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Characterization of aqueous processes on Mars through identification of phyllosilicates, sulfates and hyrated silica using CRISM hyperspectral images

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The surface mineralogy of Mars provides clues to its geologic history, including aqueous processes. Phyllosilicates and sulfates are key indicators of water on Mars and appear to have occurred in the Noachian and Hesperian, respectively (1). Hyperspectral visible/near-infrared spectral imaging is enabling identification of these mineral classes (2,3,4). Targeted Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) images collect 544 wavelengths from 0.36 to 3.9 μm in $\sim$10-12 km wide swaths at 18-36 m/pixel resolution (3). Images are processed for instrumental effects, converted to I/F and the atmosphere is removed using a ratio with a CRISM scene of Olympus Mons, scaled to the same column density of CO_2 (e.g. 3).

The Mawrth Vallis region contains one of the largest and most diverse outcrops of phyllosilicates and is hence a candidate landing site for upcoming missions. Detailed analyses of the CRISM spectra in this region indicate the presence of kaolinite, hydrated silica and mica, as well as the smectites nontronite and montmorillonite that are frequently observed on Mars (5,6). The kaolonite, mica and hydrated silica layers appear to have been deposited on top of the nontronite and montmorillonite layers, indicating a change in the aqueous environment. The kaolinite and hydrated silica deposits are often as small as 50-100 m across and typically occur surrounding the nontronite layers. The nontronite deposit may be thicker and more resistant to erosion. Ongoing analyses of the phyllosilicates at Mawrth Vallis provide clues to the aqueous processes that occurred on Mars during the Noachian period. Current hypotheses under consideration for formation of these clay layers include: initial formation of Fe/Mg-smectite as an aqueous alteration product of basalt, followed by (a) subsequent aqueous alteration and leaching of the Fe and Mg to produce montmorillonite, mica, kaolinite/dickite and opal along the upper layers of the nontronite, or (b) a change in aqueous chemistry (e.g. hydrothermal activity) that caused formation of Al-phyllosilicates and opal along the upper layers of the nontronite, or (c) aqueous alteration of a later Si-rich volcanic ash or sedimentary inflow that enabled formation of Al-phyllosilicates and opal on top of the nontronite.

Sulfate-bearing deposits occur in Valles Marineris, Terra Meridiani and the N polar region (3). We focus here on the sulfates and hydrated silica observed at Juventae Chasma, just NE of Valles Marineris (7). Several sulfate-rich mounds inside the chasma and hydrated silica/phyllosilicate deposits on the western flanks of the chasma are under analysis. The light-toned layered mounds exhibit monohydrated sulfate signatures most consistent with kieserite, plus some polyhydrated sulfates. Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE) images of these outcrops illustrate the fine, layered texture of the sulfate outcrops and show bright blocky sulfate-bearing material. In contrast, the light-toned layered deposits on the plains exhibit spectral properties of hydrated silica and non-crystalline Al/Si phyllosilicate precursors and have a distinct lithology from those within the chasmata, indicating that these likely formed via separate processes.

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