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Title: Using Mineralogy to Reveal Diverse Geochemical Environments and Climate on Mars

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Global mineralogy of the surface of Mars is recorded by orbiters. The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument on the Mars Reconnaissance Orbiter has enabled mapping hydrated minerals such as phyllosilicates and sulfates [1, 2]. Analyses of these data suggest distinct aqueous geochemical environments on Mars including warm surface waters [3], subsurface hydrothermal systems [4], hot springs [5], and cool surface waters [6].

Phyllosilicate-bearing outcrops formed on the surface of Mars are dominated by smectite clays and are characterized by horizontal layering [7]. Formation of these smectite deposits likely occurred in warm waters (25-50 °C) on early Mars. These outcrops also include pockets of sulfates formed under acidic or high salt conditions.

Other Mg-rich phyllosilicates occurring with lateral variations likely formed in subsurface hydrothermal environments [4] that were later exposed on the surface. These outcrops typically include mixtures of smectites, chlorites, serpentines, talc, zeolite, and/or carbonate and likely formed under much warmer conditions, up to 250 °C.

Combinations of polyhydrated and monohydrated sulfates occur throughout the Valles Marineris region of Mars [1]. Many of the canyons here include terraced outcrops of hydrated sulfates or variations in mixtures of sulfates with phyllosilicates and opal. Exposures of alternating polyhydrated and monohydrated sulfates are consistent with formation in geothermal systems with changing water temperatures [5].

Short-range ordered (SRO) materials such as opal, nanophase aluminosilicates, ferrihydrite and akaganéite on the surface of Mars have been recognized through analysis of data from orbital [8, 9] and surface missions [10]. In the Mawrth Vallis region, this poorly crystalline material is present at 20-30 vol.% for the light-toned regions where clay minerals are detected [6]. An X-ray amorphous component is also present at ~20-50 wt.% nearly everywhere the CheMin X-ray diffractomer has analyzed samples at Gale crater [10]. Nanophase aluminosilicates form preferentially over phyllosilicates in well-drained environments with low water/rock ratio systems [11], and cold climates such as the Antarctic Dry Valleys [12]. Thus, the presence of abundant SRO materials without phyllosilicates could mark the end of the last warm and wet episode on Mars supporting smectite formation.

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