SPECTRAL CONSTRAINTS ON THE NATURE AND FORMATION MECHANISM OF RECURRING SLOPE LINEAE

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Introduction: Recurring Slope Lineae (RSL) are dark, narrow features that extend downslope on steep, equator-facing, mid-latitude and equatorial rocky slopes of Mars [1-3]. They exhibit progressive growth over time in the downslope direction. They are observed to form and grow during multiple warm seasons (peak surface temperature ranging from 250 to 300 K) and are observed to fade and completely disappear during colder seasons. Due to their distinct seasonality, incremental growth, and observed surface temperatures, their formation has been attributed to brines.

Spectroscopic evidence for brines is now being sought through intensive monitoring of RSL with the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [8]. Here we describe results from our preliminary analysis of CRISM data over RSL slopes.

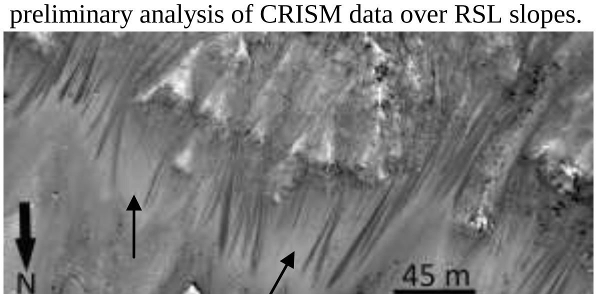

Figure 1. RSL at Palikir Crater. Arrows point at the bright fans chosen as the numerator ROI for Figure 2.

Methodology: RSL sites with the most temporal coverage by CRISM were selected for analysis. CRISM cooler conservation prevents acquisition of useful IR (1–4 μm) data during some observations, so we concentrated mostly on the VNIR region (0.4–1 μm) due to its greater availability, although IR wavelength data were also analyzed where available. CRISM I/F images were downloaded and pre-processed using ENVI's CRISM Analysis Toolkit to reduce atmospheric effects, map-project the images, and map parameters indicative of mineralogy [e.g., 4].

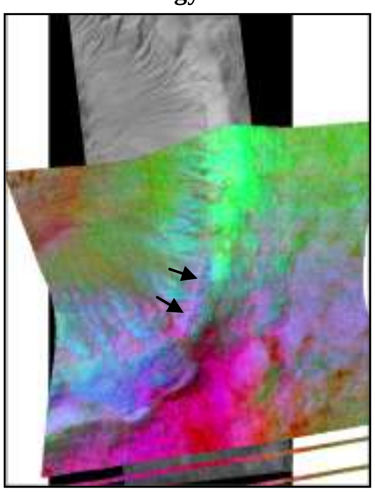

Figure 2. CRISM FRT0001E50D (R:BD920, G:R770, B:BD530) overlaid on HiRISE PSP_005943_1380. Arrows point to the general location of fans in the CRISM observation.

Spectral plots were produced from slopes with RSL activity. Individual RSL are smaller than the spatial resolution of CRISM (~18m/pixel), so we averaged data over RSL slopes and their associated bright fans (Figure 1). The average spectrum from this region of interest (ROI) was divided by an average from a spectrally neutral region in the same scene. The ratio of the same numerator to the same denominator was plotted for all CRISM observations available at each site, in order to observe time-dependent behavior in a controlled way.

Results: At Palikir Crater we defined an ROI dominated by bright fans (Figure 1), which are inferred to be deposits from past RSL activity. These fans have a distinct color in both HiRISE and CRISM images (Figure 1, 2). A broad absorption edge at 530 nm was ob-

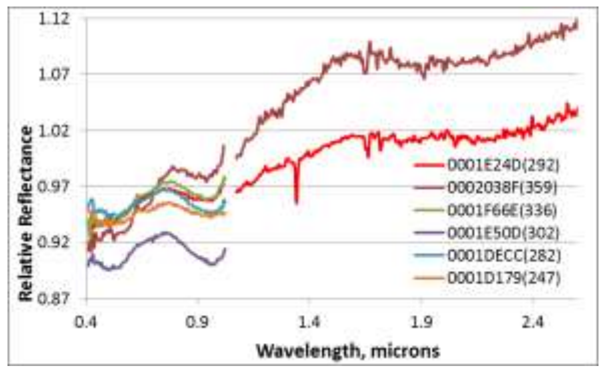

Figure 3. Seasonal variability in spectra of Palikir Crater RSL and fans. For each spectrum, the key lists its CRISM image ID (with season Ls in parentheses).

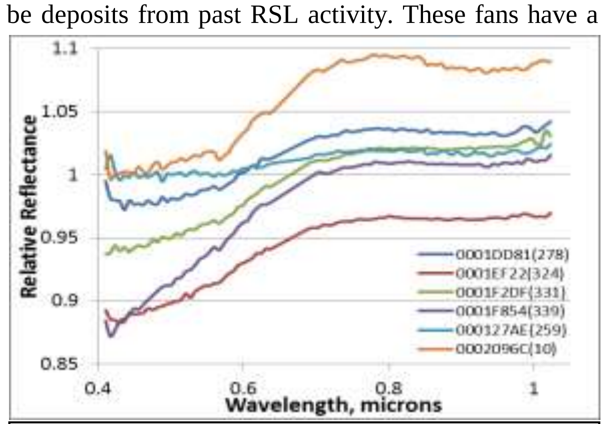

Figure 4. Seasonal variability in spectra of Tivat Crater RSL and fans, with key as in Figure 3.

served along with a band centered near 950 nm, with the depth of both bands varying over time (Figure 3). Specifically, the absorption bands are weakest prior to the onset of RSL activity (Ls 247) and strongest at the time (Ls 302) when the High Resolution Imaging Science Experiment (HiRISE) observed peak RSL activity. A broad absorption at 2100 nm is also observed in the IR portion of the spectra, where available. A similar pattern has been observed in other locations, including Tivat Crater, where a 530 nm absorption is observed to strengthen and a 930 nm band appears late in the RSL activity season (Figure 4). However, at sites other than Palikir Crater, the spatial extents of RSL and the fans are much smaller, so our ROIs likely include significant contributions from outside the small features of interest.

In Raga crater, we defined ROIs on the equator-facing slopes of the crater. The spatial extent here again is much lower for both RSL and the fans, so the ROIs likely include other materials. We observed a

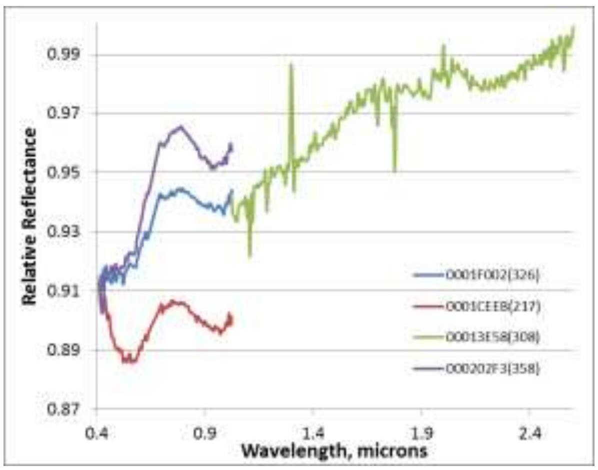

Figure 5. Seasonal variability in spectra of Raga Crater RSL and fans, with key as in Figure 3.

similar seasonal pattern at this location, with the 530 nm band depth observed to increase with increasing RSL activity. The seasonal pattern for the 950 nm band is less straightforward here.

We have looked at CRISM data, where available, from all other confirmed RSL sites from the southern mid-latitudes of Mars. Our results have been consistent in that we observe the 530 nm and 950 nm absorption at most RSL sites. We have also analyzed CRISM images for confirmed RSL sites in Valles Marineris, and they show a similar pattern.

Discussion: The 950 nm absorption band from the VNIR data combined with a broad, shallow band centered around 2.1 µm (Figures 3,4,5) could be attributed to pyroxene with small amounts of red hematite. The red hematite would also account for the observed absorption at 530 nm, the ~700 nm shoulder, and a ~1000 nm pyroxene absorption shifted to a slightly shorter wavelength than expected [e.g., 6]. The inferred fluctuation in pyroxene signature on RSL slopes (relative to the surrounding terrain) seems most readily explained as due to grain size sorting within the fans, in which a fine dust component is removed, leaving a coarser-grained residue with stronger spectral signatures of pyroxene and red hematite in the coarse component. The enhanced 530 nm band could also originate from an additional ferric component that changes in abundance over the RSL season.

Alternatively, the 950 nm absorption band could be attributed to a ferric sulfate such as botryogen [5] or a ferric oxyhydroxide such as lepidocrocite [6]. An alternative possibility is ferrous sulfate [5], but Fe^{2+} sulfates alone would neither explain the 530 nm band (attributed to Fe^{3+}) nor provide substantial freezing point depression for brine formation. In addition, we observe no OH or H_2O-related absorptions in the IR that should be present for these secondary phases.

In principle, seasonal fluctuations in spectral properties of RSL sites could also be due to wetting of the substrate. A wet substrate would lower the overall reflectance and deepen the overall band depths [7]. At Palikir Crater, the deepest band depth and the lowest reflectance occur during maximum RSL activity. If RSL are brines then it is possible that the wetness of the substrate is responsible for lowering the overall reflectance and deepening the band depth. A similar pattern is also observed in Tivat crater, where the shallowest band depth at 530 nm occurs at Ls 259 when we observe little or no RSL activity, and the deepest band depth occurs at Ls 339. IR hydration features (not yet observed) would also be expected for a wet surface, but these may vanish more rapidly than VNIR reflectance features [9]. At Raga Crater, the seasonal pattern (if any) is not yet clear.

We are continuing to monitor both equatorial and mid-latitude RSL sites with CRISM, looking for seasonal changes that might further constrain RSL formation processes.

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