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Recurring Slope Lineae (RSL) in Equatorial Mars

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Abstract

Here we report on RSL (possible water seeps) in equatorial regions of Mars, especially in the deep canyons of Valles Marineris (VM). They are active on north-facing slopes in northern spring and summer and on south-facing slopes in southern spring and summer, following the peak solar warming of these steep slopes. This equatorial activity places new constraints on the origin of RSL and has implications for future exploration.

1. Introduction

Pure water must be extremely rare and short-lived on the surface of Mars today, where it will rapidly evaporate (even boiling) and/or freeze. The possibility of present-day habitability near the surface has been enhanced by the discovery of recurring slope lineae (RSL), which could be evidence for the seasonal flow of salty water on warm slopes [1]. RSL are narrow (0.5-5 m), relatively dark lineations on steep (25°-40°) slopes that appear and incrementally grow during warm seasons and fade when inactive. They extend downslope from bedrock outcrops, often associated with small gullies, and 10^2-10^3 individual flows form in some HiRISE images. The initially confirmed RSL [1] appear and lengthen in the late southern spring/summer from 52°S to 32°S latitudes favoring equator-facing slopes—times and places with peak surface temperatures from ~250-310 K.

We consider RSL “confirmed” if we observe simultaneous incremental growth of multiple (>10) flows at a location, fading when inactive, and new features in multiple Mars years (recurrence). The current tally of confirmed RSL sites in the southern mid-latitudes is 19 [2]. Wetting the surface might explain this activity, but the exact mechanism and source of water are not understood. Concentrated brines are far more likely than pure water because of lowered freezing temperatures and evaporation rates [3], and because the surface is salty. However, the observations do not rule out fresh water in some places [4].

2. Recent Observations

Observations over the past year by the High Resolution Imaging Science Experiment (HiRISE) on MRO confirm RSL in at least 6 locations inside VM (latitude 6-15°S). There are also >10 partially confirmed or “likely” RSL sites in VM and a few other equatorial locations. The RSL extend from west-central VM to the eastern canyons, and are especially concentrated in Coprates Chasma. They have not been detected in far western VM or anywhere on Mars with dust-covered slopes or altitudes >2 km. A striking feature of the global set of confirmed and likely RSL is that they are confined to low-albedo regions.

RSL in VM are quite similar to those in the southern middle latitudes, but there are longer steep slopes in VM and longer RSL—up to a few hundred meters long. These larger features help reveal the morphologic associations and provide larger targets for CRISM spectra and THEMIS temperatures. Activity begins when THEMIS brightness temperatures for west-facing slopes in the mid-late PM are near 250 K.

RSL in VM are commonly associated with small gullies of similar size, suggesting that RSL activity may erode these channels. RSL probably interact with three basic types of surfaces: 1. Bedrock, where the RSL may temporarily darken the surface or where the darkening may be difficult to see under some lighting conditions (perhaps hiding in cracks and shadows). 2. Slopes with fine-grained soils that are slowly permeable, where RSL flow may gradually erode small gullies. 3. Slopes covered by permeable materials such as windblown sand, where water might infiltrate and wick to the surface in discontinuous lines.

3. Discussion

If RSL are due to briny water, what is the composition of the salts? Chevrier et al. [3] favored $CaCl_2$ because the eutectic temperature is about right if RSL originate from melting shallow (10-20 cm deep) frozen brines. $CaCl_2$ is expected to be abundant in the shallow subsurface of Mars [5] and is consistent with the possible chloride deposits [6]. Anhydrous chlorides lack distinctive absorption bands in either the near-IR or thermal-IR spectral regions. CRISM spectra and HiRISE color data suggest that Fe minerals are the major colorants of RSL deposits [7], even if perhaps trace components.

The origin of RSL is an open question. The seasonality and temperature dependence suggest a key role for a volatile, for which water is in the right temperature range. This includes the hypothesis that a phase change triggers dry flows. Flow of water or wet debris is an attractive model for RSL as it can explain the seasonal darkening and fading. Stable eutectic brines are not expected at the surface near the 3 PM observing time of MRO [8]. However, laboratory measurements of brine-wetted Mars analogue soil show that darkening persists when there is only a few percent water present [9].

Shallow ice in the middle latitudes could provide a water source for the RSL by seasonal melting of frozen brines. The timing of mid-latitude RSL activity corresponds to the seasonal temperature peak at depths ≥20 cm. The presence of shallow frozen brines from a former climate [3] may be more difficult to explain in equatorial VM, so the deeper and older brines envisioned by [5] are a possibility, or a modern-day recharge mechanism is required.

An alternate origin for the water is deliquescence from the atmosphere, but the peak column abundances of water vapor over these locations is just 10-20 precipitable microns. Compilation of CRISM (mid-PM) water vapor measurements show that the seasonal peaks do not correspond to RSL activity, but recharge of subsurface ice from the atmosphere might be possible.

4. Future Exploration

COSPAR has defined "Special Regions" on Mars as any regions experiencing temperatures >248 K for a few hours/yr and with a water activity >0.5, safely below the limits for reproduction of terrestrial organisms [10]. Special regions need added planetary protection during future surface exploration or sample return. Based on the best available information up to 2010, they concluded that there are probably no special regions in the equatorial latitudes of Mars. The discovery of RSL in Valles Marineris suggests that it is time to reconsider this question.

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