RECURRING SLOPE LINEAE ON MARS.

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Introduction: Recurring slope lineae (RSL) may be evidence for the seasonal flow or seepage of water, and may mark the most promising sites to search for present-day life near the surface of Mars. For animated GIFs showing RSL activity, see http://hirise.lpl.arizona.edu/sim/.

Observations: RSL are narrow (<5 m), dark markings on steep (25°-40°) slopes that appear and incrementally grow during warm seasons over low-albedo surfaces, fade when inactive, and recur over multiple Mars years [1]. RSL often follow small gullies, but no topographic changes (with one exception) have been detected via 30 cm/pixel images from MRO/HiRISE [2]. The first group of confirmed RSL appear and lengthen in the late southern spring through summer from 48°S to 32°S latitude, favoring equator-facing slopes—times and places with peak surface temperatures ranging from >250 K to >300 K.

Over the past Martian year we have monitored active RSL in equatorial (0°-15°S) regions of Mars, especially in the deep canyons of Valles Marineris [3]. These equatorial RSL are especially active on north-facing slopes in northern summer and spring and on south-facing slopes in southern spring and summer, following the most normal solar incidence angles on these steep slopes. Some of these lineae are especially long, over 1 km, again following pristine gullies.

Recently we have confirmed RSL near 35°N in low-albedo Acidalia Planitia, on steep equator-facing slopes; these RSL are active in northern summer. The global distribution of RSL (Fig. 1) shows them below 2.6 km altitude, and only on low-albedo (low-dust) surfaces.

The fans on which many RSL terminate have distinctive color and spectral properties in MRO/CRISM [4], but lack distinctive water absorption bands [5]. Ferric and ferrous absoptions increase with RSL activity, perhaps due to removal of a fine-grained surface component during RSL flow, precipitation of ferric oxides, and/or wetting of the substrate.

All RSL locations have warm peak daily temperatures (typically >273 K at the surface) in the seasons when RSL are active (Fig. 1). However, most times and places with these properties lack apparent RSL, so there are additional, unseen requirements [6]. We do not know what time of day RSL are actively flowing. The peak RSL activity corresponds to the time of peak temperatures in the shallow subsurface (<1 m) rather than at the surface, consistent with melting ice or heating hydrated salts in the shallow subsurface.

Laboratory experiments show that water or brines darken basaltic soils but may only produce weak water absorption bands undetectable in ratio spectra after partial dehydration during the low-humidity middle afternoon conditions when MRO observes [7, 8]. No entirely dry process is known to create such slowly advancing seasonal flows, but the RSL bear some similarities to avalanches on martian dunes [9]. Lab experiments show that boiling brines may trigger dry flows under martian atmospheric pressure [10] suggests a mechanism to create RSL with minimal water.

Hypotheses: The primary question about RSL is whether they are really due to water at or near the surface. All observations can be explained in this way, and no entirely dry model has been offered, but there is no direct detection of water. If they are due to water, the next key questions are where does the water come from and how is it replenished each year? Below are a few hypotheses:

1. Deliquescence. This phenomena has been reported as the source of some water tracks in the dry valleys of Antarctica, which appear very similar to RSL [11]. This hypothesis is attractive as it could explain some RSL that begin near the tops of ridges or hills. The seasonal variation in the atmospheric column abundance of water vapor does not match the RSL activity [3, 12] and the quantities of water vapor are extremely small (~100x less than over Antarctica). However, deliquescence might re-hydrate shallow subsurface chloride hydrates that liquefy upon seasonal heating [13].

2. Melting frozen brines from a past climate [14]. This model explains the observation that peak RSL activity corresponds to peak temperatures in the shallow subsurface. However, it is difficult to explain how such ices could remain present for $>10^5$ years on such warm slopes.

3. Fault-controlled migration of deep (ancient?) brines. Brines are expected to exist in the martian crust [15], and could migrate to the surface along certain pathways and reach the surface on steep slopes. In a few mapped sites, >80% of the RSL are within 50 m of a fault [16].

4. Brine convection. This process occurs in Earth's ocean and should occur in Mars' ground if saturated with brines, depositing pure (not salty) ice near the surface [17]. Saturated ground is highly unlikely in most regions where RSL are located, although fault-controlled movement of brines could also replenish shallow ice.

5. Ice replenished by vapor transport. This model [18] also forms pure ice near the surface, but vapor transport is too slow to explain yearly recurrence [20].

Implications for Future Exploration. The potential for near-surface water activity creates focused opportunities to search for extant life, especially if the hypothesis of freshwater RSL [19] is even partially correct. RSL occur on steep, rocky slopes on which landing is dangerous, but several concepts for surface exploration of RSL were presented in 2012 (http://www.lpi.usra.edu/meetings/marsconcepts2012/) Another challenge is that RSL sites will require additional expenses for planetary protection [21]. For these reasons, it is important to learn as much as possible about RSL from orbital observations such as extended MRO. There is also a need for an orbiter to search for evidence of water over a range of local times (especially ~8-10 AM when surface brines are most stable [24-25]) during the seasons when the RSL are active [22, 23]. ESA's Trace Gas Orbiter lacks high-resolution spectroscopy but will acquire 5 m/pixel color images over a range of times of day, and brightness changes from wetting and drying could be observed [8].

References: [1] McEwen, A.S. et al. (2011) Science 333, 740. [2] McEwen, A.S. et al. (2007) JGR 112, E05S02. [3] McEwen, A.S. et al. (2014) Nature Geosc. 7, 53. [4] Murchie, S. et al. (2007) JGR 112, E05S03. [5] Ojha, L. et al. (2013) GRL 40, 5621. [6] Ojha, L. et al. (2014) Icarus 231, 365. [7] Masse, M. et al. (2014) PSS 92, 136. [8] Pommerol, A. et al. (2013) JGR 118, 2045. [9] Chojnacki, M. et al. (2014) this conference. [10] Masse, M. et al. (2014) LPSC 43, 2137. [11] Levy, J. (2012) Icarus 219, 1. [12] Toigo, A. et al. (2013) JGR 118, 89. [13] Wang, A. (2014) this conference. [14] Chevrier, V. and Rivera-Valentin, E. (2012) GRL 39, L21202. [15] Burt, D. and Knauth, L. (2003) JGR 108, 8026. [16] Watkins, J. et al. (2014) LPSC 43. [17] Travis, B. et al. (2013) JGR b118, 977. [18] Grimm, R. et al. (2014) Icarus 233, 316. [19] Stillman, D. et al. (2014) Icarus 233, 328. [20] Hudson, T. et al. (2009) JGR 114, E01002. [21] Beaty, D. et al. (2014) this conference. [22] McEwen, A. et al. (2012) LPI contr. 1679, 4284. [23] Paige, D. et al. (2012) LPI Contrib. 1679, 4235. [24] Gough, R. et al. (2011) EPSL 312, 371. [25] Gough, R. et al. (2014) EPSL 393, 73.

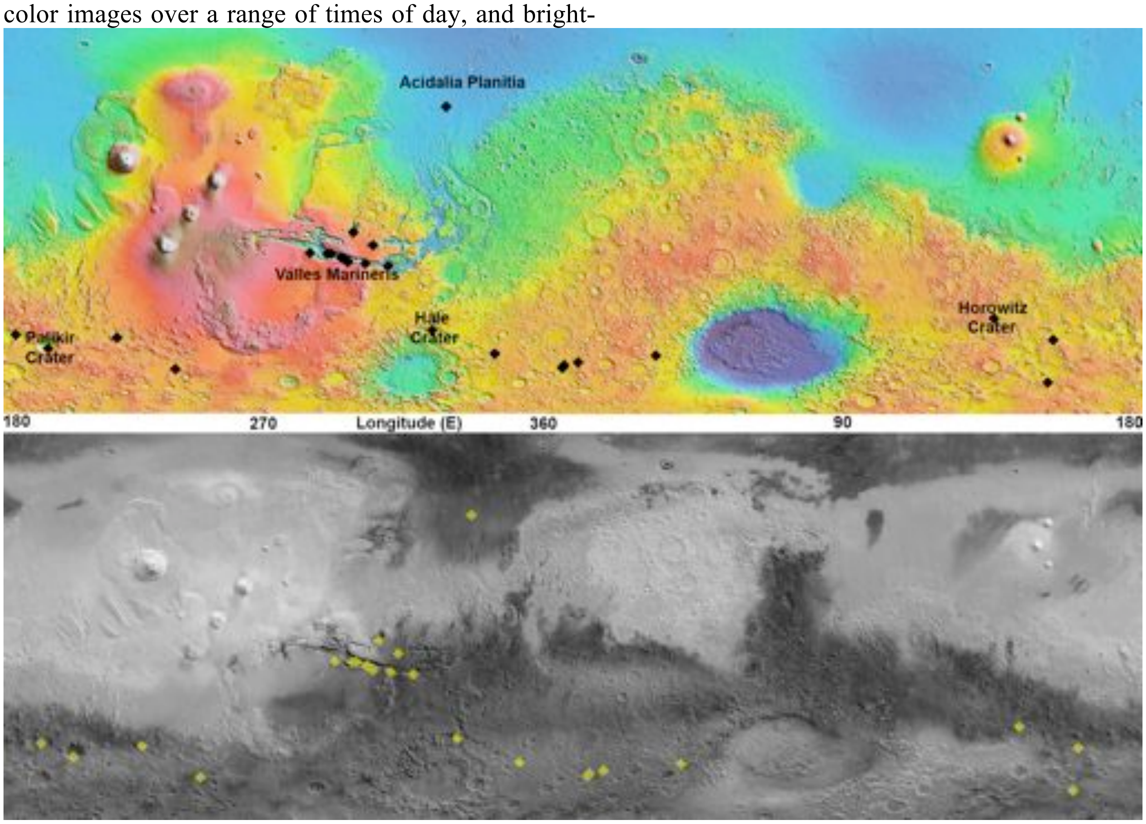

Fig. 1. Map of fully confirmed RSL sites documented by end of 2013 [3], over maps of MOLA elevation (top) and TES albedo (bottom). "Fully confirmed" means observed incremental growth, fading, and yearly recurrence of many (>10) flows on a slope.