DEVELOPING TOOLS TO HIGHLIGHT THE PRESENCE OF CARBONATES IN CRISM IMAGES OF MARS.

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Introduction: CRISM hyperspectral images of Mars have recently been used to identify what are interpreted as magnesium carbonate deposits composed of magnesite mixed with one or more hydrated phases [1]. Using existing approaches to parameterize spectral data from CRISM [2], thousands of high-resolution targeted observations have been examined for occurrences of this material. Results to date indicate that it is found primarily in association with ultramafic materials located circumferentially to the Isidis basin [1]. Given the large number of targeted observations (>9500), the weakness of the carbonate absorptions, and the presence of instrumental noise and artifacts in the data, it is unclear if this result reflects the true extent of the deposits or is limited by methods used to process the data. We are attempting to develop new techniques to identify these carbonates, leveraging the high spectral and spatial resolution of CRISM, to better assess their spatial distribution and geological context.

Approach: Martian carbonates have been observed in telescopic data [3,4], meteorites [5], and possibly dust deposits [6]. They are an expected weathering product of water and basalt in an atmosphere having CO_2 [7] and the conditions appropriate for their formation have been predicted for Mars [8]. However, until recently [1], no carbonate-bearing rock outcrops had been identified. The fact that these deposits have been observed in CRISM targeted observations (~18 m/pixel spatial resolution) indicates that high spatial resolution is essential to detecting them.

In addition, improved approaches may be needed to accentuate these materials at these greater spatial resolutions. A common approach already employed by the CRISM team is the use of spectral parameter maps that highlight the presence of specific mineralogies within a spectral data set. These have been employed with great success on many planetary bodies [e.g., 9, 10] and can effectively identify absorption features associated with a given mineral in a given scene. The existing set of parameters for CRISM [2] was developed based on occurrences of olivine, pyroxene, sulfates, and phyllosilicates detected by OMEGA, and augmented with parameters designed to detect minerals not yet observed, such as carbonates. In the case of carbonates, a calcitic spectrum was assumed. Fig. 1 illustrates three presently employed parameters that are sensitive to magnesite. The D2300 and BD3400 parameters are part of the standard multispectral parameter suite [2] and BD2500 has been recently added for hyperspectral images, as formulated in [1]. These parameters measure the strengths of overtone absorptions near 2.30, 2.51, and 3.4 µm. The presence of all three features can be used to map out the location of carbonates on the surface of Mars, as a "carbonate browse product" (a parameter at 3.9-µm which takes advantage of a strong overtone absorption is also under development).

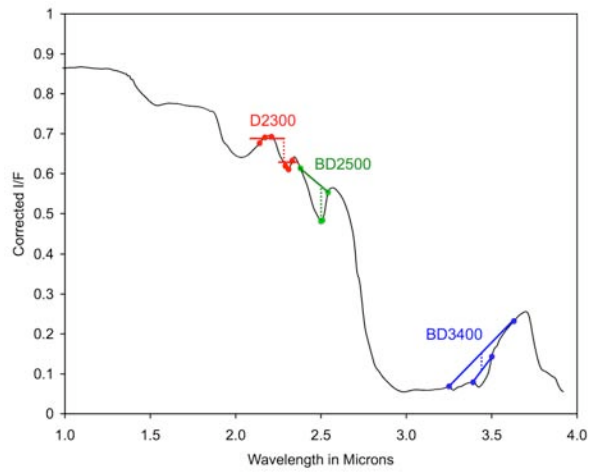

Fig. 1. Example of our approach used to compute carbonate spectral parameters using a laboratory spectrum of magnesite + hydromagnesite. Here the 2.5-µm and 3.4-µm band depths and the falloff of reflectance into the 2.3-µm band in this spectrum are determined.

To demonstrate the usefulness and limitations of this approach to searching for Martian carbonates, we examine two CRISM images of nearby parts of Nili Fossae (Fig. 2). In one image (Fig. 2 a and b), the presence of magnesium carbonates has been reported, along with olivine and phyllosilicates [1]. In the other image (Fig. 2 c and d), the presence of carbonates has also been identified, along with olivine, phyllosilicates, and Fe/Mg smectites. Using the three currently available parameters shown in Fig. 1, browse versions of each image were constructed (using the parameters D2300, BD2500, and BD3400 in the R, G, and B channels respectively) that should highlight carbonates as yellow to white in color (depending on how masked the 3.4-µm absorption is by molecular water). The browse images indicate that carbonates appear to be present in FRT0000B072 and FRT00008389 (albeit in much smaller concentrations for the latter). These results are generally consistent with those of more rigorous analysis [1].

Inspection of Figs. 1 and 2 illustrates two limitations to this approach, both of which we plan to address. First, the existing parameters we used either are "multipurpose," for example measure a generic absorption within about 0.05 µm of a target wavelength (e.g. D2300), or are tuned to look for carbonate features assuming that their wavelength positions are those in calcite (e.g. BD3400). In fact the wavelength positions of absorptions in magnesite are offset from those in calcite, reducing the parameters' sensitivity. This limitation can be addressed by reformulating measures of the three absorptions to be tuned for magnesite.

A second limitation is the presence of noise in the data, which is especially a problem at >2.6 µm due to decreased SNR of the CRISM instrument at these wavelengths [11]. Noise and systematic instrumental artifacts have the effect of masking the 3.4-µm absorption in particular. The standard set of spectral parameters is especially susceptible because it utilizes only selected channels from spectrally oversampled data, and therefore does not utilize the full potential of the hyperspectral data. Noise can be remediated in two ways, by application of improved filtering techniques [e.g. 12], and/or by fitting wavelength segments of each spectrum and evaluating the spectral parameters using the fit instead of selected wavelengths from the data themselves.

Summary: The current standard set of spectral parameters used to represent CRISM data has the capability to detect and map the Mg carbonates recently found on Mars, but is not optimized for this purpose. Any approach also suffers from noise in the data. We will implement several improvements to standard processing of the data to develop an improved method to survey the very large volume of CRISM data for occurrences of carbonates, including reformulating the spectral parameters, applying filtering, and fitting the hyperspectral data to reduce noise. With better products we can more effectively undertake a systematic search of the Martian surface for the presence of carbonates to better understand the geological context of their formation.

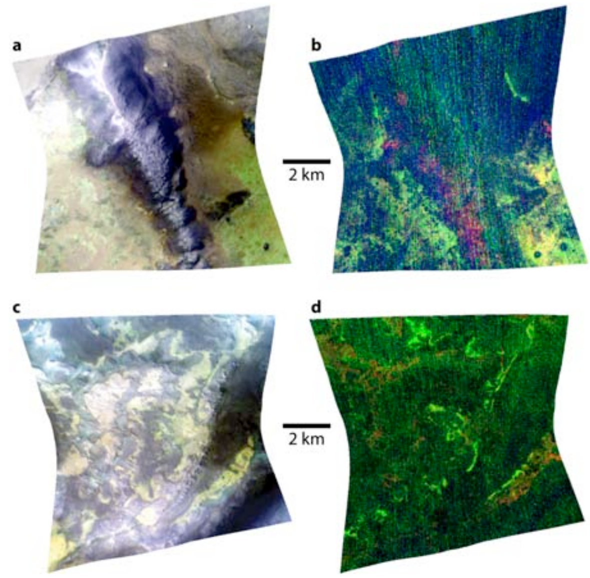

Fig. 2. [a] false-color composite of CRISM targeted observation FRT0000B072 (R-2.38 µm, G-1.80 µm, and B-1.15 µm). [b] Combination of summary parameters D2300 (red), BD2500 (green), and BD3400 (blue). [c] false-color composite of CRISM targeted observation FRT00008389 (R-2.38 µm, G-1.80 µm, and B-1.15 µm). [d] Combination of summary parameters D2300 (red), BD2500 (green), and BD3400 (blue).

References: [1] Ehlmann et al. (2008) *Science, 322,* 1828. [2] Pelkey et al. (2007) *JGR*, *112*, E08S14; [3]W.M. Calvin et al. (1994) *JGR*, *99*, 14659; [4] E. Lellouch et al. (2000), *Planet. Spcae Sci.*, *48*, 1393; [5] Bridges et al. (2001), *Space Sci. Rev.*, *96*, 365; [6] Bandfield et al. (2003), *Science*, *301*, 1084; [7] Catling (1999) *JGR*, *104*, 16453; [8] Pollack et al. (1987), *Icarus*, *71*, 203; [9], Bell et al. (2002) *Icarus, 155*, 119; [10] Lucey et al. (1998), *JGR, 103*, 3679; [11] Murchie et al. (2007), *JGR*, *112*, E05S03; [12] M. Parente, LPSC XXXIX, 2528, 2008.