EPSC Abstracts
Vol. 10, EPSC2015-786-1, 2015
European Planetary Science Congress 2015

Recurring Slope Lineae on Mars: Atmospheric Origin?

A. McEwen (1), M. Chojnacki (1), C. Dundas (2), L. Ojha (3), M. Masse (4), E. Schaefer (1), C. Leung (1)
(1) University of Arizona, Tucson, USA. (2) USGS, Flagstaff, USA. (3) Georgia Tech, Atlanta, USA. (4) Université Paris Sud, France.

Abstract

Recurring Slope Lineae (RSL) are seasonal flows or seeps on warm Martian slopes. Observed gradual or incremental growth, fading, and yearly recurrence can be explained by seasonal seeps of water, which is probably salty. The origin of the water is not understood, but several observations indicate a key role for atmospheric processes. If sufficient deliquescent salts are present at these locations, the water could be entirely of atmospheric origin.

1. Introduction

Recurring Slope Lineae (RSL) on Mars may be produced by the seasonal flow or seepage of water on relatively warm slopes. They are narrow (<5 m), relatively dark markings on steep (25°–40°), low-albedo slopes, which appear and incrementally extend during warm seasons, then fade and recur in the same approximate location over multiple Mars years [1]. RSL lack clear water absorption spectral bands, but the fans on which they terminate have distinctive color and spectral properties [2]. The lineae commonly follow small gullies, but few topographic changes have been detected via 30 cm/pixel images from the Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE). The first documented group of RSL occur between ~48–32°S latitude and develop primarily in late southern spring and summer, favoring equator-facing slopes—times and places where peak surface temperatures exceed 250 K [1]. Active RSL also occur in equatorial regions of Mars (0–15°S), most commonly in the Valles Marineris troughs [3]. Like the first group, these equatorial RSL are especially active on sun-facing slopes, moving from north- to south-facing slopes and back to track the peak insolation. We have also confirmed RSL in low-albedo Acidalia Planitia (35°N), active in northern spring and summer with the most vigorous extension in early spring [4]. RSL advance rates are highest at the beginning of each season, followed by much slower lengthening [5].

There are several key gaps in our understanding of RSL. Most importantly, the origin of water to drive RSL flow is unknown. The time of day of active flow is also unknown. Most RSL locations are steep, rocky, low-albedo slopes, with daily peak surface temperatures typically >250 K, and commonly >273 K, in the active season, but there must be additional factors, because many times and places with these properties lack detectable RSL [6]. Water has not been confirmed to be present, but laboratory experiments show that even minor amounts of water (5 wt. % and no liquid film on surface) can darken basaltic soils while producing only weak spectral features [7, 8]. These spectral features may be undetectable in CRISM spectra obtained from MRO's midafternoon orbit, due to partial dehydration and evaporation.

2. Evidence for Atmospheric Effects

The behavior of RSL strongly suggests fluid flow, and we are not aware of any entirely dry process known to create seasonal flows that progressively grow over weeks and months. Seasonal melting of shallow ice would explain the RSL observations, but it would be difficult to replenish such ice annually, and ice inherited from an earlier climate would be quickly depleted. Deeper groundwater may exist and could reach the surface at springs or seeps, but this cannot explain the wide distribution of RSL, extending to the tops of ridges and peaks [1, 9]. Also, there are apparent RSL on equatorial dunes composed of permeable sand, unlikely to be a groundwater source. This leaves an atmospheric origin, but the dryness of the Martian air (~10 pr. microns average column abundance [10]) is a challenge.

Several observations show that atmospheric dust opacity has a significant effect on RSL activity, whether or not RSL water comes from the atmosphere [1, 3, 11]. The evidence for the source of water being atmospheric includes the following:

1. RSL extend to tops of ridges and peaks in many locations.
2. RSL originate over many spots, up to thousands, within a single HiRISE image, rather than being concentrated at a few key locations like springs.
3. Perchlorates and other hygroscopic salts are common on Mars.
4. Complex RSL flow boundaries may be exactly repeated from year to year [4], perhaps explained by deliquescence of salt deposited by past RSL flow.
5. RSL fans in Valles Marineris transiently darken during or just after periods of high dust opacity [3], perhaps due to stability of deliquesced liquids into the afternoons when MRO observes.

Deliquescence provides a mechanism for trapping water from the atmosphere [12-14]. Condensation of frost is also possible at these sites but direct melting of such frost is unlikely to produce RSL [4].

Seasonal variation in the atmospheric column abundance of water vapor does not match the RSL activity over active locations [3, 15]. Although subsurface exchange during the early stages of the MY28 global dust storm has been suggested to affect column abundances [16], the progressive obscuration of water vapor as dust rises is an alternate explanation [10]. However, near-surface water vapor exchange with the shallow subsurface has been reported by MSL [17].

Can deliquescence trap sufficient water to explain RSL? RSL are highly concentrated in Coprates Chasma, with RSL and their fans covering a total area of ~6 x 10^7 m^2. Assuming 10% water by volume (5% by wt.) a 10 mm flow depth gives 6 x 10^4 m^3 of water [18]. The atmosphere over the full area of Coprates Chasm at ~10 pr. microns contains ~20× more water. Thus, sufficient water may be present in the atmosphere, but must be efficiently trapped over small areas. The principal difficulty is that evaporation during the warm part of the day may exceed deliquescence during cooler times, in spite of efflorescence relative humidities as low as 5% [13, 14], but the cooler days under dusty air may enable liquid to acumulate. HiRISE shows that there are often bright deposits after RSL have faded (possible salt deposits), but they are generally too small to be resolved by MRO/CRISM spectral imaging and may usually be anhydrous. Recent detection of hydrated deliquescent salts at RSL sites in some seasons [19] supports this hypothesis.

3. Summary and Conclusions

The potential for water activity creates new exploration opportunities, to search for extant life or resources, as well as challenges such as the definition of special regions for planetary protection. If RSL form via atmospheric deliquescence, then they are likely eutectic brines with temperatures and water activities too low to support terrestrial life [20].

References

[1] McEwen A. S. et al. (2011) *Science*, 333, 740-744.

[2] Ojha, L. et al. (2013) GRL 40, 5621-5646.

[3] McEwen A. S. et al. (2014) *Nat. Geosci.*, 7, 53-58.

[4] Dundas, C.M. et al. (2015) LPSC 46, 2327.

[5] Schaefer, E. et al. (2015) LPSC 46, 2930.

[6] Ojha L. et al. (2014) *Icarus*, 231, 365-376.

[7] Masse, M. et al. (2014) PSS 92, 136-149.

[8] Pommerol, A. et al. (2013) JGR Planets 118, 2045-2072.

[9] Chojnacki, M. et al. (2014) LPSC 45, 2701.

[10] Smith M. (2008) *AREPS 36*, 191–219.

[11] Stillman D. E. et al. (2014) *Icarus*, 233, 328-341.

[12] Gough, R. et al. (2011) EPSL 312, 371.

[13] Gough, R. et al. (2014) EPSL 393, 73.

[14] Nuding, D.L. et al. (2014) Icarus 243, 420-428.

[15] Toigo, A. et al. (2013) JGR 118, 89-104.

[16] Trokhimovskiy et al. (2015) Icarus 251, 50-64.

[17] Martin-Torres, F. J. et al. (2015) Nature Geos. 8, 357-361.

[18] Chojnacki, M. et al. (2015) LPSC 46, 2537.

[19] Ojha, L. et al., this conference.

[20] Rummel, J.D. et al. (2014) Astrobiology 14, 887-968.