**INVESTIGATING THE DISTRIBUTION OF MARTIAN CHLORINE SALTS.** J. Hanley[1], B. Horgan[2]. [1]Lowell Observatory, Flagstaff, AZ (jhanley@lowell.edu); [2]Purdue University, West Lafayette, IN.

**Introduction:** The presence of chlorine salts on Mars is important for understanding the geological and chemical history of the planet, as the presence of chlorine salts can help us infer the chemistry and evaporation history of surface lakes and playas. Furthermore, the spectral similarity between perchlorates and sulfates raises the possibility that previous sulfate detections may actually be perchlorates (Fig. 1). This has major implications for habitability, as perchlorates indicate much lower water activity brines, which are less favorable for habitability than sulfates. This is because chloride, perchlorate, and chlorate salts can all suppress the freezing temperature of water significantly, in some cases with a eutectic temperature down to 204 K [1-3]. They also slow down the evaporation rate, extending the lifetime of the liquid water solution. In a key demonstration of the importance of these salts for the stability of water on the surfaces of planetary bodies, perchlorate and chlorate hydrates were recently detected in Recurring Slope Lineae (RSL) [4]. This detection is considered clear evidence for modern transient water activity on Mars, and begs the question: where else on Mars are perchlorate brines present, now and in the past?

**Methods:** We have developed routines specifically for identification and mapping of variations in the wavelength locations of absorption band minima in CRISM spectra [5]. We have begun to apply these routines in order to identify chlorine salts in our specified CRISM images.

The majority of CRISM analyses use spectral indices, however, these indices are not able to differentiate between spectrally similar minerals, e.g. SINDEX and BD1900R. Typically, spectral indices are followed up with manual detailed investigation to characterize the spectral variability. To find and characterize specific minerals (chlorine salts) requires more precise analysis methods. These salts are spectrally similar to common Martian minerals, and may be present as part of a mixture, in isolated patches, or at the margins of larger deposits, any of which would make them difficult to identify with manual inspection. Thus, a major advantage of this study is that it relies on more precise automated methods to help with identifying possible chlorine salt spectra.

To start, we focus on the most unique spectral parameters to detect the possible hydrated chlorine salts. We map the typical hydration bands (*e.g.*, SINDEX, BD1900) and develop a spectral parameter to detect absorption at 2.15 µm, which is a unique spectral characteristic of hydrated perchlorate salts that has previously been used to identify them on Mars [4, 6, 7]. Hydrated salt absorptions tend to occur in several discrete spectral ranges: 1.16-1.20, 1.42-1.47, 1.75-1.82, 1.92-2.00, and 2.19-2.22 µm. We detect these bands as present based on our spectral indices, and then differentiate them from sulfate or other absorption bands based on their minima wavelength positions. We can then produce a map illustrating shifts in the band location corresponding to changing mineralogy (Fig 2b). These maps contribute to overall spectral analysis (Fig 3) and allow mapping of quantitative spectral units at each site (Fig 2d). Mineral units are defined based on both their characteristic band minima as well example, Fig 2d shows three mineral units defined in this image within Columbus Crater. The blue unit is defined as exhibiting band minima between 2.19-2.21 µm, the yellow unit exhibits a 2.4 µm band depth >0.5%, and the red unit exhibits both a 2.4 µm band depth >0.5% and band minima between 1.73-1.76 µm. Similar units to the yellow and blue units were previously mapped by Wray et al. [8], but the red unit is new in this study, and clearly demonstrates that this detailed analysis method can provide additional spectral information even at previously studied sites.
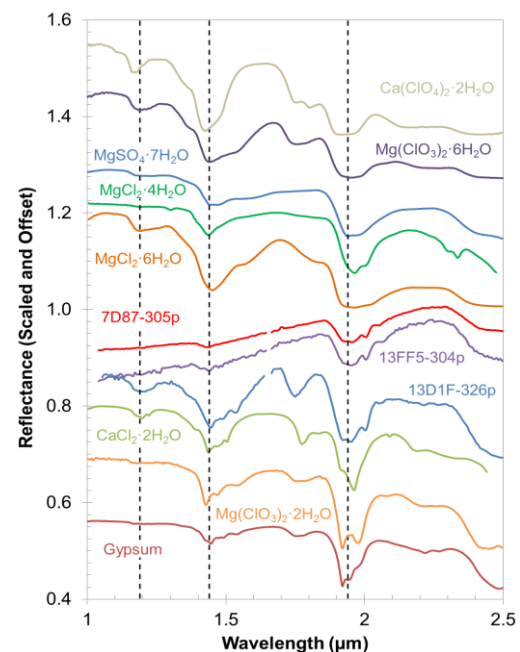


**Figure 1.** *NIR reflectance spectra of CRISM spectra [8] identified as "polyhydrated sulfates" (7D87-305p/13FF5-304p) and "gypsum" (13D1F-326p), along with reference spectra of gypsum, epsomite ($MgSO_4 \cdot 7H_2O$), and various chlorine salt hydrates for comparison [6].*

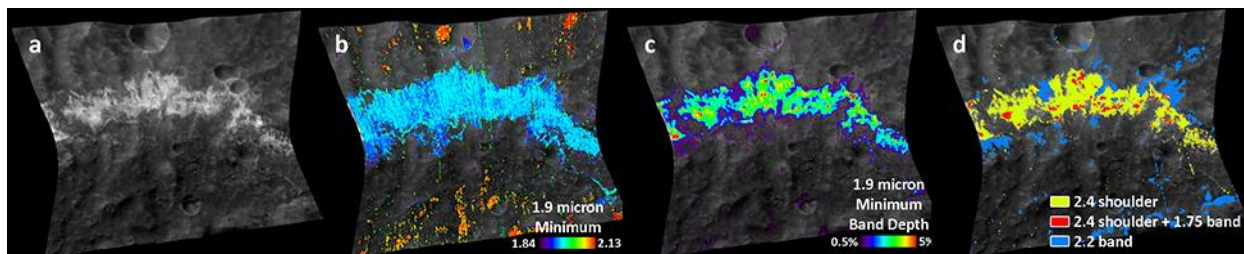*Figure 2. Spectral analysis results in FRT7D87, Columbus Crater. (a) 1.5 µm albedo, projected. (b) Band minima map for the ~1.9 µm hydration band, which shows variation (blue colors) likely due to variations in mineralogy. (c) Band depth at the ~1.9 µm minimum location identified for each spectrum, which shows more widely distributed and stronger hydration than the standard parameter. (d) Spectral units. Yellow: polyhydrated sulfates or spectrally similar phase with a strong 2.4 µm shoulder. Red: spectra with this shoulder as well as a 1.75 µm absorption band. Blue: Al-phyllosilicates with a 2.2 µm band.*
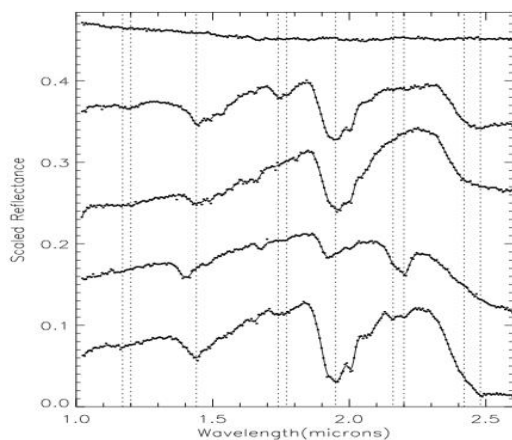


*Figure 3. Comparison of spectra showcasing spectral diversity in FRT7D87, Columbus Crater.*

Fig 3 demonstrates the spectral diversity that can be identified using this methodology. The top spectrum is from within the "spectrally neutral" mask, the second two spectra are from a unit mapped as "polyhydrated sulfates" and the bottom two spectra are classified as kaolinite. However they exhibit spectral variations (e.g. the presence/lack of a 1.75 µm band, or structure within the 1.4/1.9 µm bands) that imply mineralogical variations. These variations are detectable and mappable using our customized spectral indices and band minima mapping techniques discussed above. Based on playa analog studies [9], we expect similar small-scale mineralogical variations in evaporites, which are often heterogeneous due to their formation via precipitation or efflorescence.

**Implications:** We compare variability in our identified spectral units to our extensive database to constrain the salt assemblage present. Spectral variation within these units may include variations in band minima, spectral parameters, band depth, band width, overall slope, and shape of the bands. By using our new techniques, we are able to more accurately map variations and assess the minerals that may cause them. We will also be able to combine various parameters in order to distinguish between salts with similar spectra. For instance, although gypsum is often identified by its distinct triplet in the 1.4 µm band region along with a band at 1.75 µm, some chlorine salts possess these features as well. Gypsum also has a doublet at 2.2 µm that would rule out other salts, *however, some spectra currently identified as gypsum on Mars today do not exhibit this feature.* This is demonstrated by the spectra identified as sulfates, but in some cases may be more consistent with hydrated chlorine salts. The 13D1F from Wray et al. [8] in Fig 1, which were originally spectrum, in particular, exhibits a more complex combination of absorptions than can be explained by sulfates alone. While $CaCl_2 \cdot 2H_2O$ matches the bands at ~1.2 and ~1.4 µm, the 1.75 feature is slightly offset and the 1.9 µm band has a different shape, indicating it's unlikely to be $CaCl_2 \cdot 2H_2O$. It does however, match the spectra of $Mg(ClO_3)_2 \cdot 2H_2O$ well in each feature. Further analysis comparing band minima positions, including structure apparent in many of the 1.4 and 1.9 µm hydration bands will allow us to distinguish each salt.
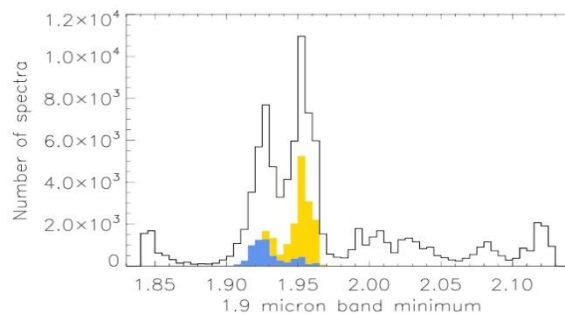


*Figure 4. Histogram of 1.9 µm band minima locations, as mapped in Figure 2b. Black line indicates all spectra with band depths >0.5% (Figure 2c), yellow and blue correspond to units in Figure 2d. The yellow unit exhibits a ~1.95 µm band, consistent with a polyhydrated sulfate or polyhydrated chlorine salt, while the blue unit exhibits a ~1.92 µm absorption consistent with an Al-phyllosilicate.*

 **References:** 1. Altheide T. et al. (2009) *EPSL, 282*, 69-78. 2. Chevrier V.F. et al. (2009) *GRL, 36*, L10202. 3. Hanley J. et al. (2012) *GRL, 39*, L08201. 4. Ojha L. et al. (2015) *Nature Geosci, 8*, 829-832. 5. Horgan B. et al. (2013) *LPSC,* Abstract #3059. 6. Hanley J. et al. (2015) *JGR, 120*, 1415-1426. 7. Massé M. et al. (2010) *Icarus, 209*, 434-451. 8. Wray J.J. et al. (2011) *JGR, 116*, E01001. 9. Lynch K.L. et al. (2015) *JGR, 120*, 599-623.