DETECTION OF CHLORINE SALT SPECTRAL FEATURES IN COLUMBUS CRATER, MARS.

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Introduction: Visible/near-infrared spectra (0.3-2.6 μm) collected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard the Mars Reconnaissance Orbiter has led to the detection of sulfates in regions around Mars including Valles Marineris and Arabia Terra [1]. Polyhydrated sulfate salt spectra exhibit water absorption features at 1.4, 1.9, and 2.4 μm while monohydrated sulfate salt spectra have water absorptions at 2.1 and 2.4 μm [1]. Both types of sulfate spectra are visually similar to spectra of some hydrous chlorine salts [2], suggesting that some previously identified salt deposits may be Cl-rich instead of S-rich. Chlorine salts have yet to be definitively detected from CRISM observations [3, 4], but anhydrous chloride salts (e.g., halite) have been detected using their unique signature in thermal infrared spectra [5, 6], and several Mars lander missions have detected perchlorate compounds [7, 8] and measured chlorine concentrations on the surface of up to 2.62 weight percent [7]. Along with the planet's history of fluvial activity, these detections make it plausible that a variety of hydrous and anhydrous chlorine salts are present on Mars in detectable quantities.

Understanding the distribution of chlorine salts is important because they expand the stability of liquid water on the Martian surface beyond other salts like sulfates. Chlorine salts can lower the freezing point of water down to 204 K [9]. The presence of hydrated chlorine salts could provide a mechanism for water-driven recurring slope lineae. Chlorine salts are known to deliquesce, releasing liquid water from their structure, intermittently causing liquid water flows on Mars under the right humidity conditions [10].

In this study, we used new parameters from [11] to locate CRISM spectra with absorption features associated with chlorine salts. We analyzed the available CRISM images covering salt deposits in Columbus Crater, Terra Sirenum.

New Parameters: The parameters we tested enabled detection of chlorine salt laboratory spectra by measuring absorptions at 2.13 μm, present in hydrated perchlorates, and at 2.22 μm, present in most oxychlorine salts [2, 11]. Mixtures with spectrally similar sulfate salts at these deposits could make a definitive determination of the type of salt difficult as well. However, a CRISM artifact near 1.9 and 2.1 μm provides an additional challenge in orbital detection of these salts [4]. This artifact does not occur in areas of more than 12 contiguous pixels, so sufficiently large detection regions in CRISM images should avoid false positives caused by this artifact. We used numerator spectra from regions of interest which contained at least 12 pixels, and most regions were made of at least 50 pixels.

Methods: CRISM data products were processed to estimated Lambert albedo using the CRISM Analysis Toolkit (CAT) for ENVI. We created summary products of the data as in [1]. We included two additional parameters to assess 2.13 and 2.22 μm absorptions (BD2130 and BD2220 respectively) indicative of chlorine salts defined by [11]. We considered at least three parameter combinations when determining which regions likely contained sulfate or chlorine salts. The first combination, hydrated perchlorates (HPC), corresponded to R/G/B: BD1435/ SINDEX_2/BD2130. Hydrated S- or Cl-salts should appear light green to white in color due to the relative strength of the SINDEX_2 parameter over the other two bands. In practice, the BD2130 parameter was often only weakly highlighted, leading to most salt detections coming from regions that were green to yellow in HPC. The second and third RGB combinations corresponded to R/G/B: BD1400/ BD1750_2/BD1900_R2 and BD2220/BD2165/ BD2190. The second combination includes parameters indicating three different hydration bands. Hydrated chlorine salts should appear white in this combination as all three bands are typically present for these salts. The third combination is meant to identify and avoid kaolinite detections. Chlorine salts should appear red in color in this combination. Finally, we compared these spectral parameter combinations to the default L-detector false color image to view geologic features on the surface and obtain spectra from regions of interest. We did not map-project CRISM images while creating ROIs in order to assist in obtaining spectrally neutral denominator spectra to ratio with from the same columns.

Site of Study: The site of this study is Columbus Crater in Terra Sirenum, which was chosen for study due to the presence of a "bathtub ring" of salts along the crater's rim, likely deposited when the crater contained a paleolake [12]. The high concentration of sulfate salts at this site suggests that chlorine salts could appear in similarly high concentrations over large areas, eliminating two difficulties with CRISM detection. Furthermore, Chaves et al., using CRISM data, found possible detections of Mg-chlorine salt or a mixture of a chlorine salt and gypsum [13]. The new parameters isolating chlorine salt features could assist in obtaining better spectra of this possible chlorine salt located in Columbus Crater.

Results: High values displayed by the BD2130 parameter allowed us to find the best spectra with absorptions unique to chlorine salts. In most images studied, the HPC browse product did not display green pixels, which would have indicated a highlighted BD2130 parameter. Only in 13FF5 and 16CFE did the HPC browse product display highlighted BD2130 pixels that were not column-dependent, and corresponded to the location of identifiable geologic features in the default ENVI window. We did not identify spectra with 2.22 µm absorptions. Pixels highlighted by BD2220 were primarily false-positives caused by the similar wavelengths features that are highlighted by BD2220 and features in phyllosilicates. The close wavelengths between the 2.22 µm feature in several chlorine salts and absorptions in phyllosilicates prevented identification of chlorine salts within the lower phyllosilicate-bearing unit. he spectra that have features most consistent with chlorine salts came from HRL_13FF5, HRL_16CFE, FRT_13D1F, and FRT_17192. These spectra exhibit an absorption shoulder at 2.4 µm, which is present in both sulfate and chlorine salts. These spectra all have a broad absorption

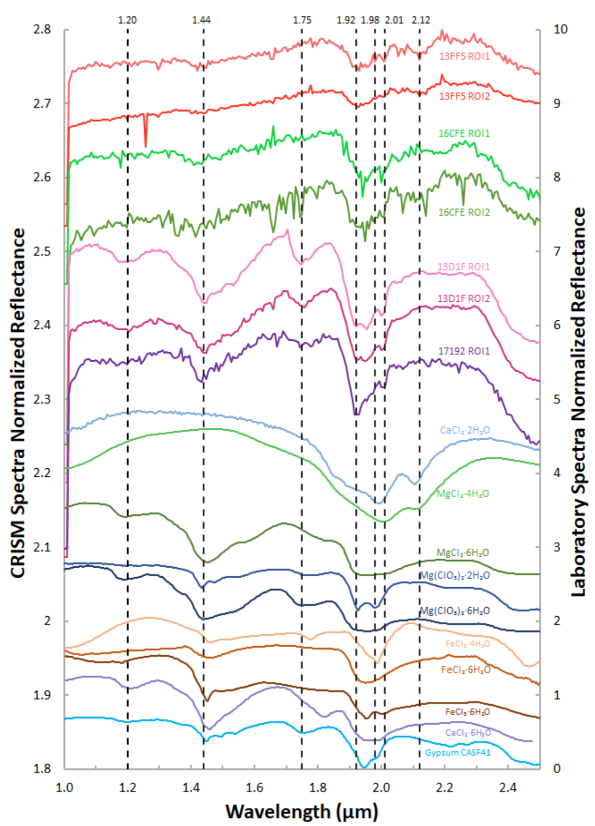

Figure 1. *Comparison of CRISM spectra with lab spectra of Cl-salts [2, 14] and gypsum [CAT spectral library] All spectra are normalized and offset.*

within this range, centered at 1.92 and 1.95 µm. The 1.92 µm absorption matches the lower wavelength absorption in the $Mg(ClO_3)_2 \cdot H_2O$ hydration doublet and does not correspond to an absorption in gypsum. The 1.95 m absorption in the doublets does match an absorption in the gypsum hydration doublet. These spectra also have a possible absorption at 2.01 µm which is present in hydrated Fe-chloride salts. However, this absorption may also be due to atmospheric CO_2, which has a similar absorption and can remain in CRISM spectra after the volcano scan correction is applied [15].

Spectra from two CRISM images have features unique to chlorine salts. Spectra from 13FF5 and 16CFE have an absorption centered near 2.12 µm. $CaCl_2 \cdot 2H_2O$ and $MgCl_2 \cdot 4H_2O$ have similar absorptions at 2.12 µm. The CRISM spectra have a hydration absorption feature centered near 1.43 µm consistent with $MgCl_2 \cdot 6H_2O$, $Mg(ClO_3)_2 \cdot 2H_2O$, $Mg(ClO_3)_2 \cdot 6H_2O$, and $CaCl_2 \cdot 6H_2O$.

Future Work: Tentative identification of chlorine salts, or at least CRISM spectra with absorption features suggestive of chlorine salts, within Columbus Crater provides motivation to use the successful BD2130 parameter in other areas of Mars to identify chlorine salts. Investigation of the other paleolakes in the Southern Highlands where sulfate salts have been previously found could yield similar results, and further refinement of techniques in using the new chlorine salt parameters could lead to a definitive identification of chlorine salts. Searching for chlorine salts in lander sites with the parameters would allow for constraints on the CRISM detection limit of salts to be determined. These ranges are likely lower than could be detected by CRISM, but isolated high concentrations of perchlorates may be detectable using these parameters.

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