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HYDRATED SILICA IN MARTIAN ALLUVIAL FANS AND DELTAS. L. Pan[1], J. Carter[2] and C. Quantin-Nataf[3]. [1]Univ. Lyon, Université Claude Bernard Lyon 1, ENS de Lyon, CNRS, UMR 5276 LGL-TPE, F-69622 Villeurbanne, France (lu.pan@univ-lyon1.fr). [2]l'Institut d'Astrophysique Spatiale, Univ. Paris-Sud 91405 Orsay (john.carter@ias.u-psud.fr). [2] Univ. Lyon, Université Claude Bernard Lyon 1, ENS de Lyon, CNRS, UMR 5276 LGL-TPE, F-69622 Villeurbanne, France (cathy.quantin-nataf@univ-lyon1.fr).

Introduction: A plethora of evidence for liquid water on the surface of Mars has been accumulated in the last decade, but the timing and mechanism for the transition of the Martian climate remain unclear. Recently proposed climatic solutions range from a generally early cold and icy environment [e.g. 1-2] to short-term or cyclic warming events during early Mars [e.g. 3], to a continued, persistent surface runoff perhaps long after Noachian [e.g. 4]. Enabled by the completed global mineralogical datasets [5-6], a combined view of morphology and mineralogy could potentially help narrow down the parameter spaces allowed for these climatic solutions.

The basaltic Martian crust is expected to liberate a large amount of silica during aqueous alteration [7]. Since the solubility of amorphous silica is linearly correlated with temperature when the pH is smaller than 8.5-9 [8], observations of precipitated silica could provide important constraints on the water temperature and chemistry. In this abstract, we first review the silica detections on Mars from orbit and in situ and then present analyses of fans and deltas with silica detections. These deposits hold clues to the record of liquid water in the last three billion years on the surface of Mars and may provide important prior information for Mars 2020 and ExoMars missions.

Silica on Mars: From in situ explorations, silica is first identified with high concentration (as much as 91 wt%) near the Home Plate outcrop in Gusev crater by Spirit rover [e.g. 9-10] and more recently trydimite and amorphous silica have been characterized by Mars Science Laboratory in Gale crater [e.g. 11-14]. From orbit, silica is first identified in deposits near the Valles Marineris canyon system [15], in Nili Fossae region [16] and in Nili Patera caldera [17] using data acquired from CRISM (Compact Reconnaissance Imaging Spectrometer on Mars). Silica is subsequently found globally in various environmental settings, including volcanic, sedimentary, aeolian and periglacial [e.g. 18-19].

Among those associated with sedimentary settings, at least 14 have been reported to be correlated with a terminal deposit of a channel (Figure 1, 18-26), including the two future landing sites of Martian rovers to be launched in 2020 (Jezero crater [e.g. 24] and Oxia Planum [18, 26]). These terminal deposits (fans and deltas) generally formed later than Noachian, and some may have formed as late as Amazonian based on crater count of restricted areas [20]. The most prominent detections (See Fig. 1A, Type I) found in bedrock deposits have a distinct spectral signature with the 1.4 µm band narrowed and shifted to shorter wavelengths, indicating a less mature phase compared to silica found in eolian sediments [19, 27]. This has been attributed to a common feature of dehydrated opal-A in the Mars

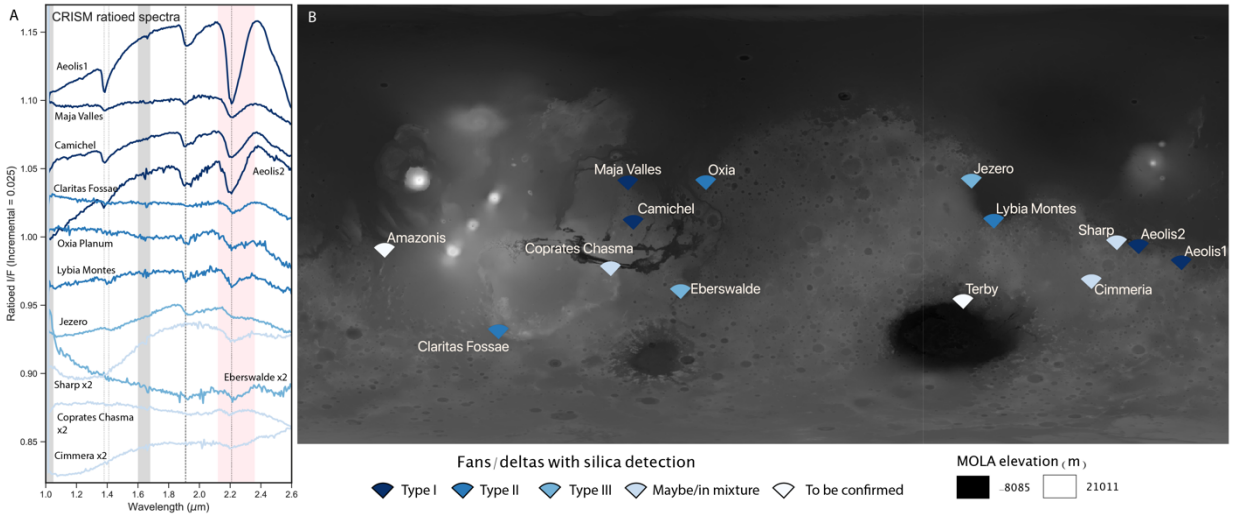


Figure 1. A) CRISM ratioed spectra of silica detections reported in previous literature associated with fans or deltas on Mars [5, 18-26], named after the closest named regions or features. The last four spectra are vertically exaggerated by 2 to show weak absorption features. The wide 2.21 µm bands of SiOH are marked by the pink shaded region. Dark grey shaded regions are known artifacts. B) Distribution of fans/deltas with silica globally. Symbols labeled with fan locations are overlain on the Mars Orbital Laser Altimeter (MOLA) topography.

environment [19] or opaline silica formed in low-temperature water-rock interactions [27].

Morphology and mineralogical features of a typical silica-bearing fan: We show the example of one of these fan deposits (Aeolis1), for which a Digital Elevation Model (DEM) based on HiRISE stereo images were used to obtain measurements of the morphometry of the channel and the fan. CRISM detections are co-registered to the images using hand-selected ground control points. The deposit is a small stepped fan with a length of 2 km and width of 1.6 km inside a degraded impact crater. A maximum volume of 1.5×10^8 m^3 of sediments has been deposited, indicating as much as ~468 km^3 liquid water may have been involved based on assumptions of water-to-sediment ratio [28]. The strong silica signature is well-correlated with the fan, in light-toned deposits (Fig. 2A). A small light-toned region on the crater floor also bears silica detections and no hydrous mineral is found on the channel wall. The fan could be divided into three well-distinguished stages of depositions, with clear breaks in slope in the elevation profile (Fig. 2B). Crater density differences indicate a lapse in time between the bottom stage and the upper two stages. The strength of the 2.21 μm absorption band due to hydrated silica detection increases with decreasing elevation, and three obvious levels of band depths are observed corresponding to the three fan stages from elevation in this image.

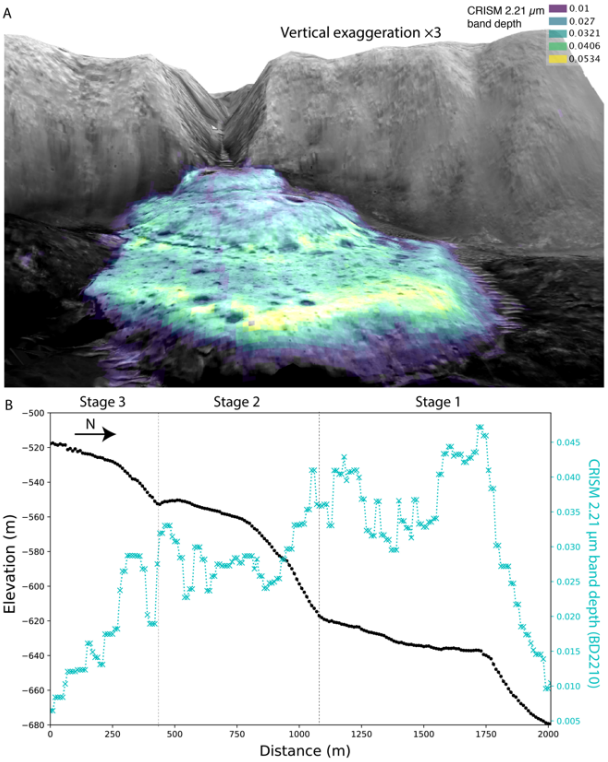


Figure 2. A) 3D rendering of an unnamed fan in Aeolis region with CRISM parameter map overlain on HiRISE image. The topography is exaggerated by 3 times. B) A cross-section along the fan direction of elevation profile (black) and extracted CRISM 2.21μm band depth (cyan) corresponding to Si-OH or Al-OH absorptions.

Formation of silica deposits and implications for the past environment: Silica deposits found in fluvial settings could be detrital, hydrothermal and diagenetic. In the case of Aeolis1 fan, the hydrated silica in large, coherent units found in the terminal deposits of a channel lacks an obvious source of equivalent size. The spectral signature consistent with the presence of opal-A, a less pristine type of silica also suggests the hydrated silica likely formed in situ and did not experience prolonged alteration afterward [19, 27]. A hydrothermal origin is unlikely since there is no obvious volcanic source nearby, and the temperature of hydrothermal fluids decreases exponentially with time and distance. Thus we favor the cases where the hydrated silica formed through diagenesis. One possible scenario is that silica was dissolved in the water right after fan formation and precipitated as water drained or temperature decreased. Alternatively, a secondary, late diagenetic event may be responsible for the formation of silica where aqueous alteration occurred separately from the fan formation. In either case, spectral variations resulted from changes in silica content or grain size are correlated to the three depositional stages of the fan.

Hydrated silica deposits are found on Mars in many young sedimentary environments. Large volumes of water are involved in the formation of these fans and deltas, and the formation of hydrated silica associated with these deposits probably represent one or more common sedimentary processes in the last three billion years. A detailed comparative study of these silica deposits may help constrain the duration of liquid water globally distributed on Mars post-Noachian.

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References: [1] Wordsworth et al. (2015) *JGR*. [2] Fastook & Head (2015) *PSS*. [3] Bishop et al. (2018) *Nat. Astro*.[4] Kite et al. (2017) *GRL*. [5] Carter et al. (2013) *JGR*. [6] Ehlmann & Edwards (2014) *Annu. Rev. Earth & Planet. Sci.* [7] McLennan (2003) *Geology*. [8] Siever (1962) *J. Geology*. [9] Squyres et al., 2008, *Science*. [10] Ruff et al., 2011, *JGR*. [11] Morris et al. (2016) *PNAS*. [12] Rapin et al. (2018) *JGR*. [13] Yen et al. (2017) *EPSL*. [14] Frydenvang et al. (2017) *GRL*. [15] Milliken et al. (2008) *Geology*. [16] Ehlmann et al. (2009) *JGR*. [17] Skok et al. (2010) *Nat. Geosci.* [18] Carter et al. (2012) *LPSC*. [19] Sun & Milliken (2018) *GRL*. [20] Hauber et al. (2013) *JGR*. [21] Goudge et al. (2015) *Icarus*. [22] Weitz and Bishop (2015) *JGR*. [23] Bishop et al. (2011) *Clays & Clay Min*. [24] Tirsh et al., (2015) *Icarus*. [25] Tanas et al. (2018) *4th Mars2020 Landing Site Workshop*. [26] Quantin et al. (2018) *LPSC*. [27] Pineau et al. (2018) *LPSC*. [28] Palucis et al. (2014) *JGR*.