Compositional Mapping of the Martian South Polar Residual Cap using hyperspectral data from CRISM

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1. Introduction

We present our research on compositional characterization of the Martian South Polar Residual Cap (SPRC), with a focus on the detection of organic signatures within the dust content of the ice. The SPRC exhibits unique CO_2 ice sublimation features known colloquially as 'Swiss Cheese Terrain' (SCT). These circular depressions are dynamic, exhibiting seasonal scarp wall retreat, which may expose dust particles previously trapped within the ice. Here, we identify suitable regions for potential dust exposure on the SPRC, and use data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board NASA's Mars Reconnaissance Orbiter (MRO) satellite to examine infrared spectra of scarp walls to establish the mineral composition of exposed dust, to eliminate the spectral contamination effects of ices on sub-pixel features, and to assess whether there might be signatures indicative of Polycyclic Aromatic Hydrocarbons (PAHs). Spectral mapping has established pure CO_2 and H_2O local ice signatures, identified compositional differences between depression rims and the majority of the SPRC, and CRISM spectra have been corrected to minimise the influence of CO_2 and H_2O ices. Whilst no conclusive evidence for PAHs has been found, depression rims are shown to have higher water content than regions of featureless ice, and there are indications of magnesium carbonate within the dark, dusty regions

2. Background

While Mars was not initially thought to have been a planet with a dynamic surface, repeat observations starting with the Mariner missions of the 1960s [1] have indicated otherwise. In particular, the polar caps exhibit significant change over time, both seasonal and long term. On board MRO, is an imaging spectrometer, CRISM [2] attaining spatial resolutions of ~20m and spectral resolutions of 6nm, which can analyse compositional properties of the Martian surface. Mars' south polar cap consists of a permanent 400km diameter layer of solid CO_2, 8m thick, overlaying water ice layered deposits [3].

So-called "Swiss Cheese Terrain" (SCT) is an unique surface feature found only in the SPRC on Mars. Its characteristic appearance (shown in Figure 1) is thought to be caused by seasonal differences in the sublimation rates of water and CO_2 ice [4]; scarp retreat through sublimation exposes material, including dust, previously trapped in the SPRC which can then be analysed using CRISM.

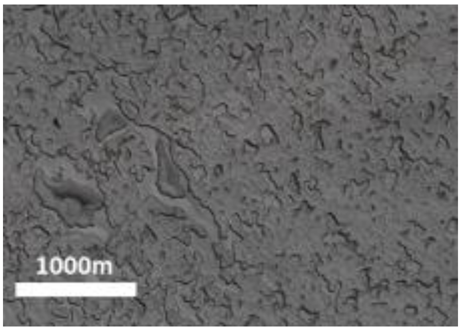

Figure 1: Example of SCT sublimation features (CTX: B08_012572_0943_XI)

a. Polycyclic Aromatic Hydrocarbons

PAHs are a group of chemical compounds consisting of benzene rings of hydrogen and carbon [5] and are considered to be important in theories of abiogenesis; the search for organic molecules on Mars is important in ascertaining Mars' past conditions, and current habitability [6].

PAHs are abundant throughout the universe, coalescing in space within dust clouds, [7] and they have been detected on two of Saturn's icy moons, Iapetus and Phoebe [8]. The delivery of complex organic compounds to planetary surfaces via bolide impact is a very important concept in astrobiology. The ability to identify PAHs could prove a critical tool in the search for putative locations for extra-terrestrial organisms.

To date, the hypothesised connection of Martian SCT and the presence of PAHs has not been systematically examined.

3. Methods

Initially, only Full Targeted Resolution (FRT) CRISM products have been considered for study to try to maximise spatial resolution (~20m/pixel) of small-scale SCT features. Analysis of the SPRC has been carried out using HiRISE, CTX, MOC-NA and HRSC imagery to better constrain regions of interest, and select CRISM scenes for spectral analysis. Five (5) candidate scenes were chosen for further analysis.

The CRISM Analysis Tool (CAT) plugin for ENVI software was used to process the CRISM scenes with corrections for photometry, atmosphere, image artefacts, 'despiking' and 'destriping', and to generate summary products. Forty-four (44) spectral summary products based on multispectral parameters are derived from reflectances for each CRISM observation that can be used as a targeting tool to identify areas of mineralogical interest for further analysis [9]. Those of particular interest to this investigation are those which highlight carbonate overtones, along with CO_2 and water ice, in order to differentiate materials of astrobiological interest from the bulk of the SPRC.

Region of Interest (ROI) band thresholds were used to identify the strongest 10% of CO_2 and H_2O ice signatures from each scene (Figure 2, left), and then ROIs of a minimum of 25 pixels chosen from the same across-track region of the scene as the dark-rim features to provide local 'pure' ice spectra. These samples were then used to carry out correction to remove the overwhelming effects of ice spectral signals on dust rim spectra.

Pelkey's summary products [9] were utilized to create RGB composite images of regions of interest to identify regions of spectral difference around dust rims (figure 2, right). Spectra for specific rim features with strong carbonate overtone responses, corrected for ices, were then analysed and compared to laboratory spectra for Martian mineralogy and PAH signatures.

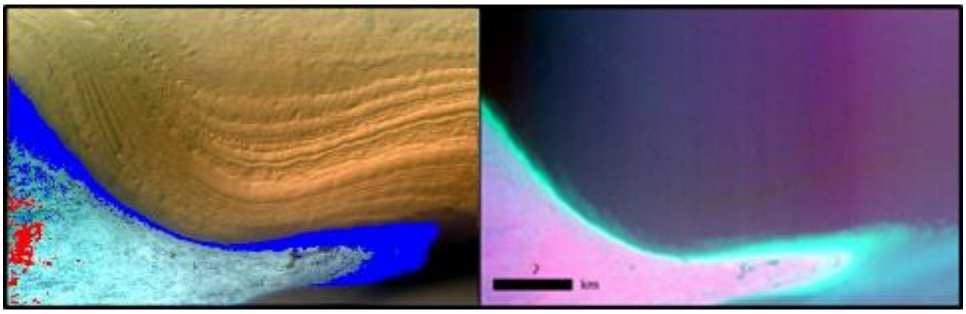

Figure 2: Left: 'True colour' visualisation of Site 1 from CRISM bands R = 230 G = 75 B = 10. Strongest 10% spectral responses for ices shown in red (CO_2) and blue (H_2O). Right: False colour visualisation of Site 1 using Pelkey (2007) summary products R = 1435 (CO_2 ice) G = 1500 (H_2O ice) B = BDCARB (carbonate overtones)

4. Conclusions

There are clear spectral differences between dust rims and non-rim regions, with indications of carbonate components within SCT dust rims. CO_2 ice signatures are a limiting factor in identifying PAHs as the removal of CO_2 ice spectrum may also remove subtle features in the 3.3µm PAH region of CRISM spectra. Work is currently being carried out to look for compositional changes over time in dust-rich regions, and how spectral changes relate to dust content and morphological processes. Further spectral data is also being collected on CO_2 and water ice mixtures to better determine their spectral contamination.

5. References

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Short Summary

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