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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 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 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 ther 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. 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.

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, 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 [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.

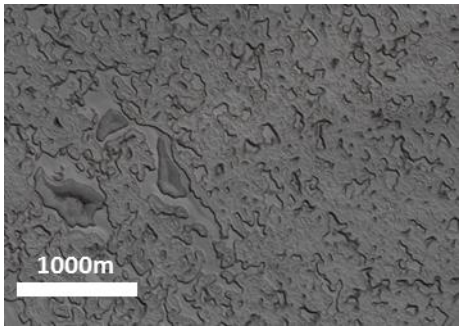

Figure 1: SCT sublimation features (CTX: B08_012572_0943_XI)

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 [8]. 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 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. 72 FRT CRISM scenes were identified as containing SCT; these were arranged into groups of stacked images, resulting in 13 stacks each containing several FRT scenes taken over a period of 3 Martian years, totalling 55 images, which could then be examined for temporal and spatial spectral changes.

The CRISM Analysis Tool (CAT) plugin for ENVI software was used to process the 55 CRISM scenes with corrections for photometry, atmosphere, image artefacts, 'despiking' and 'destriping', and to generate summary products. 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, and CO_2 and water ice, in order to differentiate materials of astrobiological interest from the bulk of the SPRC.

Pelkey's summary products were utilized to create RGB composite images of regions of interest to identify regions of spectral difference around dust rims (figure 2).

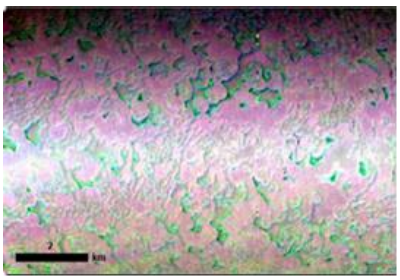

Figure 2: False colour visualization of CRISM scene 00005D24. Red: CO_2 ice, Green: H_2O ice, Blue: carbonate over-tones

3. 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 CO2 ice spectrum may also remove subtle features in the 3.3μm 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.

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