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Supporting Online Material for

Phyllosilicate Diversity and Past Aqueous Activity Revealed at Mawrth Vallis, Mars

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Materials and Methods

OMEGA provides near-global coverage with 352 channels spanning 350-5100 nm at spatial resolutions of 300 meters to a few km per pixel (*5*). The OMEGA data were corrected for the effects of the solar spectrum and the atmosphere (*25*), and endmember spectra were derived using a combination of band-depth and minimum noise fraction analyses. Relative abundance maps were created by performing singular value decomposition (*26*, *27*) on each pixel in the scene using the derived endmember spectra and constraining to fits with rms values smaller than 0.007.

In the full resolution targeted mode (FRT ~10 km downtrack by 10-12 km crosstrack) CRISM collects spectral cubes from 362 to 3920 nm sampled at 6.55 nm/channel with a spatial resolution of 18 m/pixel (*28*). CRISM data are converted to I/F by subtracting the instrument background, dividing by processed measurements of the internal calibration standard, and dividing by solar irradiance (*2*). Variations in illumination are corrected by dividing I/F by the cosine of the incidence angle (derived from MOLA gridded topography at 128 pixels/°). Atmospheric molecular opacity effects are minimized by dividing by a scaled atmospheric transmission spectrum over Olympus Mons (*7*). Spectral parameters defining key mineralogic absorptions are also derived for each image in order to highlight areas that exhibit important mineralogic signatures (*29*). A denoising algorithm removes vertical stripes by low-pass filtering in the spatial - spectral domain (*30*). It optimizes the filtering in order to preserve spatial information while cleaning the image. The process then detects and removes spectral spikes by comparing spectral channel values with thresholds and substituting the detected spikes with robust estimates. Phyllosilicate-bearing spectra are typically extracted from 3X3 or 10X10 pixel spots in the corrected image and ratioed to spectrally unremarkable spots of equal size in the same column in order to reduce column-dependent systematic noise and clarify mineral features. For a few small kaolinite-bearing outcrops single pixel spectra were extracted. Finally, the images are georeferenced and draped over MOLA terrains in order to better visualize the relative positions of the phyllosilicate deposits on the local topography.

NIR spectral properties of phyllosilicates observed at Mawrth Vallis

Fe/Mg-phyllosilicates are abundant in Mawrth Vallis and common in other regions of Mars where phyllosilicates are observed (*4*, *7*). Smectites likely comprise a large portion of these Fe/Mg-phyllosilicate outcrops. This mineral group is identified in NIR spectra by features due to structural OH and bound H_2O (e.g. *31*). The band center and shape of the OH overtone near 1.4 μm and the OH stretch plus bend combination band spanning 2.15-2.5 μm depend on the type of cations connected to OH groups in the octahedral sites. Band centers are given in Table 1 for spectra of Mars and minerals presented in Figs. 2-3.

Table 1 Band centers (μm) for NIR OH features used to identify phyllosilicates

Hectorite	Mg-OH	1.39+1.41	2.31	2.38
Mawrth Vallis Fe/Mg-smectite		1.42	2.30	2.39
Nontronite	Fe-OH	1.42	2.29	2.41
Montmorillonite	Al-OH	1.41	2.21	
Kaolinite	Al-OH	1.40	d: 1.16, 2.20	
Dickite	Al-OH	d:1.38,1.41	d: 1.18, 2.20	

Phyllosilicate formation processes and chemistry

The nature of the phyllosilicate deposits in the Mawrth Vallis region provide insights into the possible formation processes that took place and enable determination of constraints on the early aqueous activity in the region. Smectites are commonly formed in marine, lacustrine and hydrothermal environments on Earth and can provide information about the geochemical formation environment (*17*, *18*). Alteration of basaltic rocks typically produces Al- and Fe-bearing dioctahedral smectite, in some cases via formation of serpentine, and metastable Mg-smectite as intermediate phases (*32, 33*). Under long-term exposure to aqueous conditions smectites can convert to other phyllosilicates such as glauconite if microbial activity provides a reducing environment, if wet/dry cycling occurs, or in the presence of abundant iron or high salinity (*17, 34*). Alkaline conditions favor smectites under normal temperatures and pressures on Earth in the presence of Ca and favor mica in the presence of K, whereas acidic conditions support formation of kaolinite and hydrated silica (*17*, *18*).

Movie

This movie shows rotation of the mineral indicator map of CRISM image HRL000043EC draped over MOLA terrain with 20X vertical enhancement depicted in Fig. 2B. Rotation of this image enables better viewing of the Fe/Mg-smectite unit (orange/red) at lower elevations, the Al-phyllosilicate and hydrated silica units (blue) at higher elevations, and the Fe^{2+}-bearing phases (yellow/green) frequently shown at the boundary of these other units.

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