

SPECTRAL MIXTURE ANALYSIS OF HYDRATED MINERALS IN SOUTHWEST MELAS CHASMA.

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Introduction: Melas Chasma is the widest segment of the Valles Marineris on Mars and is located in the center of this canyon system. High spatial and spectral resolution orbital visible-near infrared spectroscopy of Mars by Mars Express Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) and Mars Reconnaissance Orbiter (MRO) Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) have revealed a variety of hydrated minerals that form from aqueous alteration, including hydrated sulfates, jarosite, and phyllosilicates [1-3].

In the southern wall and nearby floor of Melas Chasma, a sequence of interbedded poly- and mono-hydrated sulfate and jarosite deposits were identified within the ILDs using CRISM hyperspectral data. The interbedded sulfate layers were interpreted to have formed by cyclic deposition of the two hydrated sulfate phases during evaporation of upwelling groundwater. The jarosite-bearing units were identified stratigraphically above the hydrated sulfate deposits and thus postdate the lower Mg sulfate units. These were hypothesized to have formed either by oxidation of a fluid containing Fe(II) and SO₄ or by leaching of soluble phases from precursor intermixed jarosite-Mg sulfate units that may have formed during the later stages of deposition of the hydrated sulfate sequence [2].

In southwest Melas Chasma basin, a sequence of interbedded Fe/Mg smectite and hydrated sulfate deposits were identified and mapped. The interbedded layers are exposed at the bottom of the stratigraphic column, unconformably overlain by a thick monohydrated sulfate unit. The smectite-sulfate deposits were interpreted to have formed through either in situ weathering and fluid evaporation or transport and deposition of detrital clays by a neutral fluid containing Mg and SO₄ and subsequent evaporation [3].

Although the initial mineral identifications and analyses of the stratigraphic relationships provided clues of their alteration environments, the mineral assemblage comprising the sediments and the relative abundances of the single minerals can further provide unique constraints to their formation environments. Thus, this study aims to quantitatively map the abundance of hydrated minerals in southwest Melas Chasma (Figure 1).

Data Reduction Methodology: CRISM is a hyperspectral imager, which has been acquiring data since November 2006. CRISM has 544 wavelength channels covering 0.36-3.92 μm and has a spatial resolution of 18-36 m per pixel in targeted mode. In this study, CRISM targeted data were photometrically and atmospherically corrected using Discrete Ordinate Ra-

diative Transfer model (DISORT) [4-5]. In DISORT calculations, the lower boundary of the atmosphere was defined as a surface that scatters light according to the *Hapke* function [6], and single scattering albedos were retrieved from CRISM I/F data. The SSA spectra were then recast into radiance coefficients comparable to the lighting and viewing conditions under which laboratory spectra are acquired. The radiance coefficient data will be used for the recovery of spectral end-members using factor analysis and target transformation. After the end-members are extracted, the retrieved CRISM SSA spectra are used to perform the linear spectral mixture analysis to determine hydrated mineral abundances at southwest Melas Chasma.

Recovery of CRISM Spectral End-Members:

The factor analysis and target transformation (FATT) technique was applied to the DISORT-corrected CRISM image to determine the spectral end-members of hydrated minerals and other minor phases. In FATT, the eigenvalues and eigenvectors from the retrieved CRISM radiance coefficients between 1.05 and 2.65 μm were derived, following the methods of *Thomas and Bandfield* [7]. The eigenvalues associated with each eigenvector indicate the relative importance of the eigenvectors with respect to the total variation in the scene. A linear least squares fit of the eigenvectors onto a test vector from a laboratory spectral library was performed to determine whether the test vector is one of the components in the system.

The FATT results are shown in Figure 2. The eigenvectors from the retrieved radiance coefficients show spectral features associated with hydrated minerals as well as spectral slopes. Of hydrated phases, epsomite, kieserite, jarosite, and saponite provided good matches with absorption features in the CRISM data derived by FATT, respectively. For example, hydrated sulfates have absorption features at 1.9 (polyhydrated sulfates), 2.1 (monohydrated sulfates), and 2.4 μm ; jarosite was characterized by absorption features at 1.85 and 2.65 μm ; saponite was identified based on absorption features at 1.9, 2.31, and 2.4 μm . The FATT results are consistent with our previous identifications by directly comparing the retrieved CRISM radiance coefficients with the laboratory spectra. Other phases, including montmorillonite, kaolinite, carbonate, and perchlorates, could not be reproduced using the CRISM derived eigenvectors, indicating the absence of their signatures from the scenes. The FATT results provided a library of spectral end-members for each atmospherically corrected CRISM images, which pro-

vides crucial constraints on the spectral mixture analysis conducted in the next section.

Spectral Mixture Analysis Results: To best constrain the extent and alteration environments of hydrated minerals, quantitative estimates of abundance of these phases are essential. Single-scattering albedo for surface materials is dependent on the real and imaginary indices of refraction of constituent grains as well as the grain sizes [6]. Because mineral SSAs add linearly, a library of mineral SSAs (generated using mineral optical constants and an assumed mineral grain size) can be used for linear spectral unmixing of CRISM data. Grain sizes and packing were constrained by measurements of the thermal inertia [8, 9]. The deconvolution provides a linear least squares fit of measured spectra using combinations of the library end-member spectra, and weightings represent the component areal abundances [10].

Our initial spectral unmixing results are shown in Figure 3. The jarosite-bearing unit has a abundance of 32% jarosite mixed with ferrihydrite and epsomite. The best fit of the spectra extracted from clay-bearing region is obtained using nontronite and saponite (total 36% abundance) mixed with kieserite and epsomite. The sulfate-bearing region shows that epsomite has a abundance of 37%, and addition of opal significantly improves the fit. The derived mineral abundances can help us to better assess their formation environment, which will be conducted in the future study.

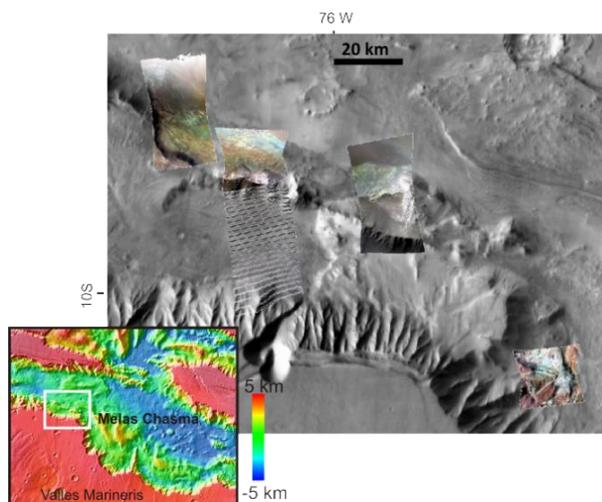


Figure 1. Southwest Melas Chasma basin. Targeted CRISM false-color images (red: 2.5 μm , green: 1.5 μm , blue: 1.1 μm) used for spectral mixture analysis are overlain on a THEMIS daytime infrared image. In this color combination, hydrated minerals are cyan to green. The inset for regional context is MOLA topography on a hillshade map and southwest Melas Chasma is indicated by the white box.

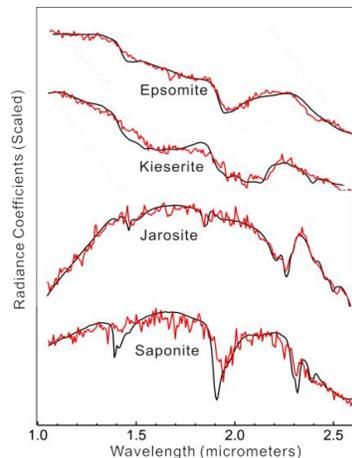


Figure 2. Factor analysis and target transformation results for CRISM images shown in Figure 1. Laboratory spectra of epsomite, kieserite, jarosite, and saponite (black lines), are well fit by the eigenvectors (red lines), indicating their likely presence in the scenes shown in Figure 1.

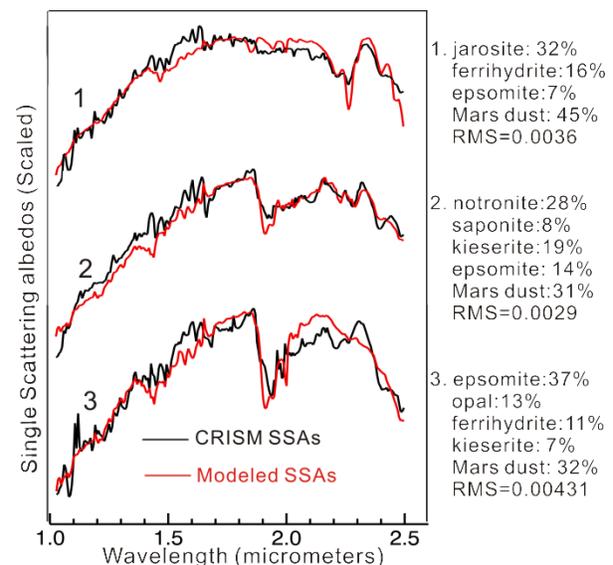


Figure 3. Spectral mixture analysis results. 1-3 represent the spots where jarosite, smectites, and epsomite were identified, respectively. The modeled mineral abundances are shown on the right of the plots.

Summary: The results from factor analysis and target transformation of CRISM data show that southwest Melas Chasma contains a variety of hydrated minerals, including epsomite, kieserite, jarosite, and clay. The abundances of these hydrated minerals were mapped by performing a linear unmixing of retrieved CRISM SSAs with DISORT radiative transfer model, and the mineral abundance results can be used to better constrain their extent and alteration environments.

References: [1] Gendrin et al. (2005) *Science*, 307, 1587-1591. [2] Liu et al. (2013a) *JGR*, submitted. [3] Liu et al. (2013b), *GRL*, submitted. [4] Stamnes et al. (1988) *Appl. Opt.*, 27, 2502-2509. [5] Wolff et al. (2007) *Seventh International Conference on Mars*, Abstract 3121. [6] Hapke, B. (1993), *Theory of Reflectance and Emission Spectroscopy*, 455 pp., Cambridge Univ. Press, NY. [7] Thomas and Bandfield (2013), *LPSC*, abstract 1325. [8] Ruff and Christensen (2002), *JGR*, 107(E12), 5127. [9] Putzig and Mellon (2007), *Icarus*, 191, 68-94. [10] Ramsey and Christensen (1998), *JGR*, 103, 577-596.