

**OCCURENCES OF POSSIBLE HYDRATED SULFATES IN THE SOUTHERN HIGH LATITUDES OF MARS.** Sheridan E. Ackiss<sup>1,2</sup> and J. J. Wray<sup>3</sup>, <sup>1</sup>Johns Hopkins University Applied Physics Lab (Sheridan.Ackiss@jhuapl.edu), Laurel, MD 20723, <sup>2</sup>School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, <sup>3</sup>School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA.

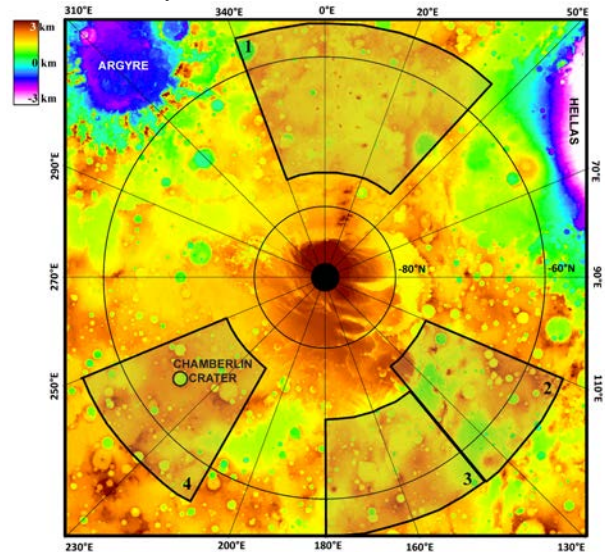
**Introduction:** Sulfates figure prominently in the record of water and habitable environments on Mars. They are found in sedimentary rocks at equatorial and middle latitudes [1–3], in sand dunes around the north polar cap [4], and in the soils of every landing site to date [5–7]. They are hypothesized to reflect a transition from a wet, neutral-pH early Mars to an arid world where fluids are typically saline, acidic, and rare [8]. Yet they occur in rock units dating from the Early or Mid Noachian [9] through the Late Amazonian [10], so have likely formed throughout Martian history via multiple processes in diverse settings.

The high southern latitudes have received little attention to date in the search for sulfates and other hydrated minerals. Similar to the north, non-ice hydration is detected from  $\sim 50^\circ$  latitude to the edge of the southern residual ice cap, with regional variations [11]. In some cases the orbital spectra are consistent with sulfates specifically [12], but no analog to the northern hemisphere's gypsum-rich (30–45%) dunes [13–14] has been reported. The gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) in those dunes is not well understood, but may be related to smaller concentrations of gypsum that are actively eroding from Planum Boreum, the north polar plateau [14–17]. The source(s) of sulfur and the reason for Ca-rich salts—in contrast to the Mg/Fe-rich sulfates that likely predominate at lower latitudes [2]—remain poorly constrained. Regardless, similar processes could conceivably produce sulfates in the south.

Alternatively, some sulfates in the southern high latitudes appear localized to mountains of the Sisyphi Montes [3], which have been interpreted as volcanoes that erupted under a Hesperian ice sheet [18]. These sulfates might have formed via volcanic hydrothermal or acid fog alteration. We seek to find new examples of hydrated sulfates at high southern latitudes in order to test multiple hypotheses based on the mineralogy and spatial distribution of sulfates.

**Methods:** We searched for sulfates using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). The CRISM instrument [19] acquires visible and near infrared (0.36–3.9  $\mu\text{m}$ ) data that record information about primary mafic mineralogy, ferric iron-bearing minerals, and hydrated minerals such as sulfates and phyllosilicates. Two hundred and seventeen CRISM hyperspectral targeted images (TRR3) were used to understand regional mineralogic trends.

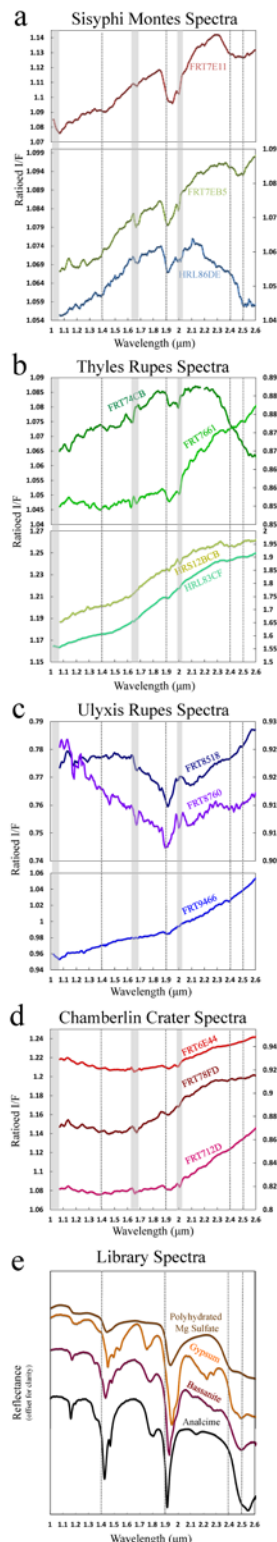
For each image we tabulated location, year and date, IR detector temperature ( $< -148^\circ\text{C}$ ), and any atmospheric hazes or surface frosts visible in browse images [20]. Summary parameters [20] showing spectral absorptions associated with hydration and sulfates were examined and used to identify regions of interest. We extracted spectra and divided by spectrally neutral regions in the same scene to remove systematic artifacts, a common method in CRISM data analysis. The resulting ratio spectra were analyzed from 1.0 to 2.6  $\mu\text{m}$  and visually compared to library spectra to identify possible hydrated mineral constituents. Images were then evaluated using standard procedures in the CRISM Analysis Toolkit (CAT), including the “volcano scan” atmospheric correction [21]. To date we have focused on 4 regions including the Sisyphi Montes (Figure 1, Box 1), the Thyles (Box 2) and Ulyxis Rupes (Box 3), and the mountainous region near the Chamberlin Crater (Box 4). The Sisyphi Montes region is composed of 21 putative volcanoes [18] and the remaining study regions contain similar geologic units but mostly lack volcanoes.



**Figure 1.** The southern highlands centered on the south pole in MOLA topography. Shaded polygons indicate study regions.

**Results:** Within the Sisyphi Montes region, we found that although the strongest unambiguous sulfate absorptions (1.44, 1.96, 2.48, and, for some sulfates, 2.2  $\mu\text{m}$ ) were located on these putative volcanoes, we observed the 1.9  $\mu\text{m}$  hydration feature (the deepest

**Figure 2.** Spectral diversity of hydrated locations in boxes 1-4 (Figure 1) and library spectra showing possible interpretations. Black lines are drawn at 1.4, 1.9, 2.4, and 2.5  $\mu\text{m}$  absorption bands to show similarities. Grey bands indicate spectral channels where the radiometric calibration is affected by detector or filter boundaries.



absorption in spectra of many hydrated sulfates) throughout the region, with a distribution consistent with seasonally variable adsorbed atmospheric water. In the remaining regions (Thyles Rupes, Ulyxis Rupes, and Chamberlin Crater) we found hydrated sulfates concentrated on the inside and rims of craters, potentially consistent with playa evaporation in the craters [22–23] or exposure of more ancient sulfates.

**Discussion:** We found that hydrated sulfates are not unique to the volcanoes but instead suggest multiple processes or a more ubiquitous process for hydrated mineral formation. Another possible scenario could be that these minerals did in fact originate from the putative volcanoes, but have since been relocated due to a long history of impacts, aeolian transport, or weathering and periglacial processes.

Our results expand the number of known areas in the southern high latitudes exhibiting hydration, and allow us to constrain the nature of this hydration. The fact that hydration is found throughout all study regions suggests a more ubiquitous process for forming the hydrated minerals, possibly similar to the icy weathering

processes proposed for the north polar region [24]. It has been suggested that such processes may have contributed to sulfate formation at lower latitudes as well, during high-obliquity periods [24]; this can be further tested by MSL/Curiosity as it traverses Gale crater [25].

A caveat of this work is the difficulty in deciphering whether the outcrops we see are more consistent with sulfates or zeolites/high-silica phases. Our strongest signature (RFT7E11) is most consistent with a polyhydrated sulfate; however, some detections may also be consistent with zeolites/hydrated silica, implying a higher-pH alteration environment.

**Future Work:** To further test these results and inferences, we will next explore lower-resolution CRISM multispectral and hyperspectral mapping data to map hydration beyond the small areas of the high-resolution targeted images. It would also be beneficial to incorporate TES/THEMIS datasets to more accurately determine if we are actually seeing hydrated sulfates or zeolites/hydrated silica phases.

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