

**INVESTIGATING HYDRATED SILICA IN THE NILI PATERA REGION, MARS.** V. Z. Sun<sup>1</sup>, J. R. C. Voigt<sup>1</sup>, and K. M. Stack<sup>1</sup>, <sup>1</sup>Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA (vivian.sun@jpl.nasa.gov).

**Introduction:** Hydrated silica (or opaline silica) has been detected on the martian surface in several remote sensing data, including near-infrared (NIR) reflectance spectra and thermal infrared emissivity spectra, as well as in situ rover observations [1–6]. The existence of hydrated silica indicates water-rock interactions during the time of formation. While opal itself forms in a variety of aqueous conditions and may not uniquely indicate conditions such as pH, opaline silica can be used as a tool to specify certain environment conditions. Specifically, the crystallinity of opaline silica is correlated with the degree of aqueous alteration [7]. Thus, the crystallinity can be used as a proxy for the intensity of water-rock interaction, where amorphous silica (e.g., opal-A) indicates short-lived aqueous alteration and more crystalline silica (e.g., microcrystalline quartz) a prolonged exposure to water [7].

Here, we investigate hydrated silica in the Nili Patera region on Mars to constrain the longevity of aqueous conditions in Nili Patera and the surrounding Syrtis Major Planum.

**Data and methods:** To detect and investigate hydrated silica in the Nili Patera region, we utilize a combination of remote sensing data, including *Mars Reconnaissance Orbiter* (MRO) datasets such as the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [8], Context Camera (CTX) [9], and High Resolution Imaging Science Experiment (HiRISE) [10] images. CRISM scenes included full resolution targeted (FRT) and short (FRS) with 18 m/pixel, half resolution long (HRL) and short (HRS) observations with 36 m/pixel. In total 106 CRISM images were evaluated. Hydrated silica was then classified based on the absorption characteristics at 1.4, 1.9, and 2.2.  $\mu\text{m}$  in the Infrared Radiation (IR) portion of the CRISM data (1.0–2.6  $\mu\text{m}$ ) [8]. We then used the position of the 1.4  $\mu\text{m}$  absorption to characterize the crystallinity of silica, with shorter wavelength position representing amorphous hydrated silica (e.g., opal-A) and longer wavelength position corresponding to microcrystalline hydrated silica (e.g., opal-CT or microcrystalline quartz) [11, 12].

To capture the broader geologic context our geological investigation is covering a greater spatial extent than previously published maps in Nili Patera [13] and at a map scale more detailed than the global geological map of Mars [14]. Therefore, we used the global CTX mosaic with a resolution of 6 m/pixel [9]

from Dicks on et al., 2018 [15]. In selected locations, we additionally used HiRISE images with a resolution of up to 0.3 m/pixel [10].

**Results and Interpretations:** The majority of hydrated silica are associated with the early Hesperian volcanic unit [eHv; 14] in Syrtis Major Planum. Our results show that hydrated silica is the sole hydrated mineral associated with the two calderas located in the central part of our study site including: Nili Patera in the north and Meroe Patera in the southeast (Fig. 1 red star clusters). This silica has a 1.4  $\mu\text{m}$  minimum position < 1.41  $\mu\text{m}$  and thus is consistent with amorphous opal-A (Fig. 1 A white box labelled 1). Within the Nili Patera caldera the hydrated silica was detected in the high-standing unit in the western portion of the caldera including Nili Tholus itself. None of the detections were associated with the caldera filling floor unit [13]. In Meroe Patera hydrated silica is located in the northern part of the caldera. In addition, we found hydrated silica with Fe/Mg/Al-clay along the flanks of the volcanic shield. Locations 2 and 3 in Fig. 1 A lie within Noachian-aged terrains and represent an outcrop that is stratigraphically lower than the lava flows at location 2 and material excavated by an impact crater just west of the Toro crater at location 3. Both locations have 1.4  $\mu\text{m}$  band position > 1.41  $\mu\text{m}$ , which is consistent with opal-CT (compare Fig 1 C).

The observation of more crystalline opal-CT in stratigraphically lower and older Noachian terrains and amorphous opal-A located in younger Hesperian-aged volcanic terrain, suggests that older Noachian units are likely to have crystalline silica whereas younger Hesperian units are likely to have amorphous silica.

In addition, the detection of opal-A in the caldera suggests that the local aqueous conditions likely ceased after the initial formation. Based on the geological context it is likely that opal-A formed shortly after the lava flows with an age of <3.7 Ga [16]—maybe as a consequence of hydrothermal activity [17]. If true, then the local cessation of water on the surface/near surface can be constrained to <3.7 Ga. Assuming that opal-A would very likely convert to opal-CT with water present [18].

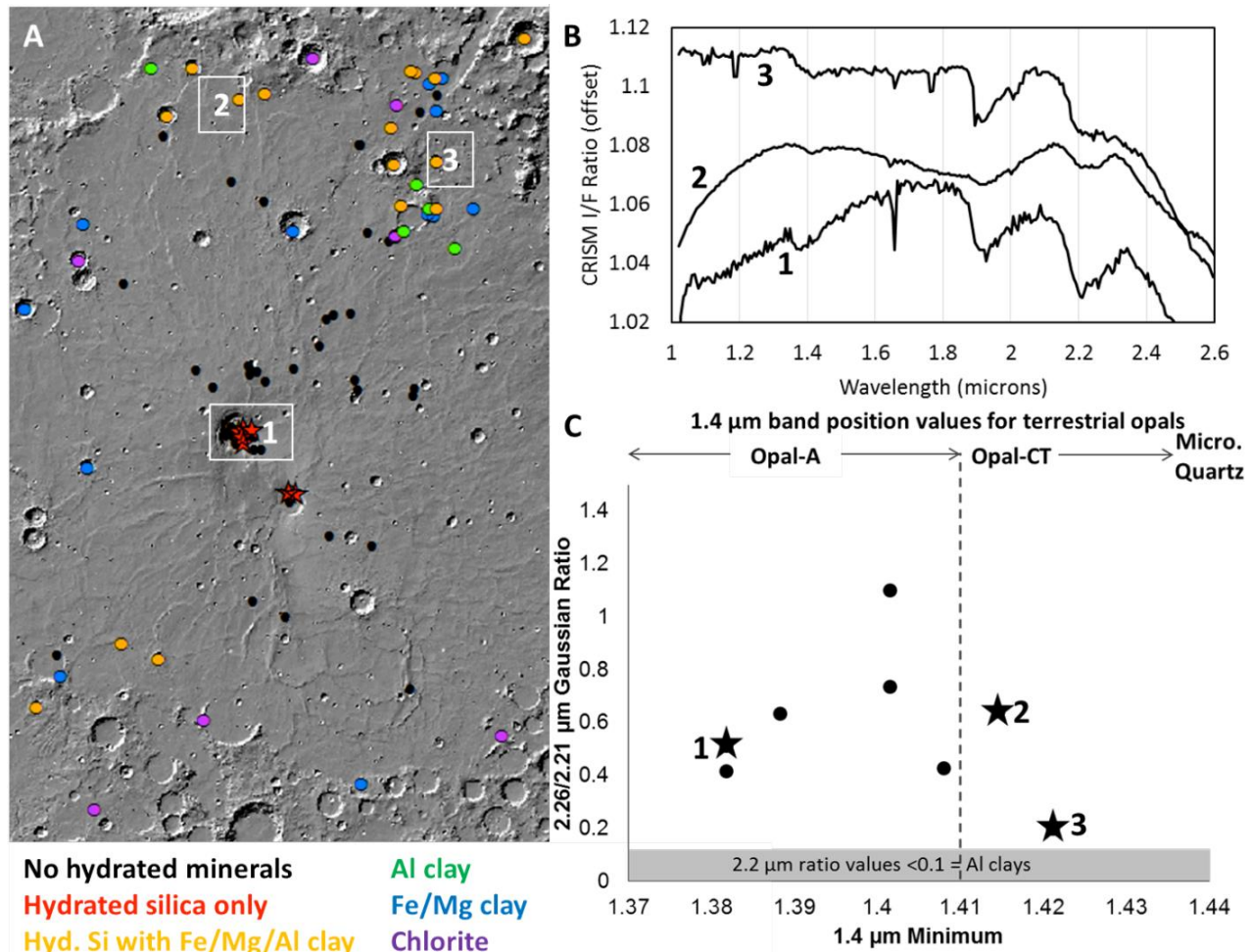
**Conclusion:** We investigated Nili Patera and the surrounding Syrtis Major Planum with the focus on the aqueous alteration based on a combination of CRISM and CTX images. Our findings support the hypotheses that amorphous silica is associated with younger terrains (e.g., the Hesperian-aged calderas) whereas more

evolved crystalline silica is located in older regions (e.g., Noachian bedrock and impact craters). Comparable analyzes of the crystallinity of opaline silica in other locations on the martian surface will help to constrain if these changes in water availability represent a global trend or if they were regional, like here in the Nili Patera region.

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**Figure 1** A) Overview of the study site showing Nili Patera and its surrounding based on a MOLA hillshade basemap. The red stars indicate the location of hydrated silica only and color-coded dots correspond to the mineralogy from the legend. Numbered white boxes show the locations of hydrated silica spectra in B) and C). B) Spectra based on CRISM data from locations 1: the Nili Patera caldera; 2: a Noachian-aged outcrop; and 3: a Noachian-aged impact crater. C) Plot of the 1.4 μm band position against the 2.2 μm ratio for selected hydrated silica with numbers corresponding to location 1–3.