

PRESENCE OF CLAY MINERALS CAN OBSCURE SPECTRAL EVIDENCE OF MG SULFATES: IMPLICATIONS FOR ORBITAL OBSERVATIONS OF MARS. Rachel Y. Sheppard¹, Ralph E. Milliken², Kevin M. Robertson². ¹Jet Propulsion Laboratory/Caltech. ²Brown University, Providence, RI. rachel.y.sheppard@jpl.nasa.gov

Introduction: Sulfates, and Mg varieties in particular, are widespread across the surface of Mars as observed from orbit [1-2] and are seen in Gale crater [3-5]. Understanding the hydration state of these sulfates and the timescales over which they may uptake and lose water due to changing atmospheric conditions is critical for constraining how they may be used to infer ancient depositional conditions, especially as the Curiosity rover nears the sulfate-rich strata of Mt. Sharp [6].

Previous lab work has shown that monohydrated Mg sulfate ($\text{MgSO}_4 \cdot \text{H}_2\text{O}$) may be stable under current martian surface conditions, while polyhydrated Mg sulfate ($\text{MgSO}_4 \cdot n\text{H}_2\text{O}$) is likely to dehydrate to an X-ray amorphous form [7-9]. Monohydrated and polyhydrated Mg sulfates are both observed across the modern surface of Mars, including closely collocated in Mt. Sharp (Fig. 1). If these two Mg sulfate hydration states are indeed present together, it could imply distinct formation processes. Furthermore, the presence of other water-bearing minerals may influence the hydration and/or stability of Mg sulfate phases exposed to Mars surface conditions.

To address this, we use near-infrared reflectance spectroscopy to observe *in situ* how water is lost (or gained) from hydrated minerals exposed to Mars-relevant conditions in a controlled lab setting. The results provide an improved understanding of the stability of hydrous minerals on present-day Mars and whether changes in sulfate hydration state could be observed from orbit.

Methods: Changes in near-infrared spectral absorptions that are characteristic of H_2O were measured in powdered smectite, Mg sulfate, and mixtures of these two materials. Samples were placed in a Linkam environmental chamber that allowed for precise control of temperature, pressure, and relative humidity conditions that are relevant to the surface conditions of Mars. Reflectance spectra (0.35-2.5 μm) were collected throughout the entire experiment.

As a separate test, random noise was added to the laboratory spectra to simulate the spectral quality of observing these mixtures from orbit rather than at the higher signal level typical of laboratory measurements.

Results: Exposure to Mars-relevant T, P, and relative humidity conditions causes rapid observable changes in VNIR spectra of smectite and Mg sulfate (Fig. 2). The observed spectral differences represent differences in water content (hydration state), mineralogy, and degree of crystallinity. Montmorillonite

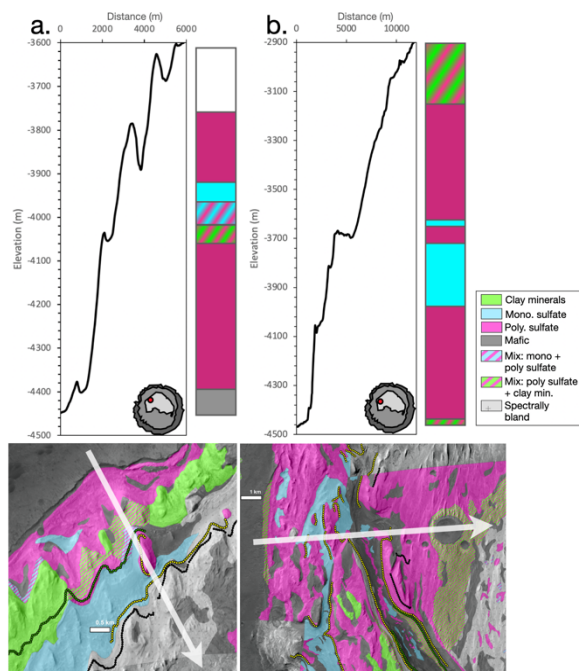


Fig. 1: Elevation profiles, mineralogy map based on orbital spectra, and mineral stratigraphic columns from two different positions in Mt. Sharp sedimentary mound in Gale crater. Note the close occurrence and occasional lateral transitions between clay mineral signatures and Mg sulfate signatures in the orbital mineralogy map. Figure modified from [5].

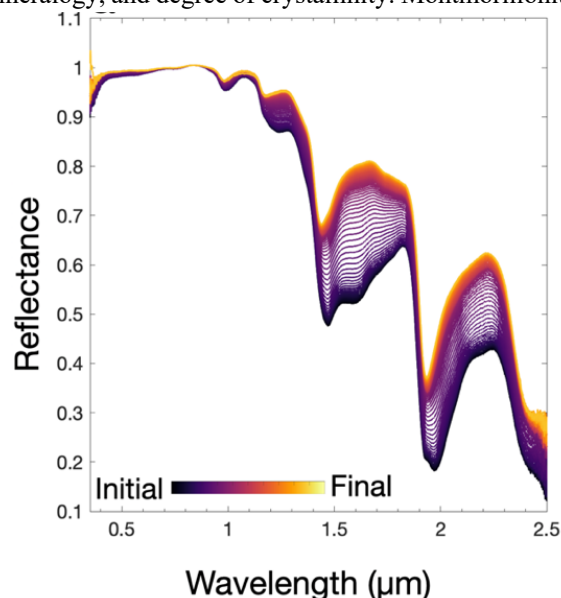


Fig. 2: Spectra from an experiment tracking the dehydration of Mg sulfate through time from initial polyhydrated Mg sulfate ($\text{MgSO}_4 \cdot 6-7\text{H}_2\text{O}$, black line) to final dehydrated but not anhydrous, amorphous Mg sulfate ($\text{MgSO}_4 \cdot 2\text{H}_2\text{O}$, yellow line).

is reduced to 1 water layer in the interlayer and Mg sulfate to an X-ray amorphous polyhydrated form with 1-2 structural waters.

A finding relevant to orbital observations of these hydrated minerals is that the presence of amorphous Mg sulfate is difficult to discern in physical mixtures that contain more than ~10% phyllosilicates by weight, even in high spectral resolution laboratory data (Fig. 3). Furthermore, when noise was added to simulate what the spectral changes associated with mineral dehydration in the mixtures would look like if observed from orbit (Fig. 4), the clay mineral can still be identified by the presence of the 2.2 μm feature but the Mg sulfate shows little effect on spectra.

Discussion & conclusions: Based on these results, we conclude that many of the spectral changes related to hydration state and crystallinity will be difficult to detect in current orbital spectral data even though they are likely to occur at the modern surface over seasonal (or longer) timescales.

This may help resolve the inconsistency that SAM EGA [10], ChemCam elemental abundance [11], and CRISM orbital spectra [3,5] observations suggest the

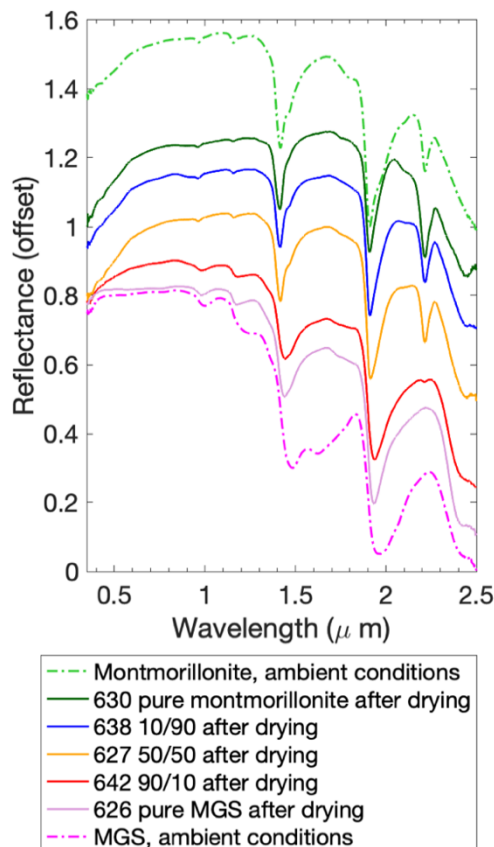


Fig. 3: Spectra of dried minerals and mixtures at the end of dehydration via exposure to dry air (solid lines) and montmorillonite and MGS at ambient (still hydrated) conditions (dashed lines).

presence of Mg sulfate along the Curiosity rover traverse, whereas CheMin XRD data [12-13] have yet to show any clear evidence of Mg sulfates. Mg sulfate may be present in amorphous form such that it can be observed in spectral and chemical but not X-ray diffraction data. In places where clay minerals are present, which is much of lower Mt. Sharp in Gale crater, the spectral features of the clay minerals can effectively mask the presence of small amounts of amorphous Mg sulfate, suggesting the latter may be more widespread in Gale crater than can currently be observed from orbit.

In orbital CRISM data, what appear to be lateral transitions between spectrally 'pure' clay and spectrally 'pure' Mg sulfate may instead be reflective of small changes in proportion between smectite and Mg sulfate. Careful documentation of the composition of the amorphous component will be critical as Curiosity enters these strata, which are likely to host both clay minerals and (possibly X-ray amorphous) Mg sulfate.

This highlights the importance of future in situ near-infrared reflectance observations to accurately determine the extent to which hydrous minerals are present at the surface and how they cycle water with the martian atmosphere under current surface conditions.

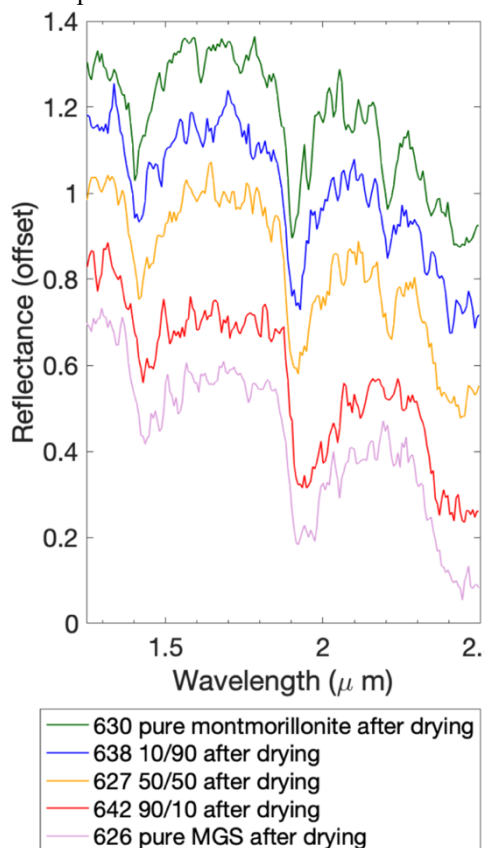


Fig. 4: Noise added versions of the dehydration experiment spectra from Fig. 2. Noise levels are appropriate to simulate CRISM conditions.

References:

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