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Hyperspectral characterisation of the Martian south polar residual cap using CRISM

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Abstract

We present our research on hyperspectral characterization of the Martian South Polar Residual Cap (SPRC), with a focus on the search for 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 flat floored, circular depressions are highly dynamic, and may expose dust particles previously trapped within the ice in the depression walls and partially on the floors. Here we identify suitable regions for potential dust exposure on the SPRC, and utilise data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board NASA's Mars Reconnaissance Orbiter (MRO) satellite to examine infrared spectra of dark regions to establish their mineral composition, to eliminate the effects of ices on sub-pixel dusty features, and to assess whether there might be signatures indicative of Polycyclic Aromatic Hydrocarbons (PAHs). Spectral mapping has 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 ice. Laboratory experiments have generated new spectra for PAHs relevant to Mars, and their detectability limits within the SPRC. Whilst no conclusive evidence for PAHs has been found, depression rims are shown to have a higher water content than regions of featureless ice, and there are indications of magnesium carbonate within the dark, dusty regions.

1. Introduction

While Mars was initially not 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. 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 [3].

Swiss Cheese Terrain (SCT) is an unique surface feature found only in the SPRC. 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 may expose dust particles previously trapped in the SPRC which can then be analysed using CRISM.

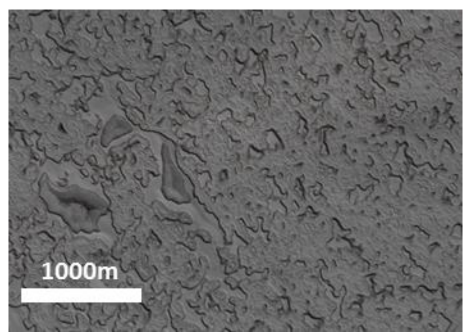

Figure 1: SCT sublimation features (CTX: B08_012572_0943_XI)

1.1 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, and have been found to coalesce in space within dust clouds, [7] and have been detected on two of Saturn's icy moons, Iapetus and Phoebe and comet 67P [8][9]. The delivery of complex organic compounds to established, habitable planets 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 Swiss Cheese Terrain and the presence of PAHs has not been systematically examined.

2. 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. 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 [10]. 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 spectral differences 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.

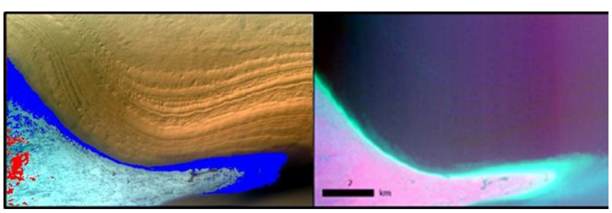

Figure 2: : Left: 'True colour' visualisation of Site 1 from CRISM bands R = 230 G = 75 B = 10. Strongest 10% spectral responses for ices shown in red (CO2) and blue (H2O). Right: False colour visualisation of Site 1 using Pelkey (2007) summary products R = 1435 (CO2 ice) G = 1500 (H2O ice) B = BDCARB (carbonate overtones)

In addition, the Europlanets Transnational Access Award was used in order to carry out a series of laboratory experiments to generate a diagnostic spectrum for PAHs of astrobiological interest in the context of Mars, to constrain the detectability limit of PAHs in CO_2 ice, and to establish PAH spectral features at wavelengths other than the absorption feature at 3.29 μm, where they might be easier to discern within the CO_2 ice spectrum.

3. Conclusions

There are clear spectral differences between dust rims and non-rim regions, with possible 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 destroy subtle features in the 3.3μm region of CRISM spectra. New features for PAHs at lower wavelengths have been established through laboratory experiments, as well as their detectability limit in SPRC conditions using the CRISM instrument's parameters. These will be applied in future to search for PAHs.

Acknowledgements

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