EARLY MARTIAN HABITABILITY AND PHYLLOSILICATES AT MAWRTH VALLIS

J. L. Bishop[1], D. Loizeau[3], N. K. McKeown[4], L. M. Saper[1,5], M. D. Dyar[6], D. J. Des Marais[2], M. Parente[7] and S. L. Murchie[8], [1]SETI Institute, Mountain View, CA 94043, USA (jbishop@seti.org), [2]Exobiology Branch, NASA-Ames Research Center, Moffett Field, CA 94035, USA, [3]ESA-ESTEC, Noordwijk, The Netherlands, [4]Dept. Phys. Sciences, Grant MacEwan University, Edmonton AB T5J 4S2, Canada, [5]Dept. Geol. Sciences, Brown University, Providence, RI 02916, USA. [6]Dept. Astronomy, Mount Holyoke College, South Hadley, MA, 01075, USA. [7]Dept. Elec. & Comp. Engineering, University of Massachusetts, Amherst, MA 01003, USA. [8]Johns Hopkins Univ. Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: Phyllosilicate–rich outcrops on Mars provide an opportunity to evaluate aqueous activity and possibile habitable environments [1]. Analysis of hyperspectral VNIR CRISM and OMEGA images have shown thick, complex profiles of phyllosilicates at Mawrth Vallis that are consistent with long-term aqueous activity and active chemistry [e.g. 2-4]. The observed phyllosilciate mineralogy implies either a change in water chemistry, a change in material being altered, or an alteration profile where the upper clays were leached and altered more significantly than those below. A change in iron in the phyllosilicate units is also observed such that an Fe^{2+}-bearing unit is frequently observed between the Fe^{3+} and Mg-rich phyllosilicates below and the Al/Si-rich materials above. On Earth abrupt changes in chemistry like this are often indicative of biogeochemical activity.

The ancient phyllosilicates here and elsewhere on Mars could have served as reaction centers for organic molecules [5]. Previous studies and hypotheses even suggest that phyllosilicates may have played a role in the origin of life [6-7]. Regardless of whether life formed on early Mars or not, evaluating the type and thickness of clay-bearing units on Mars provides insights into plausible aqueous processes and chemical conditions both during the time of formation of the phyllosilicates, and also during subsequent periods following their formation. This study evaluates CRISM spectra across the Mawrth Vallis region and describes the observed phyllosilicates and hydrated components in terms of plausible aqueous and microbial processes and the potential for retention of biosignatures, if present [1].

Results: Mawrth Vallis is dominated by two main phyllosilicate outcrops: a lower Fe/Mg-smectite unit with spectral bands near 2.3 and 2.4 µm and an upper unit with a band near 2.2 µm containing Al-phyllo-

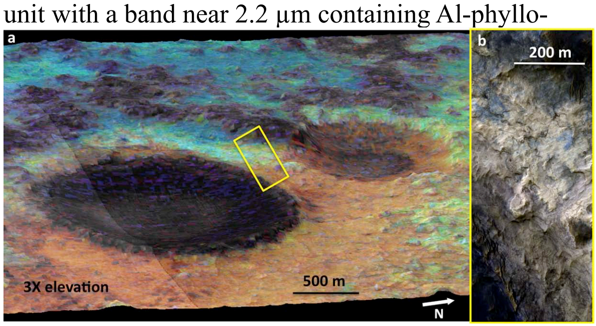

Figure 1. a) CRISM FRT000089F7 (Rd2300, Golindex, Bbd2210) over HiRISE ESP_021510_2040_COLOR, b) expanded view of the HiRISE image.

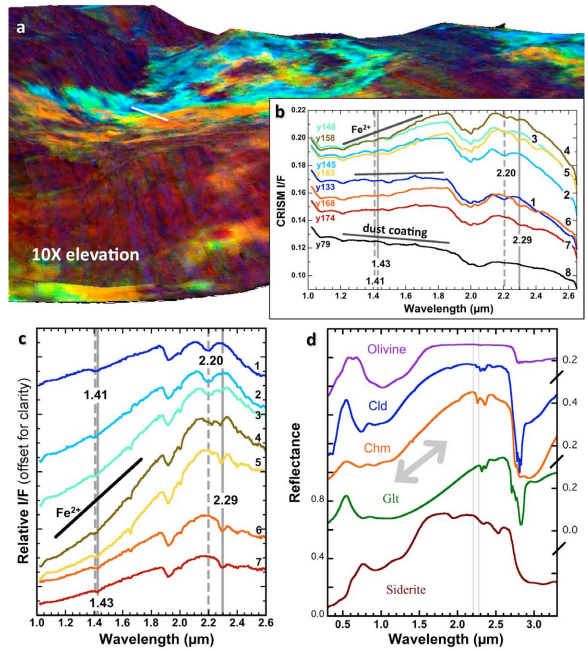

Figure 2. a) a) 3D surface of CRISM image FRT0003BFB (Rd2300, Golindex, Bbd2210) over MOLA topography, b) CRISM I/F spectra collected in numerical order across transect (white bar) c) ratioed CRISM I/F spectra, and d) Fe^{2+}-bearing minerals: olivine, celadenite (Cld), chamosite (Chm), glauconite (Glt) and siderite.

silicates and amorphous Al/Si species. Fig. 1 shows HiRISE views of the transition between these two units. Spectra are shown across transects of selected images (Figs. 2-3) in order to illustrate the transitions from Fe/Mg-smectites to the Al/Si-rich unit. These transect spectra are all ratioed to the same denominator spectrum within each image to minimize the effects of any artifacts introduced through ratioing. An Fe^{2+}-bearing phase is also present bordering the Fe^{3+}/Mg-rich and the Al/Si-rich units in many locations (Figs. 1-3). In some areas of the upper Al/Si-rich unit spectra exhibit a doublet feature at 2.20-2.22 and 2.26-2.27 µm (Figs. 2-3). This could be due to a mixture of opal, allophane or halloysite with gibbsite or an OH-bearing sulfate such as jarosite or butlerite [1]. Another explanation for this feature is acid-leaching [8].

Availability of water: Phyllosilicates generally form under high water/rock ratio environments and water availability during deposition controls the type of phyllosilicates formed [9]. Smectites are common in regions controlled by wet/dry cycling [e.g. 10]. Fig. 4

depicts a scenario where clays may have formed in an aqueous environment on early Mars. These clay-rich units remained in many cases after the liquid water was gone and would likely be buried over time. Fe/Mg-smectite is not only observed at Mawrth Vallis, but across the planet [e.g. 11-12]. Formation of a planet-wide Fe/Mg-smectite unit may have occurred early in the planets' history that was then eroded, buried or altered depending on local geologic activity.

Chemical reactions on phyllosilicates: Organic molecules were distributed to early Earth and Mars by comets and asteroids [13-14]. Phyllosilicates can catalyze reactions of these molecules, and smectites are particularly suited for this due to the acidity of their interlayer surfaces [5]. Organic reactions in montmorillonite include formation of RNA and other precursor molecules necessary for the origin of life [6-7]. These compounds bind along the smectite interlayer surfaces (Fig. 5) where their proximity facilitates reaction.

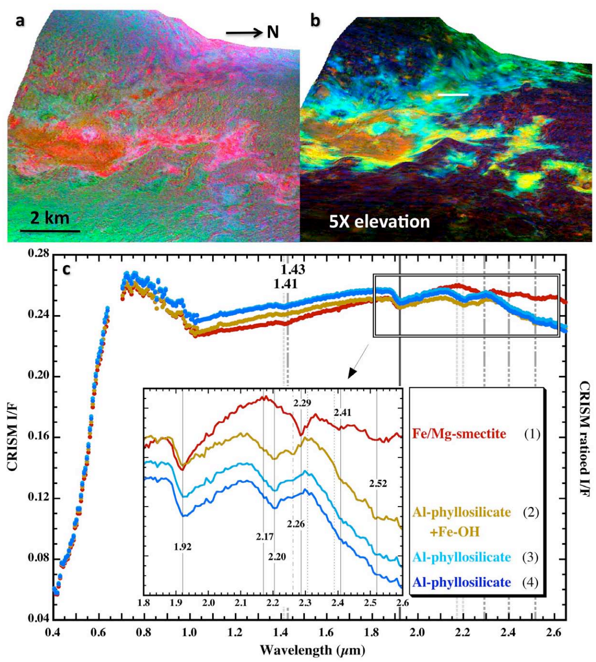

Figure 3. a) CRISM FRT0000863E draped over MOLA (Rbd530, Gbdi1000vis, Bbd920), b) same view with Rd2300, Golv, Bbd2210, c) CRISM I/F spectra collected across transect (white bar).

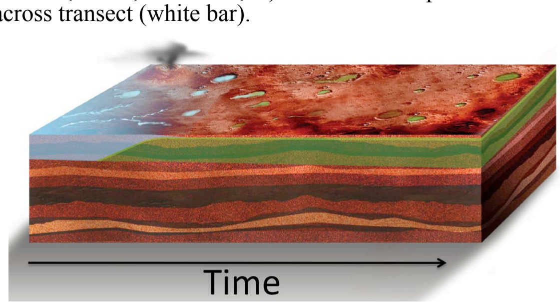

Figure 4. Martian phyllosilicate timeline illustrating that phyllosilicate formation may have been been a pervasive process in aqueous environments on the early Mars and that there may be an abundance of phyllosilicate-rich rocks on Mars below the surface [after 1].

Preservation of biosignatures: Preservation of biosignatures is favored in rapid burial conditions in fine-grained clay-rich systems (including smectites and silica) where permeability and temperatures remained low over time [e.g. 15-16]. Additionally, recent work indicates that reactive iron phases within sediments, particularly in anoxic environments, can help preserve biosignatures [17].

Early Mars Exploration: Mawrth Vallis provides a unique window into Early Mars due to the large concentration of phyllosilicates [2,18] and clear indication of *in situ* alteration. Mawrth Vallis may afford the best case study for investigating habitability and searching for potential past life of the Earlier Maritan epoch.

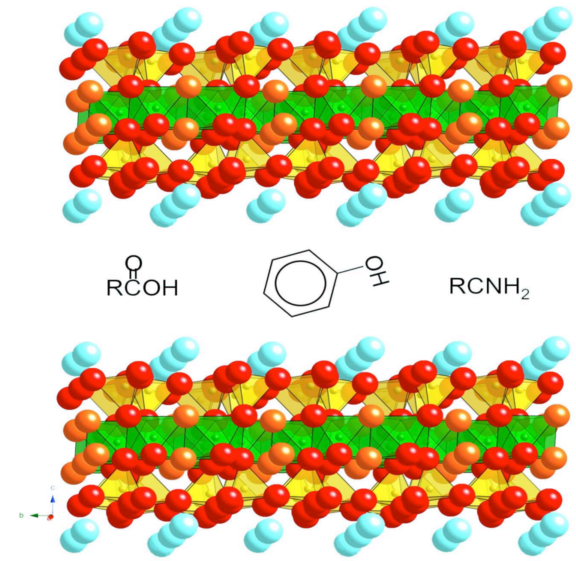

Figure 5. Smectite structural model illustrating how an expanded interlayer region could enable organic molecules to react with each other and the clay mineral surface [after 1].

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Additional Information: Support was provided by the MRO project, the European Space Agency, the NSF, the NAI, and the SETI Institute REU program.