

INVESTIGATING FRACTURED PHYLLOSILICATE-RICH DEPOSITS AT MAWRTH VALLIS, MARS. C. Gross¹, J. L. Bishop², J. Carter³, B. Horgan⁴, D. Loizeau³, C. Orgel¹ and F. Poulet³. ¹Institute of Geological Sciences, Planetary Sciences and Remote Sensing Group, Freie Universität Berlin, Germany (christoph.gross@fu-berlin.de); ²SETI Institute & NASA-ARC, Mountain View, CA, USA; ³Institut d'Astrophysique Spatiale, Paris- Sud University, Orsay, France; ⁴Purdue University, West Lafayette, IN, USA.

Introduction: Mawrth Vallis displays a unique set of accessible phyllosilicate-rich materials on Mars. The region is believed to harbor one of the most promising locations for the search for past and present life on the red planet. Besides the mineralogy, the stratification of the rocks observable over a large area offers a particular opportunity to study depositional environments and also the climate history of Mars during the most crucial phase of the planet [1]. Unfortunately, technological limitations hampered the selection of the site for ESA's ExoMars mission aimed for 2020. The proposed landing site at Mawrth Vallis was located roughly 1000 m higher in elevation than the competing Oxia Planum site, and the diverse geology exposed translated into terrain roughness deemed less trafficable for the rover. Collectively, these terrain constraints were a strong driver for its non-selection. Nonetheless, investigation of the Mawrth Vallis region continues using orbital data in order to further advance our understanding of the mineralogy and geochemical history of this ancient site. Here, we examine the working hypothesis that a part of the clay stratigraphy could have been formed under low temperature hydrothermal conditions.

Context: Within the Mawrth Vallis region and within the proposed ExoMars landing ellipse, numerous fractures are observed. Their sizes vary typically from a few tens of meters to several hundreds of meters with a few extending up to kilometers [2]. Some fractures show a positive relief and/or are surrounded by a light-toned area at times forming a halo (Fig. 1). Others contain a dark-colored infilling, presumably due to dust or sand deposition. Apparently, most fractures occur at the transition of the extensive Fe/Mg-rich phyllosilicate unit, containing a large abundance of nontronite (30-70%) and the Al-rich unit above it in the stratigraphy. The filled fractures can be explained as the result of fluid circulation inside the fractures that results in precipitation of minerals inside and in vicinity of the fractures, forming the light-toned infills and halos.

Terrestrial Analogue Material: A suite of different samples originating from hydrothermal environments [3] was considered in evaluating the possibility of low temperature hydrothermal processes at Mawrth Vallis. They originate from an active submarine fault zone (ca. -1100 m) at the Lesser Antilles Island Arc. One sample (CG18), is characterized as a mixture of volcanic ashes and carbonate, indurated by a nontronite-manganese matrix. Partly, indurated layers

are visible, containing elevated MnO concentrations. Under the microscope, grains of feldspar, pyroxene, glass and rhyodacitic fragments, as well as pelagic carbonates as clasts of different size can be found, in general varying between 0.25-0.63 mm. The embedded mineral grains show little evidence of disintegration and look mostly unweathered.

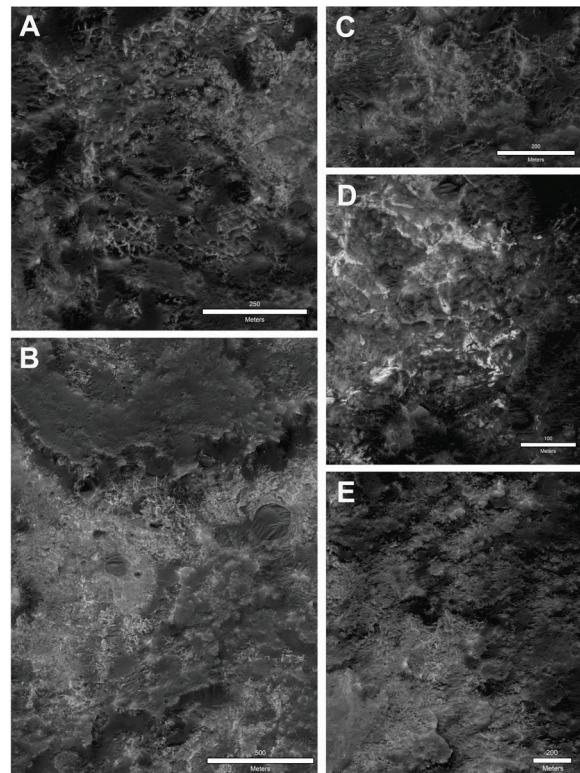


Figure 1: Overview of fractures at different scales present within the proposed ExoMars landing site envelope. A-C: Dense network of fractures standing out of the surrounding materials. D: Light-toned halos clearly visible at some locations.

SEM imagery and EDX measurements show that the grains are covered with a thin SiO₂ film, followed by a thick (~10 µm) layer of nontronite that is then covered by the Mn-oxide birnessite resulting in a tree-layer structure. X-ray diffraction confirms nontronite and plagioclase as the most abundant minerals in the sample. Also, calcite and quartz are present. Another interesting observation is the presence of elongated and branching microtubes within the SiO₂ coating at the surface of some grains. The tubes, which are partly filled, have a diameter of 2-7 µm and are only found on grain surfaces within the SiO₂ layer. The structures

show a relatively straight orientation, sometimes branching at 90° angles. Some grains are completely covered with the microtubes. Fig. 2 shows a comparison of spectroscopic measurements of sample CG18 and spectral data from martian nontronites detected by orbiting instruments in the Mawrth Vallis region [4; 5]. This striking resemblance and the presence of fracture networks could point to reasonable processes for past and present Mars. Sample CG18 was ground for spectral analysis and consequently the layer-like texture of the sample was destroyed. However, one can assume that broken-down material would cover the surface in a martian outcrop scenario and also display a spectrum of mixed materials, as well as the large size of pixels of the remote-sensing spectrometers where one spectrum represents a mixture of material.

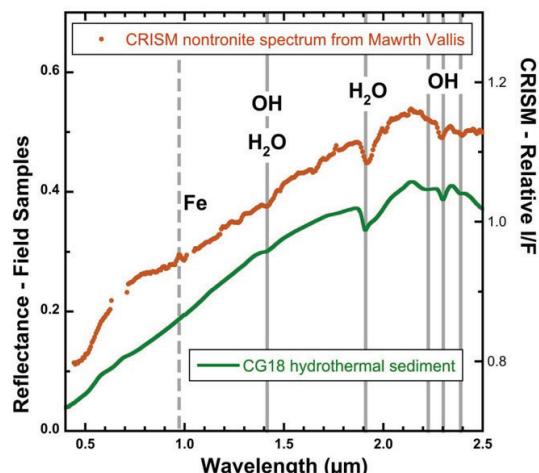


Figure 2: Martian CRISM spectrum of nontronite from the Mawrth Vallis region (red) compared to the spectrum of the sample CG18 (green) measured with an ASD-spectrometer. The notable slope of sample CG18 could result from sample texture or an amorphous component in the sample.

Discussion: [6] investigated low-temperature Fe-Mn-Si precipitates with an inferred formation temperature of < 30° C from the Galapagos spreading center. A well crystallized nontronite was described as a hydrothermal product. Filamentous structures were found in iron oxides and silicate rocks of the East Pacific ridge [7] and a possible bacterial influence was suggested. [8] describe filamentous structures indicating bacterial activity as a prevalent phenomenon in the upper portions of hydrothermal systems. Biogenic formation of nontronites in white smoker chimneys at the Galapagos spreading center and the Marianna Trench was proposed by [9]. This interpretation is based on the resemblance of delicate micro tubes composed of nontronite and bacteria building up layered structures. [9] conclude, that thick mats of Fe-oxidizing bacteria could restrain the dilution of low temperature hydrothermal

fluids and the low mixing rate will then lead to more stable redox conditions. This would hamper the nontronite precipitation but not the precipitation of Fe-oxhydroxides. Also, [10] lists birnessite reduction as a possible energy source for chemotrophic organisms. However, it has to be considered that the mixing of seawater with a hydrothermal fluid at different physicochemical conditions also leads to specific mineral precipitations without the influence of bacteria. [11] investigated the parameters needed for the precipitation of manganese oxides (pyrolusite/todorokite) using Geochemist's Workbench software and a fluid composition of the East Pacific Rise. The calculations show that nontronite precipitates at 90°C and a pH of 5.6, while at temperatures of 280°C pyrite precipitates. A considerable increase of the pH is observed between 100°C and 30°C. High pH values accelerate the formation of nontronites [12]. Following the calculations of [11] the pH is at 6.2 at a temperature of 45°C. At this point, MnO₂ precipitates from the solution. Amorphous silica starts at 20°C. In summary, the hot solution mixes with seawater as it ascends through the upper sediment layers and cools down. Nontronite, manganese oxides and amorphous silica can precipitate out of solution at specific temperatures within one hydrothermal cycle. The observed microtubes in sample CG18 could thus also represent small fluid-pathways.

Conclusion: The widespread presence of mineralized fractures at Mawrth Vallis remains puzzling. Unerringly, fluids percolated through these fractures, pointing to a potential hydrothermal system where the mineralized fractures are present, but a broad and regional hydrothermal alteration, even at low temperatures, appears as an unlikely scenario for the formation of such thick and continuous nontronite-rich deposits present over 100's of km. A relation to the presumably volcanic capping unit overlying the phyllosilicate sequence as well as diagenetic processes need to be further investigated. An in-situ campaign at Mawrth Vallis would dramatically increase our understanding of one of the potentially most habitable regions on Mars.

References: [1] Bishop, J. L. et al. (2018) Nature Astronomy, v. 2, no. 3, p. 206-213. [2] Loizeau et al. (2012) Planetary and Space Science, v. 72, p. 31-43. [3] Gross, C. et al. (2015) Proceedings AGU Fall Meeting, San Francisco, p. Abstract #69053. [4] Poulet, F. et al. (2005) Nature, v. 438, p. 623-627. [5] Bishop, J. L. et al. (2008) Science, v. 321, p. 830. [6] Corliss, J. B. et al. (1978) Earth and Planetary Science Letters, v. 40, no. 1, p. 12-24. [7] Alt, J. C. (1988) Marine Geology, v. 81, no. 1, p. 227-239. [8] Juniper, S. K. & Fouquet, Y. (1988) Canadian Mineralogist, v. 26, no. 3, p. 859-869. [9] Köhler, B. S. et al. (1994) Clays and Clay Minerals, v. 42, no. 6, p. 689-701. [10] Westall, F. et al. (2015) Astrobiology, v. 15, p. 998-1029. [11] Marbler, H. (2004) PhD-thesis: Freie Universität Berlin. [12] Harder, H. (1978) Clays and Clay Minerals, v. 26, no. 1, p. 65-72.