HYPERSPECTRAL MAPPING OF THE MARTIAN SOUTH POLAR RESIDUAL CAP USING LABORATORY ANALOGUES AND ORBITAL IMAGERY.

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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 shortwave infrared spectra of dark regions to establish their mineral composition and evolution over time, compare the results to laboratory analogues, and assess whether there might be any spectral signatures indicative of Polycyclic Aromatic Hydrocarbons (PAHs).

Laboratory experiments have generated new spectra for PAHs relevant to Mars, and established their detectability limits within SPRC analogues. Whilst no conclusive evidence for PAHs has been found, depression rims are shown to have a higher water content than regions of featureless ice, to exhibit changes in dust content as they evolve, and there are indications of magnesium carbonate within the dark, dusty regions.

Introduction: Dynamic features have increasingly been observed on Mars; repeat observations starting with the Mariner missions of the 1960s [1] have indicated the Martian Surface exhibits a range of interesting changing surface processes. In particular, the polar caps exhibit significant change over time in addition to seasonal changes in ice coverage. On board MRO is an imaging spectrometer, CRISM [2] attaining spatial resolutions of ~20m and spectral resolutions of 6nm, which can be employed to analyse compositional properties of the Martian surface. The south polar cap of Mars consists of a permanent 400km diameter layer of solid CO_2, around 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.

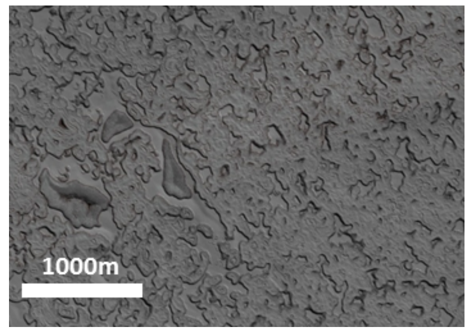

Figure 1: SCT sublimation features (CTX: B08_012572_0943_XI)

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 as well as on comets [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 provide 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.

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, and to generate summary products. 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]. 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. 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.

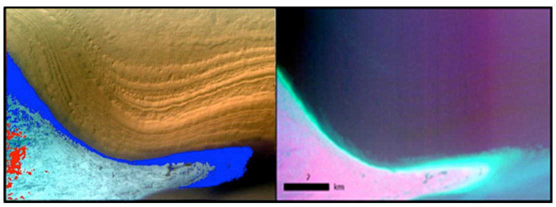

Figure 2: Left: 'True colour' visualisation of Site 1 from CRISM bands R = 230 G = 75 B = 10. Strongest 10% spectral responses for ices shown in red (CO2) and blue (H2O). Right: False colour visualisation of Site 1 using Pelkey (2007) summary products R = 1435 (CO2 ice) G = 1500 (H2O ice) B = BDCARB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

Laboratory experiments were performed to constrain the detectability limit of PAHs, and to establish PAH spectral features at wavelengths other than the well-known absorption feature at 3.29 µm. There is currently no existing published evidence of PAH detection within CO_2 ice features. The site of the laboratory experiments was the "Cold Surface Spectroscopy" facility (CSS) at the Institut de Planétologie et Astrophysique de Grenoble (IPAG) Grenoble, France using the spectro-gonio radiometer and its CarboN-IR environmental cell, which have been specifically developed for studying planetary analogues.

In addition, both unsupervised classification and comparison with laboratory analogue spectra is used to ascertain end member ratios and look at compositional changes over time, and the relationship between SCT morphology and dust content.

Results: The detectability limit of PAHs was established within SPRC analogues, end member spectra have been established for all components of interest, and new diagnostic absorption features for PAHs have been recorded at a number of wavelengths.

There are clear spectral differences between dust rims and non-rim regions, with indications that the initial stages of SCT pit formation result in lower dust content on pit rims as the scrap walls collapse, with an increase in dust content as the fully formed pits become more circular and retreat laterally, leaving behind concentrations of dust. No in-situ evidence of PAHs has been observed, but this work provides the necessary baseline spectra, detectability limits and understanding of pit formation relating to dust content, to improve interpretation of orbital data, and will form the basis for continuing research of dynamic features on Mars in order to detect organic material, and contribute to the search for habitable environments on Mars.

References:

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