar environmental conditions and therefore should be expressions of the same processes. Nearby RSL tend to follow a similar pattern of growth, stabilization, and fading. Here we observe anomalous RSL with typical neighbors.

How can observations of anomalous RSL inform potential growth and fading mechanisms?

	Growth mechanism	Fading mechanism
Wet	Liquid trickles downhill, wicking up to darken surface.[1,7] Liquid source may be: ○ melting ice patches or ground ice.[1] ○ deliquescing brines.[1,9] ○ an aquifer.[8]	1. Evaporation. 2. Retreat of capillary front. 3. Streak freezes.[1]
Dry	Dust grains move downhill, changing albedo by exposing dark substrate or via grain size effects. Destabilized by: ○ gradual deposition.[5] ○ wind.[11] ○ gas pumping resulting from a temperature gradient.[10]	1. Seasonal winds die down and suspended dust settles. 2. Aeolian activity covers streaks with nearby material. 3. Substrate changes albedo after exposure to surface conditions.[5]

Table 1. Summary of proposed growth and fading mechanisms for RSL.

2. Early Faders

Typical RSL fade at about the same time in a single location.

Early faders fade while neighboring RSL are still growing or stable.

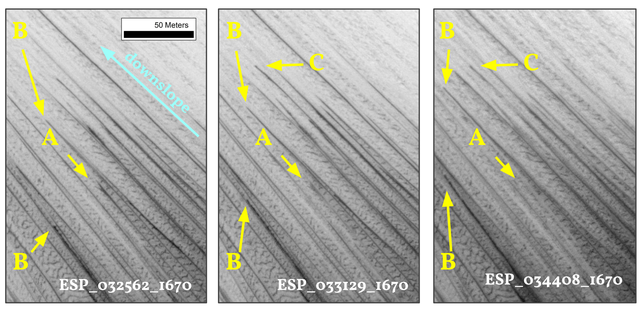


Figure 1. RSL on a fan in Coprates Chasma (-64.57, -13.02). RSL A fades as RSL B continue to grow and RSL C stays roughly stable. Downslope is to the northwest.

Wet	Implications	Dry
Explained by exhaustion of single RSL source, allowing a continuous fading mechanism to dominate. • Melting of ice patches allows individual source to be exhausted before all freeze. • Freezing as a fading mechanism is not consistent with the presence of early faders since freezing conditions should affect neighboring RSL equally. • Evaporation is consistent.		Difficult to reconcile with environmentally controlled fading mechanisms (dust, aeolian activity, exposure to surface conditions). • Stable/growing RSL must be continuously refreshed • Growth mechanism must be locally variable, consistent with volatile-driven Knudsen pump proposed in [10]. • Wind or grain accumulation would need to vary between neighbors.

3. Surface Disturbances

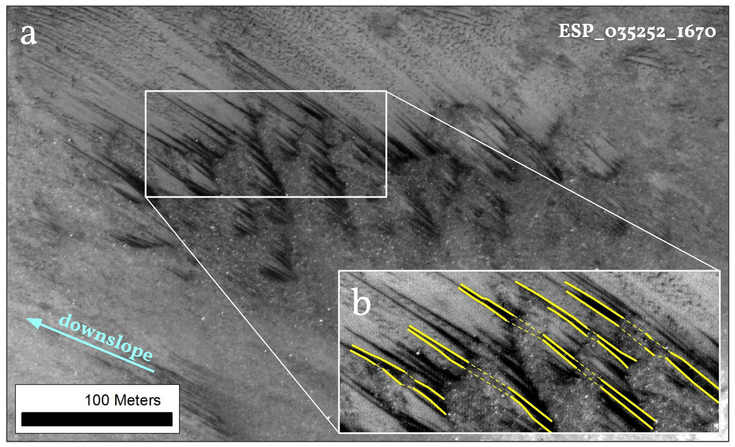
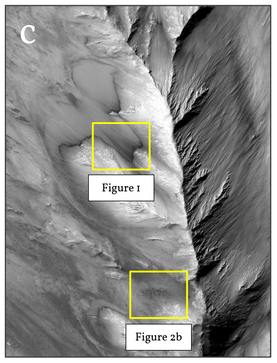


Figure 2. RSL in Coprates Chasma (-64.57, 13.05). 2a shows a surface disturbance interfering with continuous visibility of RSL, with examples outlined in 2b. Note: imagery time resolution confirms RSL, but not that RSL grow above disturbance before growing below it. 2c gives context for 2a and Figure 1.



Typical RSL are visibly continuous from beginning to end. However, in some locations, the path of RSL is interrupted by a surface disturbance.

In Figure 2, the surface disturbance significantly affects the path, though RSL exist upslope and downslope. In Figure 3 the RSL appear to continue mostly unchanged despite disturbance.

If an instance can be confirmed topographically and temporally, suggests that formation mechanism must explain RSL that continue downslope despite a surface deposit.

Limitations

- Shadows in these images suggest that the disturbances are deposits, but DEMs could confirm.
- Time resolution too coarse to confirm whether RSL grow above disturbance before growing below.

Wet	Implications	Dry
• Consistent: water/brine would flow in subsurface, could continue underneath disturbance. • Altered flow also reasonable.		• Continuation of slow grain flow should be altered or halted. • Possible that flow continues along paths below image resolution. • Wind as driving force is consistent: operates above the surface.

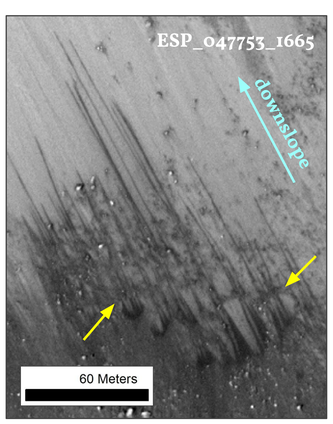
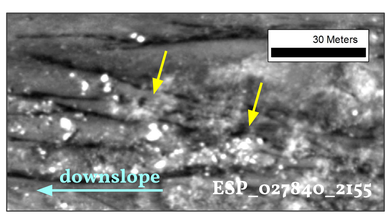


Figure 3. RSL in Coprates Chasma (-63.27, -13.31), left, and Rauna Crater (-32.07, 35.25), below. Examples of surface disturbances indicated with yellow arrows. RSL visible between disturbances, continue downslope.



4. Mid-Slope RSL

Typical RSL visibly begin:

- In rough terrain.
- Near tops of ridges or crater walls.[1,4]

Mid-slope RSL visibly begin:

- Partway down a slope.
- On a surface that is smooth at HiRISE resolution.

Wet	Implications	Dry
• Change in surface texture/thickness could inhibit wicking to surface. • Subsurface groove could conduct water from source to mid-slope. • Water source mid-slope would require explanation.		• Consistent with grain flow mechanisms. Slope increase favors flow due to destabilization. • Wind/deposition both consistent. • Mid-slope volatile source for destabilization needs explanation.

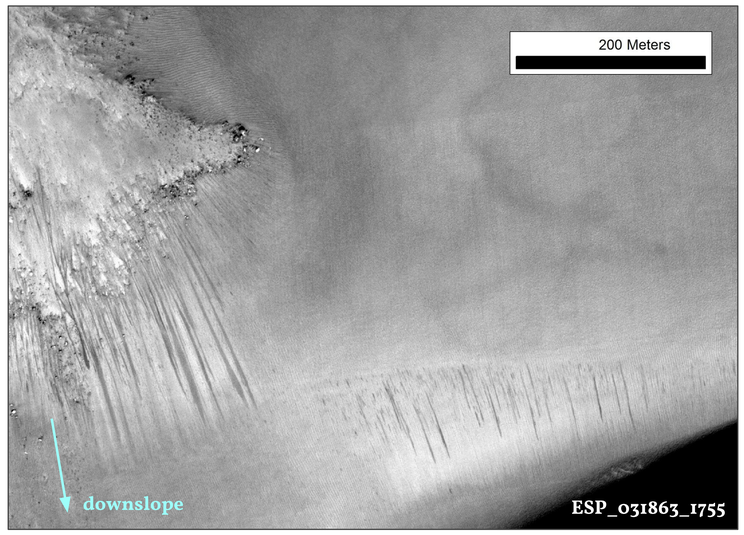


Figure 4. RSL in Juventae Chasma (-61.44, -4.74). Some grow in the usual setting, while some appear on a smooth slope nearby. Seasonality is identical for both patches. Rightmost patch is associated with very slight slope increase. North is left.

5. Conclusions

Anomalous RSL should be considered when evaluating potential growth and fading mechanisms.

Wet	Summary	Dry
• Model is consistent with anomalous RSL. • Early faders suggest RSL evaporate after source stops and that source is different between neighboring RSL. • Wet flow could continue under surface disturbance. • Subsurface topography required to explain mid-slope streaks.		• Current models challenging. • Early faders suggest fading mechanism is local and/or that grain flows are precise and grain sources are locally variable (most consistent with grain pumping due to shadow or volatile source. • Grain flow should be affected by surface disturbances unless wind-driven.

References

[1] A. S. McEwen, et al. Science, 333(6043):740–743, 2011. [2] L. Ojha, et al. Icarus, 231:365–376, 2014. [3] A. McEwen, et al. Nature Geoscience, 7(1):53– 58, 2014. [4] M. Chojnacki, et al. Journal of Geophysical Research: Planets, 121(7):1204–1231, 2016. [5] C. M. Dundas, et al. Nature Geoscience, 10(12):903– 907, 2017. [6] D. E. Stillman, et al. Icarus, 285:195–210, 2017. [7] D. E. Stillman, et al. Icarus, 233:328–341, 2014. [8] D. E. Stillman, et al. Icarus, 265:125–138, 2016. [9] L. Ojha, et al. Nature Geoscience, 8(11):829– 832, 2015. [10] F. Schmidt, et al. European Planetary Science Congress, 11:EPSC2017-260, 2017. [11] M. Vincendon, et al. Icarus, 325:115 – 127, 2019.

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