SPECTRAL AND MINERALOGICAL DIVERSITY OF THE POLYHYDRATED SULFATE CLASS IN VALLES MARINERIS

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Introduction: Polyhydrated sulfate (PHS) deposits identified throughout Valles Marineris [1] display strong H₂O/OH absorption features but lack distinctive cation absorptions [2]. PHS can represent complex mixtures of hydrated species (sulfates and/or phyllosilicates) or a single higher-hydrated phase with weak cation absorptions. Qualitative identification using spectral parameters cannot account for the subtle variations in their non-diagnostic hydration bands resulting in poorly constrained mineralogy.

Hapke’s radiative transfer model (RTM) [3-4] is commonly used for spectral un-mixing for airless planetary surfaces [5-6] and has been shown to be effective at constraining the variations in the hydration bands in laboratory [7] and CRISM data [8-9]. Here we use RTM of PHS deposits across Valles Marineris to correlate subtle variations in OH and H₂O absorptions with spectral parameters and mineralogy.

Methods: A total of 27 CRISM images across Capri Chasma, Aram Chaos, Melas Chasma, and East Candor Chasma were chosen based on their strong PHS detections with variable spectral shapes. A database of PHS spectra was compiled from these regions and systematically studied using a combination of spectral parameter plots and RTM to assess the local and regional variability of the mineralogy.

Existing spectral parameters (SINDEX, BD1900) were used in addition to custom parameters involving the band depth, position, shape of the 1.9μm, 1.92μm, 1.96μm, 2.02μm, 2.13μm and 2.4μm bands (Fig.1).

The parameterization of the Hapke model used in this study is the same as that of Li and Milliken (2015) [6]. The model inputs are, the CRISM reflectance data, viewing geometry (i, e, g) from CRISM DDR data, end-member single scattering albedo and their densities. CRISM reflectance spectra were converted to SSA which were then weighted using linear combinations of end-member SSA. The combination of minerals that provided the best RMS error in the least squares minimization was used with no concern for the overall abundances. This method does not provide reliable quantitative information due to the unconstrained dust effects and unknown particle sizes, however it does help to constrain the mineralogy and is effective as a qualitative mapping tool [8].

The end-member reflectance spectra used in the un-mixing were measured in RELAB at Brown University with an ASD fieldspec3 spectrometer and Linkam environmental stage configured with a viewing geometry of: i = 30°, e = 0°, g = 30°. A total of 45 end-members were simultaneously used in the modeling, which included silicates, phyllosilicates, sulfates, zeolites, and hydrated silica. In addition, a horizontal end-member was used as an albedo correction for the dust and particle size effects.

Results: Band ratios were used to track the variations in the H₂O and OH vibrational bands that identify four different ‘spectral classes’ associated with PHS deposits (Fig.1). Spectral classes include: 1) pure kieserite 2) kieserite-PHS mix 3) PHS type 1 and 4) PHS type 2. Kieserite is identified by the 2.4μm and 2.13μm bands while hexahydrate, melanterite, fibroferrite are associated with 1.92μm, 1.96μm and 2.02μm bands.

Regional spectral parameter plots (Fig.2) show that the spectra from distinct regions plot separately creating a range from low to high kieserite (1.96μm /2.4μm ratio) and PHS (1.92μm /2.02μm) respectively. As an example, image 3050 in Capri Chasma has low kieserite and high PHS abundance, whereas 13F5B in Melas Chasma has high Kieserite and low PHS abundance. The inherent variability of spectra from a given image can also be assessed, where image 2FAF (East Candor) is more variable than image C815 (Aram Chaos).

A direct comparison of the spectral variations with the geomorphology on a local scale helps to identify the significant sub-classes. Spectral parameter maps for images in Capri Chasma, Aram Chaos, Melas Chasma, and East Candor Chasma were made using band ratios

Fig.1. Spectral types are observed in a) an individual image (2FAF) from East Candor Chasma, b) over the four regions studied to date. c) The contributing pure endmembers for the 4 common spectral classes. The stippled lines mark the absorption bands used for identification.
1.9μm /1.96μm, 1.96μm /2.4μm, 1.96μm/2.13μm, 1.92μm/2.02μm. An example of a spectral parameter map for image 2F87 in Capri Chasma (Fig. 3a) suggests that there are multiple PHS deposits of variable composition in close proximity to as well as isolated from the kieserite deposit (red area on the left).

Subsequent modeling identified the key mineralogical phases associated with the different spectral classes. Spectral fits (Fig.4) were good (RMS ~ 10^{-4}) with low residuals and no obvious misfits. The model consistently picked hexahydrite, melanterite and fibroferrite as the key PHS mineralogical types. The modal mineralogy maps (Fig.3b) follow the spectral parameter maps quite closely suggesting that the modeling is working properly and that the spectral types determined from the spectral parameters are based on mineralogical differences.

**Conclusions:** A detailed survey of the PHS across Valles Marineris shows that there are distinct spectral types over local and regional scales. Comparing spectral parameters (specifically band ratios) proved to be an effective method for tracking the different types of PHS. The Hapke modeling was able to distinguish between the subtle changes in the 1.9 μm band to assign a mineralogical phase to the different classes.

Spectral parameter maps were strongly correlated to the modal mineralogy maps. It is shown that hexahydrite is associated with the 1.92μm band, melanterite with the 1.96μm band and kieserite with the 2.13μm and 2.4μm bands. The spectra that displayed a strong kieserite component were often associated with hexahydrite in various amounts and most likely represent a mixture of the two phases at the CRISM resolution. Kieserite and hexahydrite either represent intimate particulate mixtures of the two phases or fine scale layering associated with evaporate deposits. The presence of melanterite suggests deposition from an iron rich fluid either from a different hydrological event or from evaporation following the concept of chemical divides [10].