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Multiple Mineral Horizons at Mawrth Vallis, Mars, Represent Changing Environmental Conditions

Janice L. Bishop (1), Christoph Gross (2), Jacob M. Danielsen (1,3), Selena L. Perrin (1), Jasper K. Miura (1,4), Gabriela S. Usabal (1,4), Alexander Sessa (5) and James J. Wray (5)
(1) SETI Institute, Mountain View, CA, USA, (jbishop@seti.org), (2) Freie Universität Berlin, Berlin, Germany, (3) San Jose State University, San Jose, CA, USA, (4) Brown University, Providence, RI, USA, (5) Georgia Tech, Atlanta, GA, USA.

Abstract

Mineralogical evidence for multiple aqueous alteration settings at Mawrth Vallis, Mars, indicates changes in the geochemical environment. A thick layered horizon of Fe/Mg-smectite is covered by a unit containing Al-phyllosilicates, opal and allophane. Smaller outcrops of sulfates are observed in many locations and spectral "doublet" features of several small outcrops between the phyllosilicate units are likely due to mixtures of sulfates and phyllosilicates and may represent evaporite or hydrothermal settings.

1. Introduction

The mineral assemblages observed in the Mawrth Vallis region include Fe-rich and Al-rich phyllosilicates, sulfates (Fe-rich, Ca-rich, and Al-rich), iron oxides/hydroxides (FeOx), opal, and poorly crystalline aluminosilicates [e.g. 1]. In this study we are comparing VNIR spectra collected by CRISM of these distinct mineralogical horizons (Figure 1) to spectra of samples from the field and lab mixtures in order to identify their aqueous alteration components and characterize their likely formation conditions on Mars.

1.1 Samples from analog sites

Phyllosilicate- and sulfate-bearing samples from the Painted Desert [2], volcanic vent sites [3,4], and Chilean salars [5] were used to characterize the spectral properties of materials related to outcrops in the Mawrth Vallis region. The Painted Desert includes wide expanses of alternating phyllosilicate- and FeOx-bearing units, likely formed in a pedogenic environment [6] similar to Mawrth Vallis. One region of the Painted Desert contains outcrops of jarosite and gypsum [2] that exhibit a spectral doublet similar to the features observed in Mawrth Vallis spectra. Hydrothermal vents at La Solfatara, Italy [3] and Kilauea, HI [4] exhibit jarosite- and gypsum-bearing units along with hydrated silica and clays. Shallow salt ponds such as the salars in Chile [5] or Western Australia [7] contain mixtures of gypsum, jarosite, alunite, halite, opal, and phyllosilicates and are examples of potential evaporite environments on Mars.

1.2 Mineral mixtures

Mixtures of minerals were prepared in the laboratory in order to characterize changes in the spectral properties of sulfates mixed with phyllosilicates or opal. Mixture samples most relevant to this study included jarosite/nontronite [8], jarosite/gypsum [2], alunite/kaolinite [9], and gypsum/opal [10].

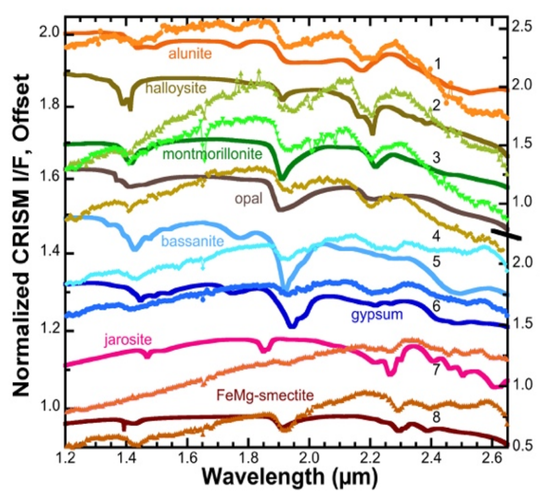

Figure 1: VNIR CRISM spectra of alteration phases observed at Mawrth Vallis representing changing geochemical environments. Lab spectra of minerals are shown for comparison.

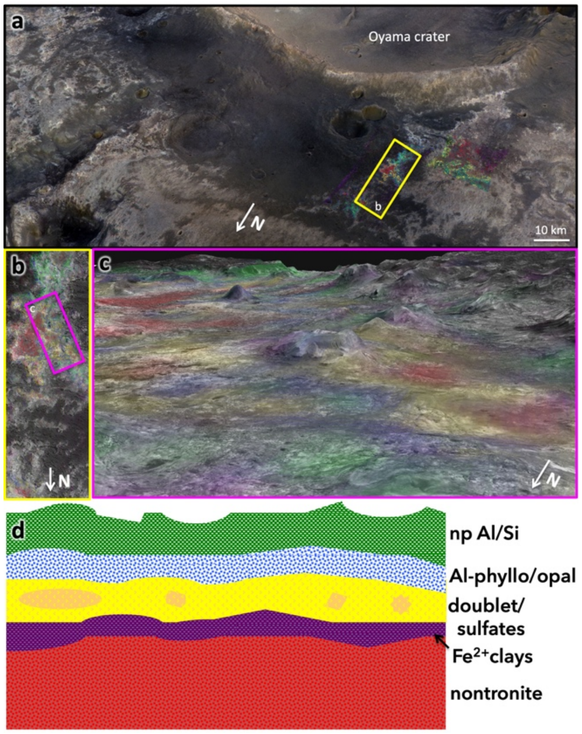

Figure 2: View of multiple mineral horizons at Mawrth Vallis. a) HRSC oblique view with 5x vertical exaggeration featuring phyllosilicate- and sulfate-bearing outcrops in CRISM false-color data, b) CRISM false-color data over HiRISE for region in yellow box, c) HiRISE stereo terrain model with CRISM false-color data for region in pink box, d) diagram of approximate stratigraphy of phyllosilicate- and sulfate-bearing units.

2. Implications from Spectral Analyses

The Mawrth Vallis region of Mars exhibits some of the thickest outcrops of layered clay-rich material that includes stratigraphic changes in clay chemistry, redox reversals, and isolated sulfates [e.g. 1]. These minerals are identified through VNIR spectra collected by CRISM in orbit around Mars [11]. Changes from Fe-smectite to jarosite represent pH shifts from neutral/alkaline to acidic environments. Similarly, montmorillonite deposits transforming to kaolinite/alunite also indicate decreasing pH. Assemblages containing gypsum and opal are characteristic of evaporitic salars, while siliceous sinter, jarosite and/or alunite can represent hydrothermal settings including acidic groundwater or fumerole vents. Redox changes in any of these settings represent a potential energy source for microbes. Coordinated analysis of analog field sites with orbital remote sensing can enable documentation of changing environments on Mars and a better understanding of potential habitable environments or ecosystems there.

Acknowledgements

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