

# Spectral Evidence for Hydrated Salts in Seasonal Brine Flows on Mars

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## Abstract

Recurring Slope Lineae (RSL) are seasonal flows on warm Martian slopes initially proposed, but not confirmed, to be caused by briny water seeps. Here we report spectral evidence for hydrated salts on RSL slopes from four different RSL locations from the Compact Reconnaissance Imaging Spectrometer for Mars on board Mars Reconnaissance Orbiter. These results confirm the hypothesis that RSL are due to present-day activity of briny water.

## 1. Introduction

Pure water would rapidly evaporate and/or freeze on the present-day surface of Mars at most times and places; however brines are far less volatile compared to pure water due to their lower freezing points and evaporation rates [1-2]. Various salts (e.g. sulfates, chlorides and perchlorates) have been detected on the surface of Mars from remote and in situ investigations [e.g. 3-5]. These salts can lower the freezing point of water by up to 80 K, lower the evaporation rate of water by an order of magnitude, and can be hygroscopic (i.e. able to easily absorb atmospheric moisture) [e.g. 6-8], thus increasing the possibility of forming and stabilizing liquid water on the surface of present day Mars [e.g. 9].

Recurring Slope Lineae (RSL) are narrow, low-reflectance features forming on present-day Mars that have been hypothesized to be due to the transient flow of liquid water. RSL extend incrementally downslope on steep, warm slopes, fade when inactive, and reappear annually over multiple Mars years as monitored by the HiRISE camera on board the Mars Reconnaissance Orbiter (MRO) [e.g. 10-12]. In the southern mid-latitudes of Mars, RSL are observed to form most commonly on equator facing slopes, but in equatorial regions RSL often “follow the sun”,

forming and growing on slopes that receive the greatest insolation during a particular season [10]. The temperature on slopes where RSL are active typically exceeds 250 K and often but not always exceeds 273 K, although sub-surface temperatures would be colder. These characteristics suggest a possible role of salts in lowering the freezing point of water, allowing briny solutions to flow [10-12]. Confirmation of this wet origin hypothesis for RSL would require either (i) detection of liquid water absorptions on the surface, or (ii) detection of hydrated salts precipitated from that water. The mineralogical composition of RSL and their surroundings can be investigated using orbital data acquired by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) also on board MRO, which acquires spectral cubes with 544 spectral channels in the visible to near-infrared range of  $\sim 0.36 \mu\text{m}$  to  $3.92 \mu\text{m}$  [13], within which both liquid water and hydrated salts have diagnostic absorption bands at  $\sim 1.4 \mu\text{m}$ ,  $\sim 1.9 \mu\text{m}$ ,  $\sim 3.0 \mu\text{m}$ . Additionally, hydrated salts may have combination of overtones at other wavelengths from  $1.7 \mu\text{m}$  to  $2.4 \mu\text{m}$ . We present results from examination of individual pixels containing RSL at four different sites.

## 2. Results

We found hydration absorption bands at four different RSL locations (Table 1). All the HiRISE/CRISM observations reported here of the southern mid-latitude RSL sites were acquired during the late southern-summer ( $340^\circ < L_s < 360^\circ$ , where  $L_s$  is the areocentric longitude of the Sun), when the RSL had reached their maximum extent for the year and were fading.

*Palikir crater:* The CRISM pixels closest to wide RSL in Palikir exhibited absorption features at wavelengths near  $1.48 \mu\text{m}$ ,  $1.91 \mu\text{m}$ ,  $2.15 \mu\text{m}$  and  $3.0 \mu\text{m}$ . Although liquid water has absorptions at most of

these wavelengths, the absorptions observed in CRISM images are too narrow to be explained by liquid water. Alternatively, they are consistent with hydrated salts; a linear spectral mixture of Martian soil, Mg-perchlorate and Mg-chlorate provided the closest match to the observed spectrum from Palikir. The observed hydration bands were also transient: present in images that had extensive RSL in late summer and absent in those that had short/narrow RSL. This confirmed that hydration features observed at Palikir were due to areally extensive presence of RSL, and perhaps due to greater stability of hydrated salts in late summer when temperatures drop.

Table 1: List of locations inspected and summary of hydration bands observed.

Site	Geological Setting	Hydration bands ( $\mu\text{m}$ )	Metal-OH bands ( $\mu\text{m}$ )
Palikir crater (-41.6°N, 202.3°E)	Crater wall	1.4, 1.9, 3.0	2.15
Horowitz crater (-32.0°N, 140.8°E)	Central peak	1.9, 3.0	2.15, 2.42, 2.52
Hale crater (-35.7°N, 323.5°E)	Central peak	1.4, 1.9, 3.0	None
Coprates Chasm (-14.7°N, 304.6°E)	Canyon wall	1.9	None

*Horowitz crater:* At two of the central peaks in Horowitz, we observe absorptions at 1.9  $\mu\text{m}$ , 2.15  $\mu\text{m}$  and 2.52  $\mu\text{m}$ . A linear spectral mixture of Martian soil and Na-perchlorate provided the best match to the observed spectra. We could not confirm the transient nature of the spectral absorption bands at this site because of lack of repeat CRISM coverage.

*Hale crater:* Some of the most intense RSL activity in the southern mid-latitudes occurs on the central peak structures of Hale crater. Analysis of the CRISM data shows strong  $\sim 1.46$  and 1.9  $\mu\text{m}$  absorption features in the location where dense RSL activity is observed in the HiRISE image. A linear spectral mixture of Mg-perchlorate and Martian soil provided the best match to the observed spectra.

*Coprates Chasma:* In equatorial Coprates, RSL are abundant and in some cases entire fans

associated with RSL are observed to change their reflectance [10]. Spectra of RSL fans in Coprates were analyzed and were found to show transient, and we found multiple places in the CRISM images with 1.9  $\mu\text{m}$  absorptions. Without detection of other absorptions, assignment to a particular salt mineralogy is not possible, but it does suggest precipitation of salts and related wetting and/or modification of grain sizes as a viable mechanism for the change in albedo of the fans, possibly explaining VIS-NIR spectral changes previously reported in RSL fans [14].

### 3. Discussion

The origin of water forming the RSL is not understood [10-12], given the extreme aridity of Mars' surface environment. Water could form by the surface/sub-surface melting of ice, but the presence of near-surface equatorial ice is highly unlikely. Water could also form via deliquescence by hygroscopic salts, although it is unclear how the Martian atmosphere can sufficiently supply water vapor every year to create RSL [10, 15]. The absence of concentrated deliquescent salts would rule out this hypothesis. Another hypothesis is seasonal discharge of a local aquifer, which concentrates salt deposits as the brine evaporates, but then lineae emulating from the tops of local peaks [10] are difficult to explain. It is conceivable that RSL are forming in different parts of Mars via different formation mechanisms. The new compositional insights reported here from widely separated sites provide essential new clues.

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