RECENT GULLY ACTIVITY ON MARS: CONSTRAINTS FROM COMPOSITION AS SEEN BY CRISM ON MRO.

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Introduction: Martian gullies are widespread on Mars, with most occurrences found in the southern hemisphere [e.g., 1-7]. Indicative of recent downslope movement, their initial discovery was taken as evidence for recent liquid water activity on Mars [1-2]. Since, multiple alternative models have been proposed for their formation mechanism, including groundwater release [e.g., 1-2, 4, 8], melting of snow or near-surface ground ice [e.g., 6-7; 9-10], dry granular flows [e.g., 11-12], or alternatively different CO_2-driven mechanisms, including release of liquid CO_2 [e.g., 13] and CO_2 frost sublimation [e.g., 14-18].

Recent studies using high resolution images obtained with the High Resolution Imaging Science Experiment (HiRISE) on the Mars Reconnaissance Orbiter [19] have revealed morphological changes to gully channels and aprons over intervals as short as one Martian year [16-18; 20-22]. These studies demonstrated that active gullies are widespread and are consistent with seasonal activity [16-18; 20-22]. Some authors have proposed liquid water in the form of melting of H_2O-ice as the driving mechanism for the observed activity [20-21], while others have supported a mechanism driven primarily by CO_2 frost sublimation [16-18; 22].

Investigation: To determine if compositional information could provide additional insight into gully formation and seasonal activity, we analyzed over 100 images of gullies and their apron deposits taken with the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on the Mars Reconnaissance Orbiter (MRO) [23] over multiple Martian years.

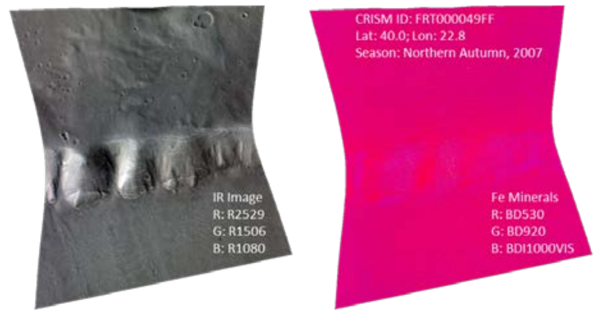

Figure 2: Spectrally indistinct gullies coated in dust.

Newly processed prototype TRR3 (calibration level 3) and Map-projected Targeted Reduced Data Record (MTRDR) hyperspectral image cubes [24] were used to identify and extract spectral information from multiple locations in the northern and southern hemisphere of Mars. These included 18m/pxl full resolution FRT and 36m/pxl high resolution HRL and HRS CRISM images. Additional coordinated high resolution HiRISE images (0.25-1m/pxl) were used to provide detailed morphological information at individual sites, while Mars Orbital Laser Altimeter (MOLA) and HiRISE DTM data were used to obtain topographical information. Our study focused on non-dune Martian gullies, which are much larger landforms than gullies on Earth and are more comparable in size to terrestrial ravines or gorges [25].

Observations: Many of the gullies observed in our study are spectrally indistinct from their surroundings and coincide with high albedo regions (Fig. 1). This is most likely due to mantling by martian dust (Fig. 2), which suggests a lack of gully activity (i.e. older age) or fast rate of dust accumulation.

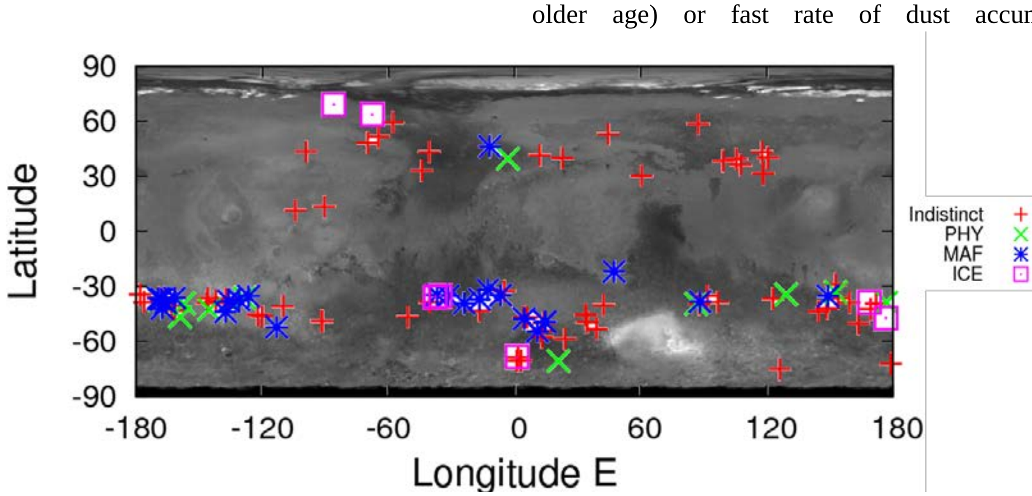

Figure 1: Distribution of martian gullies studied with CRISM and predominant spectral signatures identified. Background is an albedo map generated using MOC data.

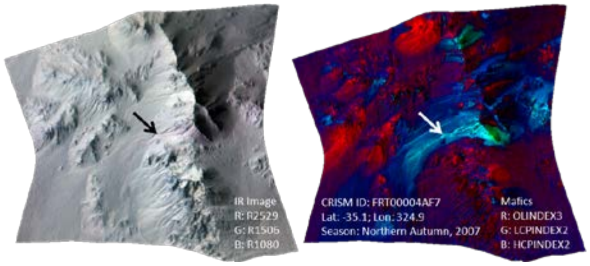

Figure 3: Mafic material transported downslope (arrow).

Detections where spectral contrast from surroundings was observed were found to predominate in the southern hemisphere and coincided with locations outside or near the edge of high albedo regions (Fig. 1). In these instances, gullies exposed and transported underlying material downslope. This material consisted predominantly of mafic composition (Fig. 3). In few instances, spectral signatures for phyllosilicates and sulfates were detected. However, these occur in pre-existing layers that are exposed and transported downslope. Rarely were spectral signatures for hydrated minerals or alteration products observed in place within gullies that transported mafic material downslope, indicating very limited chemical interaction with liquid water.

Spectral evidence for seasonal ice was observed in mid- to high latitude gully channels and their apron deposits. These spectral signatures were consistent with the presence of both CO2 and H2O ice (Fig. 4). However, in some cases only detections for H2O ice were observed, primarily in shawdowed regions and steeper slopes with angles >> 20 degrees. Analysis of slope data suggest that at these steep slope angles, little volatile material would be needed to cause transport of material from the surface [26]. Thus, the freeze/thaw cycle of seasonal frost may suffice in incising gullies on Mars.

Summary: Most gullies on Mars are spectrally indistinct from their surroundings, indicating older age due to inactivity or active coating by dust. In instances where mineralogic signatures are detected, they primarily reflect underlying material. This implies ongoing activity that prevents dust accumulation from masking spectral signatures. However, gullies do not show spectral evidence for deposition of hydrated minerals or in situ alteration associated with long-lived water-rock interactions. Observations of freeze/thaw activity from seasonal CO2/H2O frost in mid- to high-latitude gullies contribute to recent gully formation and evolution. Taken all together, our observations suggest a limited role for liquid water in the formation of gullies and their deposits.

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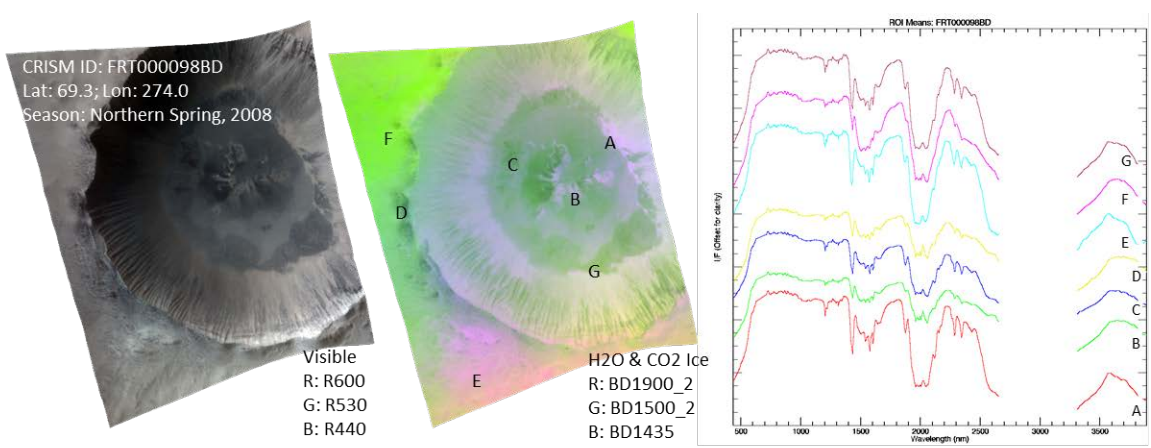

Figure 4: Martian gullies with CRISM spectral parameters and signatures consistent with both CO2 and H2O ice.