MINERALOGY OF LAYERED OUTCROPS AT MAWRTH VALLIS AND IMPLICATIONS FOR EARLY AQUEOUS GEOCHEMISTRY ON MARS.

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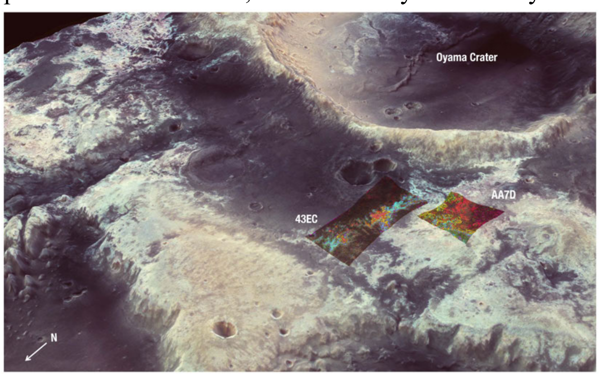
Introduction: Recently developed CRISM parameters and newly available DTMs are enabling refined characterization of the mineralogy at Mawrth Vallis. A stratigraphy including 5 units is mapped using HRSC DTMs across 100s of kms and using HiRISE DTMs across 100s of meters. Transitions in mineralogic units were characterized using spectral properties and surface morphology. The observations point to an ancient wet and warm geologic record that formed the thick nontronite unit, a period of wet/dry cycling to create acid alteration, followed by leaching or pedogenesis to result in Al-phyllosilicates, and finally a drier, colder climate that left the altered ash in the form of nanophase aluminosilicates, rather than crystalline clays.



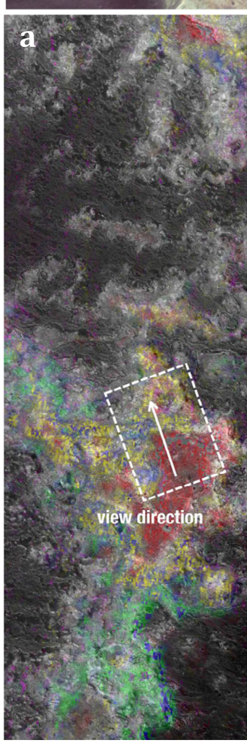
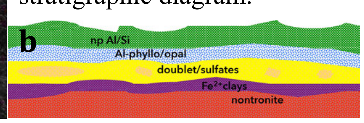


Fig. 1 (above) CRISM parameters over HRSC mosaic for NW region of Mawrth Vallis.

Parameter colors:
green=allophane, imogolite & np aluminosilicates (BD2190)
blue=Al-phyllosilicates & opal (BD2210_2)
yellow="doublet" materials incl. jarosite/sulfates (MIN2250)
purple=Fe^{2+}clays mixed with other materials (Olindex3)
red=nontronite or Fe^{3+}/Mg-smectite (BD2290)

Fig. 2 (a, left) CRISM parameters for HRL000043EC draped over HiRISE PSP_005819_2050. (b, below) approximate stratigraphic diagram.



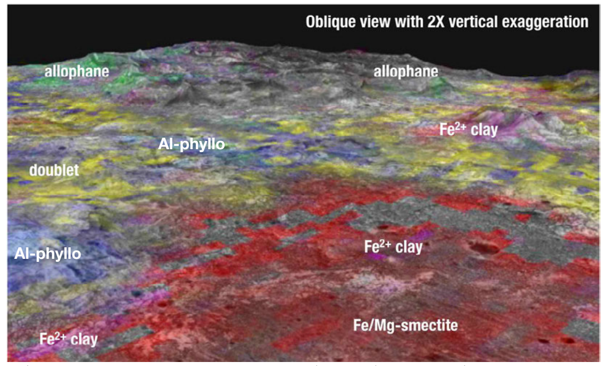


Fig. 3 CRISM parameters draped over HiRISE DTM; location marked in Fig. 2. Image width ~2 km.

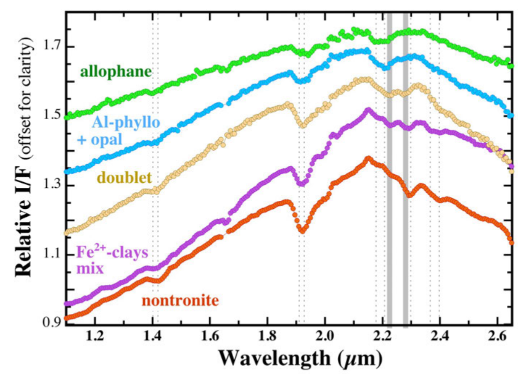


Fig. 4 Example CRISM spectra from HRL000043EC of 5 units represented in Figs. 1-3.

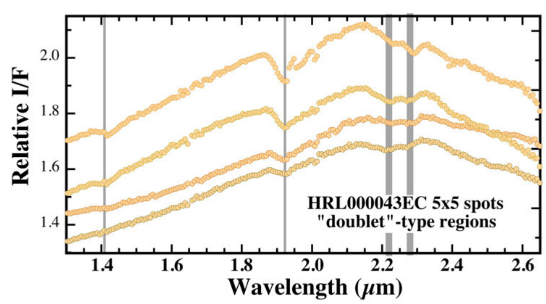


Fig. 5 CRISM spectra of "doublet" type unit illustrating variability in band position and strength.

Methods. MTR3 versions of several CRISM images [1] together with new parameters [2] were utilized to document more refined mineralogy than previously possible in the Mawrth Vallis region. CRISM spectra were averaged over 5x5 or 10x10 pixels and ratioed in column to enhance spectral surface features.

Nanophase (np) aluminosilicates were differentiated from Al-phyllosilicates and opal [3] using the

BD2190 parameter that detects the OH combination band near 2.19-2.20 µm for allophane and imogolite and the BD2210_2 parameter that maps Al-OH and Si-OH species near 2.20-2.22 µm due to opal, hydrated silica, montmorillonite, kaolinite and related clays.

Doublet-type units were mapped using i) CRISM parameter MIN2250 (Figs. 1, 2, 3, 6), ii) a modeling algorithm that evaluates the band centers of the doublet components at 2.20-2.25 versus 2.25-2.30 µm, and iii) Tetracorder 5.15 for the 2.0-2.5 µm region bands [4].

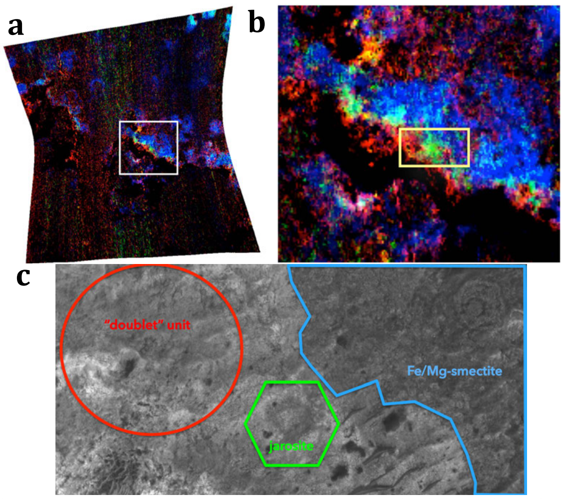


Fig. 6 Jarosite (green) outcrop bordering "doublet" materials (red) and Fe/Mg-smectite (blue) in CRISM image FRT00003BFB. a) full CRISM image with new color scheme in order to differentiate jarosite from the doublet unit, b) zoomed in view of CRISM units, and c) HiRISE view of the morphologies, width ~1km.

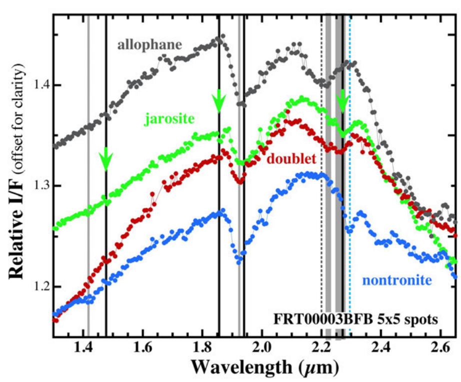


Fig. 7 CRISM FRT00003BFB spectra collected from the regions shown in Fig. 6 (same color scheme). Green arrows mark jarosite bands.

Results. The stratigraphy commonly observed across the Mawrth Vallis region is illustrated well in CRISM images HRL000043EC and FRT0000AA7D (Figs. 1-3). Overlaying the CRISM data on MOLA elevations, HRSC DTMs and HiRISE DTMs showed that the np aluminosilicates (e.g. allophane) are always at the top of the profile and that the doublet unit (yellow) occurs between the lower Fe/Mg-rich clay units and the upper Al/Si-rich units (blue/green). Pockets of

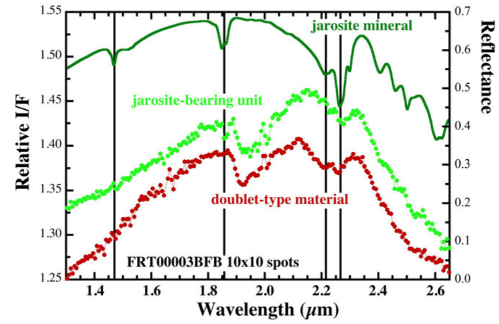


Fig. 8 A VNIR reflectance spectrum of jarosite for comparison with spectra of jarosite-bearing and doublet-type CRISM spectra from image FRT00003BFB.

Fe^{2+}-bearing clay (purple) are observed in Fig. 3 on top of the nontronite unit (red). Spectra of this Fe^{2+}-bearing unit are characterized by a steeper slope from ~1-2 µm and they often include a mixture of the lower nontronite features and the upper doublet features; in some cases chamosite-type features are included near 2.25 and 2.37 µm (e.g. Fig. 4). The band centers and relative intensities of the doublet features are highly variable (Fig. 5), which is consistent with a system more complex than just mixtures.

In order to evaluate the doublet-type unit in more detail, additional analyses focused only on the nontronite, doublet and potential jarosite-bearing units (Fig. 6). The CRISM spectra attributed to jarosite include bands at 1.47, 1.86 and 2.27 µm (Figs. 7-8). Spectra of jarosite also include a shoulder or weak band near 2.22-2.23 µm. Many of the doublet-type spectra have bands near 2.22-2.23 and 2.26-2.27 µm that are roughly similar to the positions of the jarosite bands, although the relative intensity is inconsistent with jarosite, and other diagnostic jarosite features are missing. However, similar acid-alteration processes are likely responsible for the formation of the doublet-type material and jarosite. The small occurrences of jarosite may indicate localities where acidic conditions persisted longer, thus enabling its formation.

Layered outcrops observed at Mawrth Vallis are thicker than in other regions of Mars, but may represent processes that took place on a wider scale in wet areas of the planet during the Noachian. Namely the formation of Fe/Mg-rich phyllosilicates in a warm and wet environment, a transition to acidic alteration phases and sulfates during a period of wet/dry cycling, crystallization of Al-rich phyllosilicates through pedogenesis or leaching, and persistence of np-aluminosilicates marking the end of the wet climate on Mars.

References: [1] Seelos, F.P. (2012) Planetary Data Workshop. [2] Viviano-Beck, C.E. (2014) JGR, doi: 10.1002/2014JE004627. [3] Bishop, J.L. & E.B. Rampe (2016) in revision. [4] Clark et al. (2015) AGU.

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