

Phyllosilicates in Shalbatana Vallis, Mars. Lauren P. Kimbrough¹ and J. J. Wray¹, ¹School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA (lpkimbrough3@gatech.edu), (jwray@gatech.edu).

Introduction: “Following the water” has been a major theme of NASA’s multi-decadal effort to identify habitable environments—and ultimately biosignatures—on Mars. As highlighted in recent debates about where to land on the surface, evidence for liquid water can be either morphological or mineralogical; at the most compelling sites, both types of evidence are present and they complement each other [e.g., 1]. Shalbatana Vallis, one of the several large outflow channels debouching into Chryse Planitia, is one such site.

Shalbatana Vallis was likely active from the Noachian through the Late Hesperian epoch (~3.4 Ga). A point of particular interest along its course is a local basin (3°N, 43.3°W), fed by multiple inlet channels, where six fan-shaped deposits and a deeper set of light-toned materials were respectively interpreted as potential deltaic and evaporitic sediments [2]. The largest of the inferred deltas additionally preserves features interpreted to be shorelines [3]. This evident fluvial-lacustrine setting motivated work by [4] that identified layered polyhydrated sulfate minerals in the putative basin floor evaporites, and Fe/Mg-phyllosilicate minerals in the Shalbatana valley wall upslope (Fig. 1). Subsequent work with newer spectral data confirmed these findings and suggested the additional possible presence of opaline silica and/or Al-phyllosilicates [5].

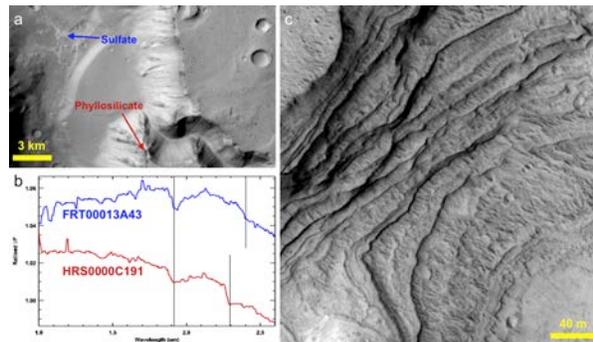


Figure 1. Shalbatana Vallis paleolake identified by [2,3]. (a) Phyllosilicates on the valley wall eroded to form fan/delta, and light-toned hydrated deposits on the basin floor (CTX P17_007824_1812). (b) CRISM spectra, colored as in (a). (c) The basin floor deposits are finely layered (HiRISE PSP_010316_1830).

Here we report the initial results of a survey for other similar materials exposed elsewhere along Shalbatana Vallis. We have found several new exposures of Fe/Mg-phyllosilicates, indicating extensive water-rock interaction throughout this region, likely during the Noachian period as elsewhere on Mars [e.g., 6].

Methods: To identify minerals of interest, we used the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board NASA’s Mars Reconnaissance Orbiter. We used Google Earth to select our CRISM images, prioritizing those that appeared to cover light-toned deposits in local basins analogous to that in Fig. 1. The CRISM Analysis Tool (CAT) add-on to the ENVI software was used to further process our selected images. Atmospheric correction, production and flattening of summary parameters, and map projection were all conducted in ENVI utilizing standard procedures [7]. To identify locations with spectral absorptions characteristic of hydrated minerals, we used many spectral summary parameters, but those that proved most significant were BD1435, BD1900, BD2290, and D2300; these each quantify the strength of an absorption centered near the quoted wavelength (in nm), respectively indicative of hydroxylated (OH-bearing) material, hydrated (H₂O-bearing) material, Fe-phyllosilicates, and Fe/Mg-phyllosilicates [8].

For each area highlighted by the above parameters, we extracted spectra using the Region of Interest (ROI) Tool. For each spectrum, a ratio was taken of the specific area of interest divided by a generic region in the same column. This reduced residual artifacts and noise in the spectra and elucidated the mineral features. The ratioed spectra were then compared to other spectral data from published databases in order to determine the mineral composition.

Spectral Analysis: Spectra examined to date show evidence for widespread iron- and magnesium-bearing phyllosilicates, with some that are specifically consistent with Mg-smectite, Fe-smectite, and perhaps localized examples of serpentine. The most significant concentrations of phyllosilicates were found >200 km south (upstream) of the aforementioned paleolake basin, in or near the Orson Welles crater and farther south. The majority were located in light-toned (possibly paleo-lacustrine) deposits inside craters, or exposed along crater rims. Fig. 2 shows a representative example.

The Fe/Mg-phyllosilicates were detected and mapped most readily using their water absorption features at 1.9 μm and 1.4 μm (Fig. 2). Those occurring in light-toned crater floor materials have especially sharp and deep absorptions at 1.9 μm , attributed to H₂O. Spectra were also taken around the rims of craters such as that in Fig. 2; on the rim, the absorption features at 1.4, 1.9, and 2.3 μm (Fig. 3) resemble those of Mg-smectite. Additional absorption features at 2.4 and 2.5

μm appear unexpectedly strong, and the $2.3 \mu\text{m}$ band appears more asymmetric than in typical spectra of pure Mg-smectites, suggesting additional mineral components may be present. Some spectra also exhibit an absorption feature at approximately $0.8 \mu\text{m}$ (not shown), which deviates from laboratory Mg-smectites.

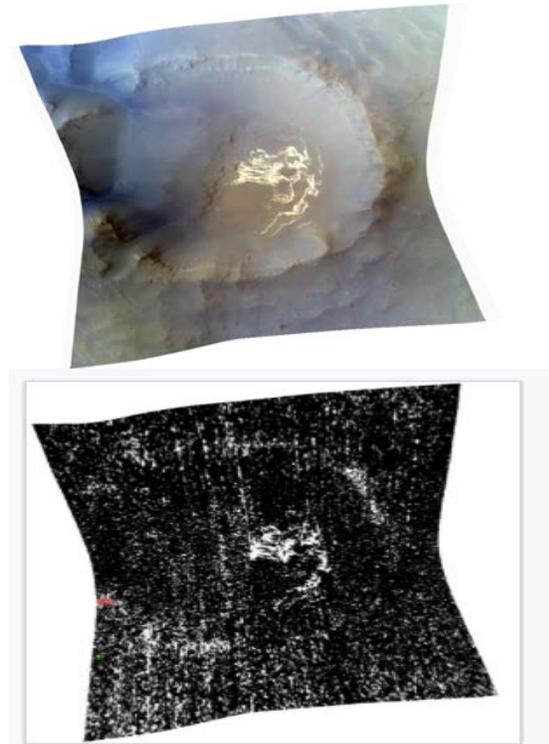


Figure 2. CRISM image FRT00008EBF, covering a $\sim 10 \text{ km}$ wide crater on the Shalbatana Vallis floor south of Orson Welles. Top image is a three-band visible composite image, whereas bottom maps hydrous minerals via the BD1435 parameter [8]. Red area at bottom marks the source of the spectrum below.

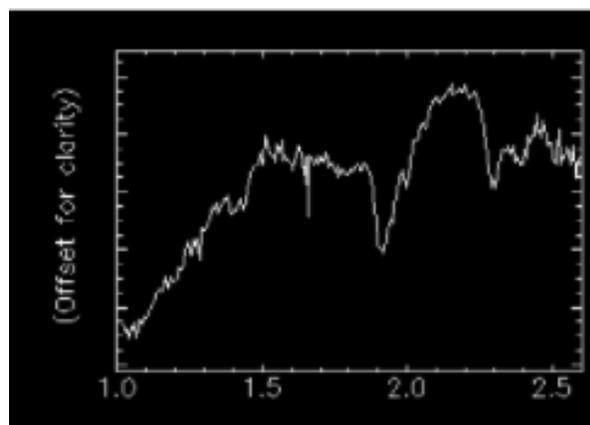


Figure 3. Ratio spectrum from crater rim materials in CRISM FRT00008EBF, which we interpret as consistent with Mg-smectite. Wavelengths are in μm .

Elsewhere, using the BD2290 parameter, we extracted ratio spectra containing a very deep $1.9 \mu\text{m}$ band along with a small concavity at $2.1 \mu\text{m}$, similar to spectra of serpentine previously identified on Mars [9].

Discussion: All of the spectra indicating phyllosilicates were discovered near Orson Welles and south of this crater, consistent with previous studies of this region [10]. The phyllosilicates occur at multiple altitudes in nearby smaller craters. No significant phyllosilicate spectral signatures were found in northern regions of the basin, although this could be due to poorer exposure and/or lack of CRISM coverage over key locations.

The regions in which phyllosilicates were detected may have undergone aqueous alteration resulting from interaction with water sourced from ices, liquid aquifers, or gases as in chemical weathering via acid fog [11]. The outcomes of alteration can be influenced by temperature, time, parent rock mineralogy, rock permeability, and water/rock ratio; therefore we are continuing to refine our mineralogical analyses so as to better constrain these unknowns. These alterations could provide further understanding of the geological conditions on Mars during the Noachian period, when these rocks cut by Shalbatana Vallis originally formed. Aqueous alteration appears to have been regional or even global in the Noachian and to have continued during the Hesperian period as well [12]. Alterations could have resulted from weathering, subsurface bodies of water interacting with the rocks, or impact-induced hydrothermalism dissipating heat around the surface and melting the ice. The high concentration of phyllosilicates found specifically within the paleolake deposits could have originated from the transportation of sediments deposited by the Shalbatana-carving flood(s), and/or by smaller-scale erosional events.

In any case, continued study of this region's rich aqueous history should provide further understanding of Mars's early climate and geomorphological history.

References: [1] Grotzinger J. P. (2009) *Nature Geosci.*, 2, 231–233. [2] Di Achille G. et al. (2007) *JGR*, 112, E07007. [3] Di Achille G. et al. (2009) *GRL*, 36, L14201. [4] Wray J. J. et al. (2009) *AGU Fall Meeting*, Abstract #P41B-06. [5] Di Achille G. et al. (2013) *LPS XLIV*, Abstract #3027. [6] Ehlmann B. L. et al. (2016) *JGR-Planets*, 121, 1927–1961. [7] Murchie S. L. et al. (2009) *JGR*, 114, E00D07. [8] Viviano-Beck C. E. et al. (2014) *JGR-Planets*, 119, 1403–1431. [9] Ehlmann B. L. et al. (2010) *GRL*, 37, L06201. [10] Wintzer A. E. et al. (2011) *LPS XLII*, Abstract #1557. [11] Ming D. W. et al. (2008) in *The Martian Surface*, ed. J. Bell, Cambridge Univ. Press, 519–540. [12] Le Deit L. et al. (2012) *JGR*, 117, E00J05.