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GEOLOGICAL SIGNIFICANCE OF HYDRATED SILICA ON MARS AS SEEN BY CRISM DATA COMPARED TO TERRESTRIAL ANALOGS. M. Pineau¹, L. Le Deit¹, B. Chauviré², J. Carter³, B. Rondeau¹ and N. Mangold¹. ¹LPG, UMR CNRS 6112, Univ. Nantes/Angers, France (maxime.pineau@univ-nantes.fr), ²ISTerre, Univ. Grenoble-Alpes, France, ³IAS, Univ. Paris-Sud, France.

Introduction: Orbital studies of Mars have shown abundant mineralogical evidences of water-rock interactions using the VNIR imaging spectrometers OMEGA and CRISM [1,2]. However, there are only few constraints on the physicochemical conditions of the climate prevailing during early Mars. In particular, relative contributions of hydrothermal activity and continental weathering are still uncertain.

Several minerals, such as hydrated silica, can form at low temperature by continental weathering, suggesting surface-atmosphere interactions [3]. But, they can also form at higher temperatures by hydrothermal alteration [3]. In that case, subsurface hydrothermal activity would not imply the occurrence of an open system with surface-atmosphere interactions to form hydrous minerals, and no interpretation on the past climate can be deciphered from the observation of such geological contexts.

Previous studies showed that the near-infrared spectral signature of hydrated silica could give information about its crystallinity (hydrated glass, opal-A/CT, chalcedony) [3,4,5,6]. Moreover, specific band shape measurements (Concavity-Ratio-Criterion CRC) can provide constraints on the formation processes of terrestrial opals (continental weathering versus hydrothermal alteration) [3]. We applied these spectral criteria to reflectance spectra of terrestrial varieties of hydrated silica and to CRISM data in order to better understand the major geological processes that formed hydrated silica on Mars.

Material and methods: We have compared terrestrial data of several types of hydrated silica (hydrated glasses, opal-A/CT, chalcedony) (**Fig. 1**) with specific spectral criteria: Concavity-Ratio-Criterion [3] and band minimum positions (**Fig. 2**). NIR spectral acquisitions of terrestrial hydrated silica were carried out at ambient and at Mars-relevant atmospheric pressure (~ 7.5 mbar during ~ 3 to 15 hours) [7]. We have used CRISM data and plot them in the framework of terrestrial data results in order to check for spectral signatures ascribable to weathering or hydrothermal alteration. I/F-converted CRISM images are corrected from atmospheric gas absorptions by the scaled volcanoscan method [8]. Extraction of hydrated silica CRISM spectra have been conducted using the processing tools specified in [9]. These spectral analyses have been correlated with HiRISE and CTX images in order to

assess the geomorphological settings of these hydrated silica-bearing deposits.

Fig 1. Reflectance spectra of terrestrial hydrated silica varieties, vertical lines indicate positions of main classical hydrated silica absorption bands.

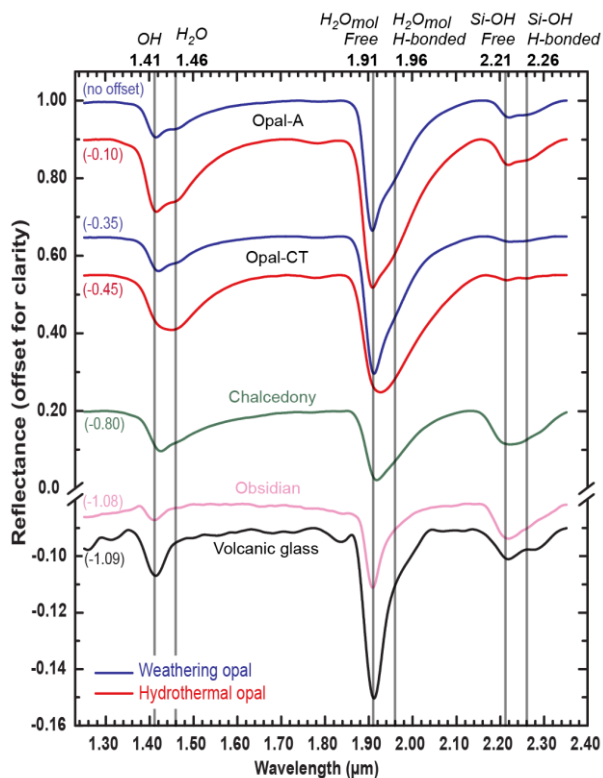
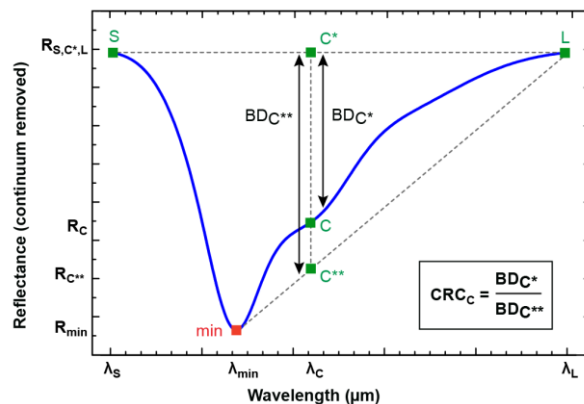


Fig. 2. Diagram illustrating the Concavity-Ratio-Criterion (CRC) calculation of an asymmetric absorption feature (from [3]).



Results: Criteria applied to terrestrial data at terrestrial atmospheric pressure show that both the 1.4 and 1.9 μm bands allow distinguishing between opal-A/CT via the band minimum positions; opal-A having the lowest minima [3,4,5,6]. Moreover, the two absorption features allow to discern between weathering/hydrothermal opals by the CRC calculations, weathering opals having lower CRC values than hydrothermal opals [3]. The 2.2 μm band does not permit to distinguish neither the type of opals nor their formation processes [3,6].

Contrary to previous studies that investigated the NIR spectrum of hydrated silica at low atmospheric pressure [5,6], we see that the dehydration of silica on Mars is not systematic and less intense than proposed before [5,6]. Indeed, only 2 samples of our dataset show spectral variations that indicate that they dehydrated. For these samples, band minima shift to lower wavelengths [5,6] and the CRC values dropped. To remain as conservative as possible, we still took into account these variations for the martian application of our spectral criteria.

The application of these spectral criteria to CRISM data show two major geomorphological contexts where hydrated silica is detected (**Fig. 3**). First, hydrated silica-bearing bedrock deposits (e.g. alluvial fans, stratified deposits, etc.) consist of amorphous and/or dehydrated silica [6]. Spectral criteria associate these detections to weathering opal-A, that are dehydrated, or to volcanic glasses that were altered by superficial processes of alteration (**Fig. 3**). Secondly, hydrated silica-bearing reworked deposits (e.g. aeolian dunes and mega-ripples) are constituted of more crystalline and/or hydrated silica [6] that is associated to hydrothermal opal-CT or chalcedony (**Fig. 3**). As expected, the calculated criteria on the 2.2 μm band of the CRISM data do not allow to distinguish silica origins and/or crystallinity [6] as all detections have very similar values.

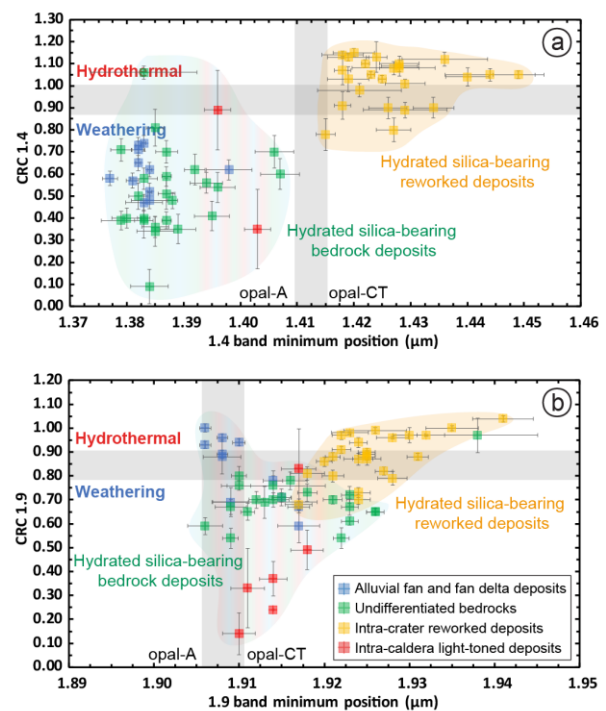
Discussion: Overall, concavity criteria measured on our limited set of selected martian places show results that are in agreement with geological origins proposed in the literature (weathering sites: Aeolis Mensae, Camichel crater, Valles Marineris, Nilosyrtris Mensae; hydrothermal sites: Antoniadi crater, Elorza crater, Iani Chaos). Some differences between our results and the literature are however raised for sites like Noctis Labyrinthus and Nili Patera. These differences highlight that post-depositional processes may have modified the initial signature of these deposits or that they were formed by low-temperature hydrothermal activity.

Conclusions: These two spectral criteria, band minima positions and CRC, show that it is possible to use near infrared signatures as a proxy to determine

processes of hydrated silica formation where the geological contexts are ambiguous, especially on Mars.

The next two space missions Mars2020 (NASA) [10] and ExoMars (ESA) [11] aim to send two new rovers on Mars. There will be new hyperspectral spectrometers, which have never been shipped on a martian rover yet. Given the interest in silica-rich deposits for exobiology [12,13], the use of our spectral criteria in any in-situ detection of hydrated silica deposits would help to better understand the origin of the alteration processes at the martian surface.

Fig 3. Plots showing the band minimum positions vs. CRC calculations for CRISM data for the 1.4 μm (a.) and 1.9 μm absorption features (b.). The thresholds are those obtained on terrestrial data measured at Mars-relevant atmospheric pressure.



References: [1] Carter et al. (2013) *JGR*, 118, 1–28. [2] Ehlmann & Edwards (2014) *Annu. Rev. Earth Planet. Sci.*, 42, 291–315. [3] Chauviré et al. (2017) *Eur. J. Miner.* 29, 409–421. [4] Langer & Flörke (1974) *Fortschr. Miner.*, 52, 17–51. [5] Rice et al. (2013) *Icarus*, 223, 499–533. [6] Sun & Milliken (2018) *GRL*, 45, 221–228. [7] Haberle et al. (2017) *Cambridge Univ. Press*. [8] McGuire et al. (2009) *PSS*, 57, 809–815. [9] Carter et al. (2013) *PSS*, 76, 53–67. [10] Wiens et al. (2017) *Spectroscopy*, 32, 50–55. [11] Vago et al. (2017) *Astrobiology*, 17, 471–510. [12] Ruff & Farmer (2016) *Nat. commun.*, 7, 13554. [13] McMahon et al. (2018) *JGR Planets.*, 123, 1012–1040.