PHYLLOSILICATE DIVERSITY OBSERVED BY CRISM IN MAWRTH VALLIS: IDENTIFICATION OF NONTRONITE, MONTMORILLONITE, KAOLINITE, AND HYDRATED SILICA.

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Introduction: Layered deposits containing phyllosilicates occur throughout the Mawrth Vallis region [1, 2, 3]. The majority of these are spectrally dominated by the Fe/Mg-smectite that is found in regions extending several hundreds of meters in some locations. In many places other phyllosilicates and hydrated silica are observed as well. These deposits are often as small as 50-100 m across and are frequently observed surrounding the nontronite layers, which tend to occur at lower elevations. The observations from the visible/near-infrared (VNIR) hyperspectral Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) images are consistent with previous identifications of Al-rich and Fe-rich phyllosilicates first made by the Observatoire pour la Minéralogie, L'Eau, les Glaces et l'Activité (OMEGA) instrument [3]. However, the increased spatial resolution of CRISM enables characterization of phyllosilicates on a finer scale [4]. These new CRISM observations reveal the diversity of phyllosilicates present in the Mawrth Vallis region and indicate a wider range of aqueous activity than previously realized.

Methods: Targeted MRO/CRISM images collect 544 wavelengths from 0.36 to 3.9 µm in ~10-12 km wide swaths at 18-36 m/pixel resolution [5]. 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 as in [4, 6]. Ratios to spectrally unremarkable regions in the scene are used to resolve spectral features. Spectra were extracted from 5X5 or 10X10 pixel regions when possible.

Discussion: Shown in Fig. 1 are CRISM spectra from an image located in the western part of Mawrth Vallis where the diversity of phyllosilicates is one of the largest observed for Mars. Fig. 2 contains spectra from an image in the SE of Mawrth Vallis along the

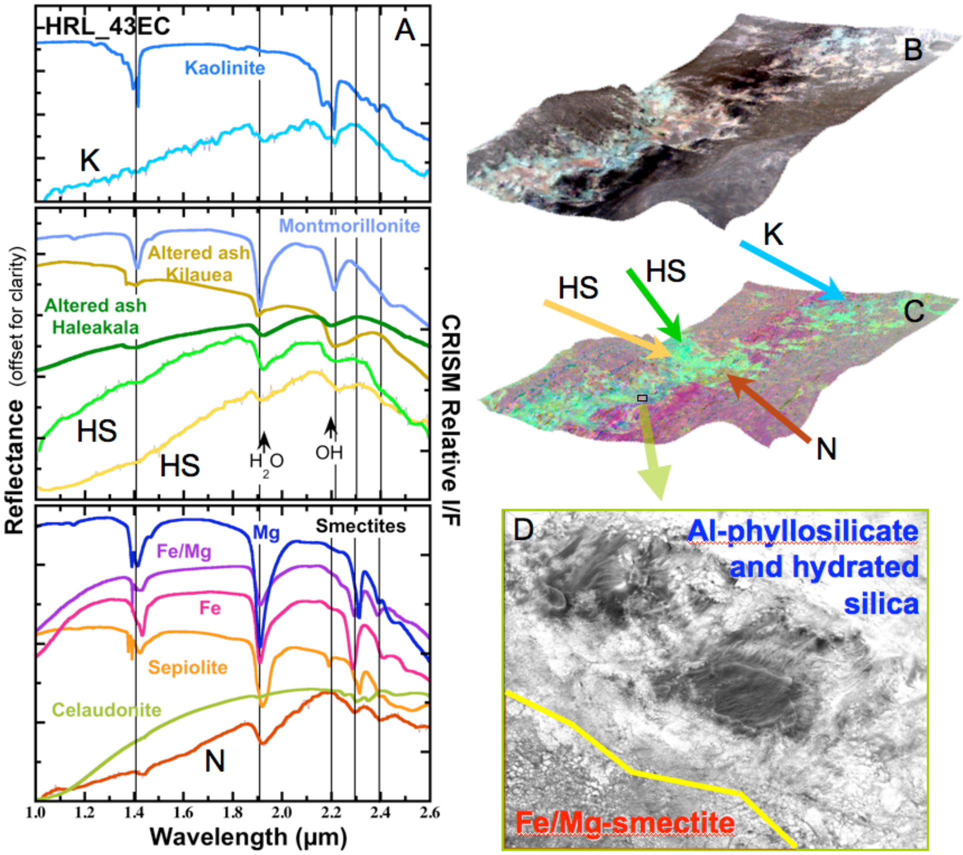

Fig. 1 (A) Ratio spectra from CRISM image HRL_43EC (raw and 5-pt smoothed spectra shown) compared to VNIR lab spectra of phyllosilicates and opaline materials, (B) false color IR image (R2.5, G1.5, B1.1 µm) draped over MOLA terrain (10X vertical enhancement), (C) mineral indicator map draped over MOLA terrain (10X vertical enhancement) showing Fe/Mg-smectite in orange, Al-phyllosilicate and hydrated silica in blue and Fe^{2+}-bearing phases in yellow/green, and (D) portion of HiRISE image PSP_005819_2050_RED showing the stratigraphic transition from the Fe/Mg-smectite in the lower left to the Al-phyllosilicate and hydrated silica to the upper right.

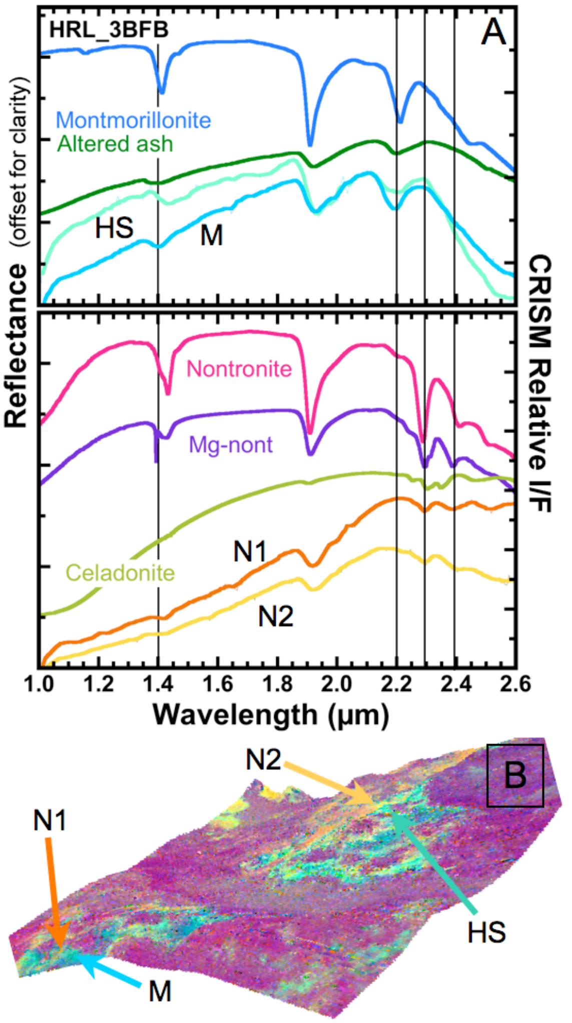

Fig. 2 (A) Ratio spectra from CRISM image HRL_3BFB (raw and 5-pt smoothed spectra shown) compared to lab spectra, (B) false color IR image (R2.5, G1.5, B1.1 µm) draped over MOLA terrain (5X vertical enhancement), and (C) mineral indicator map draped over MOLA terrain (5X vertical enhancement) showing Fe/Mg-smectite in orange, Al-phyllosilicate and hydrated silica in blue and Fe^{2+}-bearing phases in yellow/green.

channel. The most prevalent spectral type for the Mawrth Vallis area is attributed to Fe/Mg-smectite (Mg-nontronite) based on the presence of bands at ~1.4, 1.92, 2.30, and 2.39 µm (Figs. 1,2: N). The 2.30 and 2.39 µm bands lie in between those observed for pure nontronite and the Mg-smectite hectorite. Additional spectra consistent with kaolinite or dickite contain a band at ~1.4 and a doublet at 2.16 and 2.20 µm (Fig. 1: K). This spectrum also includes a broad band near 1.93 µm consistent with bound water in another component (e.g. opal or ferrihydrite) of this layer. Other spectra exhibit bands near 1.4, 1.92, and 2.21 µm that are consistent with the Al-smectite montmorillonite (Fig. 2: M). Similar spectra having broad features near 2.18-2.26 µm are attributed to hydrated silica (Figs. 1, 2: HS) and are described in more detail in [7]. Examples of this are the opal formed in hydrated ash at a solfataric site on the southern rim of the Kilauea caldera [8] and hydrated amorphous Al/Si formed in altered volcanic material at Haleakala crater [9]. An Fe^{2+} slope is observed in many regions that is attributed to ferrous mica such as celadonite.

Fe/Mg-smectite is common in this region and is thought to have formed first as the mafic rocks and/or basaltic ash reacted with water. Subsequent aqueous events and/or changes in the aqueous environment are likely to have enabled formation of montmorillonite, kaolinite, and hydrated silica. These other phyllosilicates and hydrated phases are typically found at higher elevations than the Fe/Mg-smectites and frequently appear surrounding the Fe/Mg-smectite deposits. Further joint CRISM-CTX-HiRISE analyses are needed, as initiated by [10]. Layers of kaolinite and hydrated silica are observed several 100s of meters across in some regions, which implies a pervasive alteration event. The extent of phyllosilicates in this region [11] and distribution of the phyllosilicate mineralogies [12] are described in related abstracts.

We are investigating possible hypotheses of formation of the phyllosilicate layers: (1) Fe,Mg-smectite formed as an alteration product of basalt during an aqueous event in the Mawrth Vallis region in the early Noachian period, (2a) subsequent aqueous alteration and leaching of the Fe and Mg produced montmorillonite, kaolinite/dickite and opal along the upper layers of the nontronite, or (2b) a change in aqueous chemistry (e.g. hydrothermal activity) caused formation of Al-phyllosilicates and opal along the upper layers of the nontronite, or (2c) aqueous alteration of more Si-rich volcanic ash or perhaps sedimentary inflow enabled formation of Al-phyllosilicates and opal on top of the nontronite.

Acknowledgments: Lab spectra were measured at Brown/RELAB. The efforts of the CRISM, HiRISE, and OMEGA science teams are greatly appreciated.

References: [1] Loizeau D. et al. (2007) *JGR, 112,* E08S08, doi:10.1029/2006JE002877. [2] Michalski J. R. and E. Z. Noe Dobrea (2007) *Geology, 35,* 951-954. [3] Poulet F. et al. (2005) *Nature, 438,* 632-627. [4] Mustard J. F. et al. (2007) *Nature,* submitted. [5] Murchie S. et al. (2007) *JGR, 112,* E05S03, doi:10.1029/2006JE002682. [6] Pelkey S. M. et al. (2007) *JGR, 112,* E08S14, doi:10.1029/2006JE002831. [7] Milliken R. E. et al. (2008) *LPSC.* [8] Bishop J. L. et al. (2005) *LPSC*, #1456. [9] Bishop J. L. et al. (2007) *Clays Clay Miner., 55,* 1-17. [10] Wray, J. J. et al. (2007) *7th Mars Conf.*, #3119. [11] Noe Dobrea E. Z. et al. (2008) *LPSC*, #1077. [12] McKeown N. K. et al. (2008) *LPSC,* #1400.