WHAT WAS THE ROLE OF WATER IN ILD FORMATION ON MARS?: INSIGHTS FROM NEW CRISM TECHNIQUES. K. S. Hill[1], J. C. Bridges[1], K. B. Smith[3], D. G. Tragheim[3] and S. J. Davies[2], [1]Space Research Centre, Dept. of Physics & Astronomy, University of Leicester, Leicester, LE1 7RH, UK. [2]Dept. of Geology, University of Leicester, LE1 7RH, UK. [3]British Geological Survey, Nottingham, NG12 5GG, UK, ksh12@le.ac.uk.

Introduction: Interior Layered Deposits (ILD) can potentially reveal the history of climate variation on Mars. Many ILD successions are found in equatorial regions within large impact craters such as Becquerel Crater, 22^{0}N, 353^{0}E or topographical lows like Valles Marineris. We consider the role of water in the formation of the ILDs within craters. Becquerel contains light-dark cyclic layers on the meter scale as recent HiRISE results demonstrate. The processes which lead to ILD are as yet unknown with various formation models proposed; including lacustrine events, wind-blown sediments or a similar mechanism to the North Polar Layered Deposits (NPLD) [1,2,3].

Here we report the results of a study applying a principal component analysis technique to extract statistical spectral variance of CRISM scenes in order to better understand the mineralogical information that can be extracted. Our ultimate aim is to constrain the formation of the Interior Layered Deposits (ILDs), and in particular assessing the role of water in their formation, comparing the results from different analysis methods.

We hypothesize that the sediments are analogous to the current NPLD which suggests a climatic control dominated by orbital forcing [2,3,4,5] and deposition from the air rather than water. The 10:1 average cyclicity of ILD layering in Becquerel suggests deposition from the air was also controlled by regular variations in the climate. CRISM can help assess the role of water in the formation of ILDs by indicating the presence, or lack of, hydrated minerals such as clays or sulfates.

Data: CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) is a visible-near infrared (VNIR) and infrared (IR) imaging spectrometer on-board the Mars Reconnaissance Orbiter (MRO). In targeted mode, CRISM offers the opportunity for interpretation of remote sensing hyperspectral data with extensive coverage of the surface of Mars (15-19 m/pixel, 362-3920 nm and at 6.55 nm/channel over 544 channels [6]).

Tests of the method have been conducted using the Nili Fossae region which has been well characterized in published works [8]. The main focus of the study was on the ILD sediment mounds within craters of the Arabia Terra region, Becquerel Crater and Schiaparelli Crater 0.08^{0}S, 14.4^{0}E, and the ILD mounds of Galle Crater, 51^{0}S, 331^{0}E, Gale Crater, 5^{0}S, 137^{0}E, with comparison to several areas of NPLD.

Method: Data processing uses the CRISM Analysis Tool (CAT) [6] in conjunction with ENVI. The spectral data has been processed to account for all instrumental effects and reduced to radiance from which I/F are calculated. This data is corrected for photometric and atmospheric effects by division of the solar incidence angle and taking a ratio to the scaled transmission spectrum of the atmosphere, respectively. The transmission spectrum is derived from the column density of CO_2 across a CRISM observation at Olympus Mons. CRISM Clean is applied to filter the data and reduce the effect of noise before the data is map-projected.

Data Analysis: The currently supported method to find spectral trends within the chosen CRISM scenes, uses mineral indicators. These result in band ratio mineralogical maps [6] which are then used to guide the extraction of spectra which are compared to a reference library for identification [7,8,9]. This process requires a dusty, spectrally indistinct profile with which to normalise the data, to remove topographical and residual atmospheric effects; emphasizing a dominant mineral signature. This method has shown a lack of hydrated mineral signatures in the Becquerel Crater sediments which is consistent with the orbital forcing hypothesis.

We present a comparison of the capabilities and limitations of a variety of multispectral and hyperspectral methods, used as standard in other areas of remote-sensing, when applied to CRISM using CAT and ENVI 4.7 image processing software. These include Principal Components Analysis (PCA) and Minimum Noise Fraction (MNF) transforms, which effectively reduce the redundancy often found in hyperspectral data.

Testing: These alternative methods were tested on the strong hydrated signatures of Nili Fossae, 22^{0}N, 76^{0}E and the dust-covered Tharsis region 10^{0}N, 247^{0}E [1,8]. The statistical nature of the PCA results allows for a more robust selection of a spectrally bland denominator spectrum with which to ratio to a region of interest in order to remove artifacts, as opposed to simply selecting a ‘dark’ pixel. Particularly over the Nili Fossae area, the PCA technique highlighted more subtle spectral variation, including the mixing of end-members. The Tharsis region highlights the difficulties of the ratio technique when the CRISM scene holds little variation in surface type with noise artifacts of the instrument dominating the cause of the spectral variance.

Results: The statistical analysis of PCA on the spectral variance within the Arabia Terra region corroborate the initial findings using the mineral indicators method. The ILD show little variance in composition across the formation, with a flat, featureless ratioed spectrum showing no evidence of hydration.

Discussion: The use of the PCA method has improved the detail of the mineralogical maps in identifying the subtle changes in the spectral content, aiding more accurate selection of whole-pixel spectra for further analysis. Results from Nili Fossae support the previous identifications and abundances of fayalite, smectite and carbonate [8].

One possible explanation of the null result in Arabia Terra ILDs is that the spectral signatures in this region are masked by an alteration layer, potentially a global dust covering, which would give rise to spectroscopic uniformity [10,11,12]. However the Mars Global Surveyor Thermal Emission Spectrometer (MGS-TES) recorded a thermal inertia of >300 tiu across Arabia Terra [13] which would suggest that dust conditions were not prohibitive. In addition, the visible imagery exposes a clear distinction between the ILD and the dark sands at its base. The similarity between the spectral signature of the dark sand and the ILD alludes to a homogenous basaltic composition. On balance the lack of hydrous minerals detected by CRISM in the ILD of Becquerel and Schiaparelli Crater support the formation theory of dust deposition during periods of high obliquity and makes deposition from water a more unlikely mechanism.

Using the PCA technique as a statistically-based analysis approach improves the likelihood that the full mineralogical variety of a CRISM observation will be identified.

References: [1] Kargel J. S. (2004) *Mars A Warmer, Wetter Planet*, Springer 557pp. [2] Laskar J. et al. (2004) *Nature, 419*, 375-377. [3] Bridges J. C. et al. (2008) *LPSC XXXIX*, #1913. [4] Hill K. S. et al. (2010) *LPSC XXXXI*, #2227. [5] Mangold, N. et al. (2003) *3rd Mars Solar Sci. Con*. #8071. [6] Pelkey S. M. et al. (2007) *JGR 112*, E08S14, 18. [7] Bishop J. L. et al. (2008) *Science 321*, 5890, 830-833. [8] Mustard J. F. et al. (2008) *Nature 454*, 305-309. [9] Ehlmann B. L. et al. (2009) *JGR 114*, E00D08, 33 [10] Flahaut J. et al. (2010) *LPSC XXXXI*, #1524. [11] Isobe H, et al. (2010) *LPSC XXXXI*, #1292. [12] Clark B. C. (2010) *LPSC XXXXI*, #1419. [13] Putzig N. E. et al. (2007) *Icarus, 191*, 68-94.

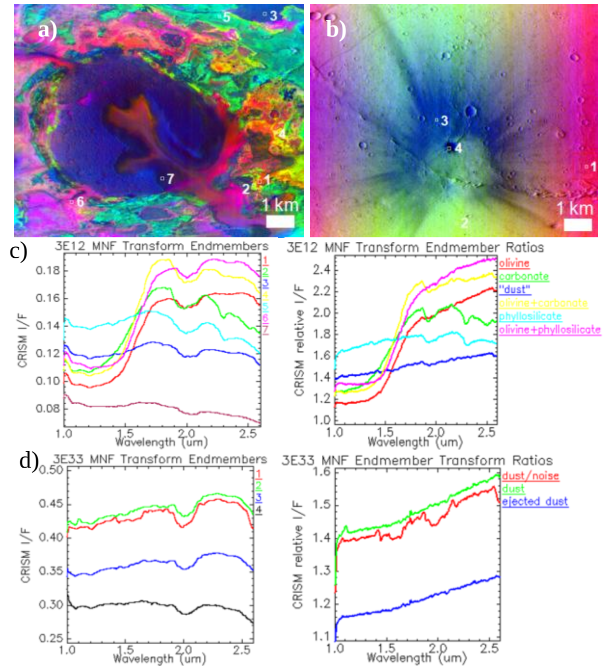

Figure 1 – Endmember extraction results using PCA bands 1,2,3; spectra colour matched to image, of a) hydrated minerals in Nili Fossae b) bland dust-covering of Tharsis and the raw extracted CRISM spectra and the ratioed results c) Nili Fossae d) Tharsis.

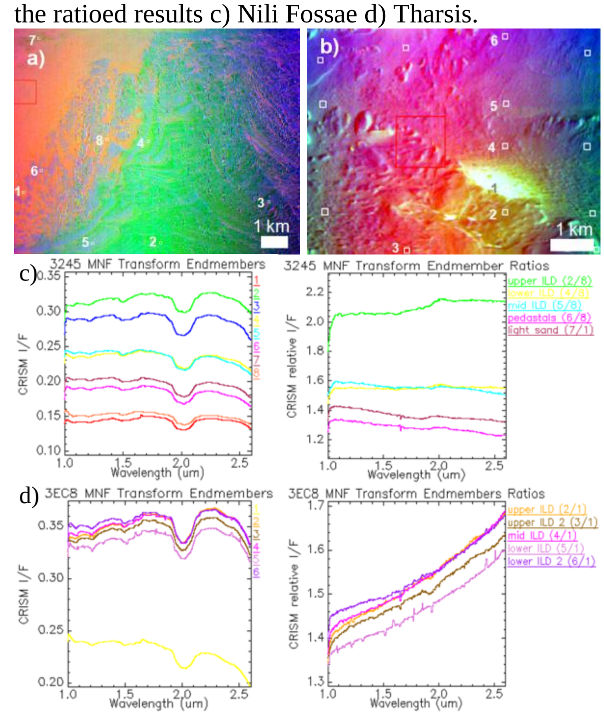

Figure 2 – Endmember extraction results using PCA bands 1,2,3; spectra colour matched to image, of Arabia Terra ILD a) Becquerel Crater, b) Schiaparelli Crater and the raw extracted CRISM spectra and the ratioed results c) Becquerel Crater d) Schiaparelli Crater, showing a lack of hydration features.