# IN-DEPTH STUDY OF THE SILICA-RICH DEPOSITS IN WESTERN HELLAS BASIN, MARS

M. Pineau[1], J. Carter[1,2], B. Chauviré[3], L. Le Deit[4] & N. Mangold[4].
[1]LAM, Aix-Marseille Univ., Marseille, France (maxime.pineau@lam.fr), [2]IAS, Univ. Paris-Sud, France, [3]GeoGems, Guérande, France, [4]LPG, Nantes Univ., France.

**Introduction.** Observations of hydrated Si-rich minerals (HySi) in the Hellas Basin region were first made using the TES, THEMIS, and OMEGA instruments [1,2] and follow-up CRISM observations showed that they consist of nearly "pure" poorly crystalline hydrated silica [3,4]. HySi deposits are mostly located in topographic lows and exhibit rough, lineated, often layered loose morphologies without clear boundaries, and possibly reworked by periglacial processes [2,4]. First proposed geological origins include direct precipitation from saturated groundwater (i.e., spring deposits, duricrusts) without post-exhumation events to explain the subsistence of immature silica not associated with more crystalline Si-varieties. However spectral criteria (SC) surveys applied to CRISM data showed that Hellas HySi deposits consist of semi-crystalline silica (i.e., opal-CT or chalcedony) that would rather show mature deposits of diagenetic origin or a higher-degree aqueous alteration [5,6]. Thus, while the mineralogical composition of these deposits was well studied already, the geological context of formation is still unclear. In this study, we propose to reassess the distribution of HySi deposits and the associated mineralogy in the Western Hellas Basin using the MOCCAS newly published catalog [7] and investigate the spectral properties of it using criteria to determine their putative geological origins (i.e., CRC) [8,9,10].

**The largest known Si-rich deposit on Mars.** Previous studies showed that the Western Hellas HySi deposits are exposed along a ~650 km stretch covering a total area of nearly ~450 km² in a limited elevation ranging from -6500 to -5000 m [4]. However, combining MOCCAS, CRISM and OMEGA datasets, we show that these deposits are much more spatially exposed than previously thought. The silica deposits in Hellas cover a total area ~7,530 km² [Fig1], which makes these the largest known deposits of silica on Mars. They are topographically exposed from ~ -7500m to ~ +2350m (including HySi deposits detection located in craters on the western promontories of the Hellas Basin); most of the deposits being exposed at the bottom of Hellespontus Montes (from ~ -7000m to ~ -2000m). The deposits intersect the Nh1 units (basin-rim unit) and Ah7 units (rugged floor unit), thus covering Early Noachian to Early Amazonian geological units of [11].

**References.** [1] Poulet et al. 2006, LPSC-XXVII. [2] Bandfield J. 2008, GRL. [3] Carter et al. 2011, EPSC Abstracts. [4] Bandfield et al. 2013, Icarus. [5] Smith et al. 2013, Icarus. [6] Sun & Milliken 2018, GRL. [7] Carter et al. 2023, Icarus. [8] Chauviré et al., 2017 EJM. [9] Pineau et al. 2020, Icarus. [10] Pan et al. 2021, PSJ. [11] Tanaka et al. 2014. USGS. [12] Chauviré et al. 2021, EPSL.

**Associated mineralogy and implications.** The MOCCAS catalog shows that the HySi deposits of Western Hellas Basin are associated with sulfates and Fe/Mg-clays the latter being above the HySi in the Hellas' stratigraphy at a large scale [Fig1] [7]. This mineralogical distributions and associations are reminiscent of semi-closed lacustrine basins occurring in semi-arid climates on Earth and experiencing evaporative events. At a lower scale, HySi can be spectrally observed alone, spatially close to sulfates (alunite, jarosite), and sometimes in mixture with those. The association of silica and sulfates, especially alunite, would infer a formation under acidic aqueous conditions. Nevertheless, HySi deposits show a great diversity in terms of geomorphologies and textures including smooth dusty surfaces, aeolian-related landforms, finely layered periglacial deposits, rocky indurated outcrops, among others.

**Spectral characterization of silica phases.** With our current dataset, we observe mostly (poorly-)crystalline silica (opal-CT and/or chalcedony), with minor amount of amorphous silica (opal-A and/or Si-rich glass) [Fig2a,b]. CRC-calculations tend to favor a low-temperature of formation (e.g., continental weathering, spring deposits from near-surface waters, silcretisation-like process) [Fig2c]. Interestingly, we also observe silica spectra with $H_2O_{ice}$ signatures for some locations [Fig2a]. These deposits can be in form of "frozen opal" [12] which is in agreement with surface temperatures and atmospheric pressure derived from GCM model at the time of spectral acquisition [Fig 2a]. Future work will be needed to better constrain the phase type and the the geological origin of these last HySi deposits. Indeed, the presence of ice bands disturbs the SC calculations, which makes the study of these particular deposits more challenging [Fig2b,c].

**Conclusion and Future work.** Our preliminary results show that the HySi deposits observed in Western Hellas are much more extended than previously thought and that it is sometimes detected along with sulfates phases or water ice. SC survey show that HySi deposits can have been formed by one major geologic event that has affected all the Western margin of the Hellas Basin. We will combine our refined knowledge of the mineralogy of the HySi itself using SC (e.g. CRC), its association with other phases (e.g. water ice and sulfates), and a systematic study of the geomorphology and stratigraphy of the HySi unit in order to better disentangle between formation processes.

**Acknowledgments.** We acknowledge the support from the Agence Nationale de la Recherche (ANR, France) under the contract ANR-20-CE46-0013 entitled PaleoSilica, the Centre National d'Études Spatiales (CNES, France) and the Centre National de la Recherche Scientifique (CNRS, France).

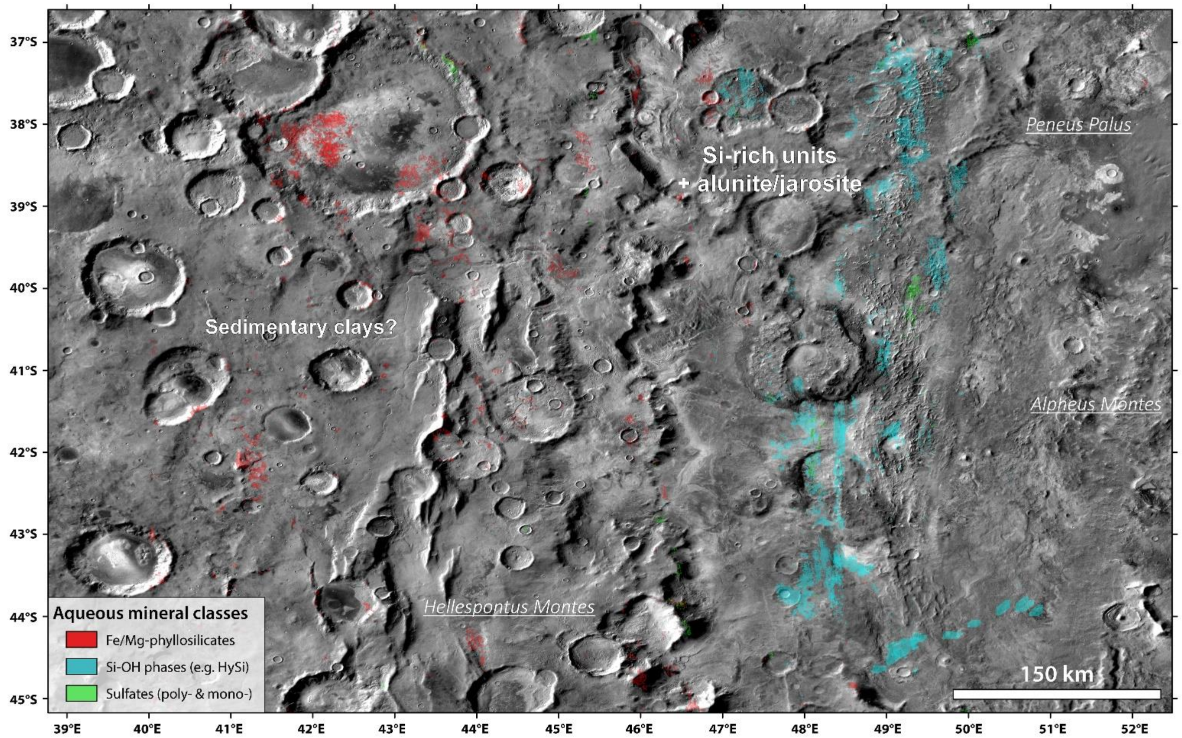

**Fig1 – Map of the aqueous mineral classes detected in Western Hellas Basin.** Detections are compiled from the MOCCAS catalog [7] including both OMEGA and CRISM datasets. Background is Mars Odyssey THEMIS-IR day Global Mosaic.

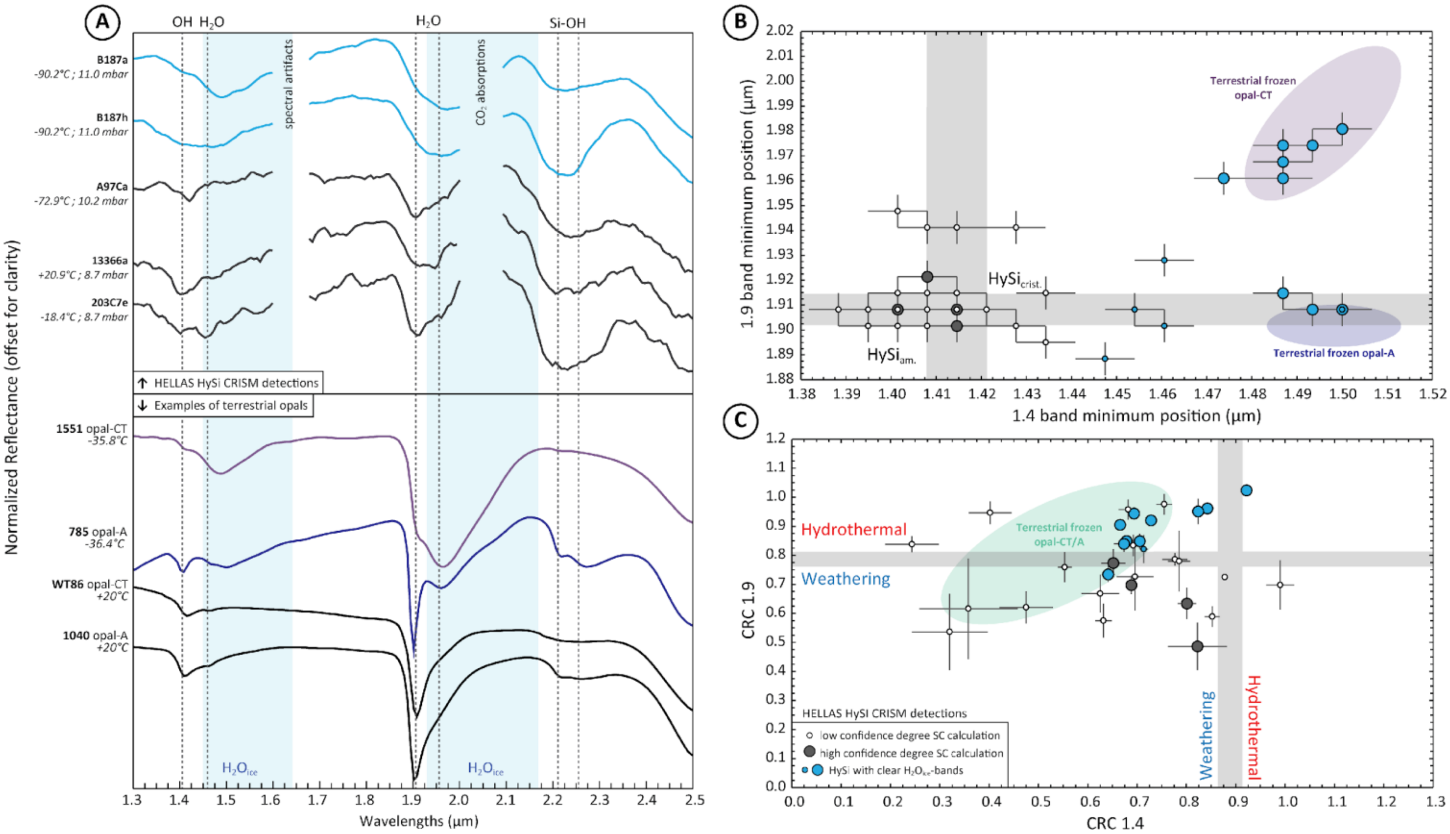

**Fig2 - Near-Infrared spectra of HySi and spectral criteria results applied on the 1.4 and 1.9 µm absorption bands. A.** Example of HySi near-infrared spectra from Hellas compared to terrestrial opals. Blue areas indicate water ice absorption regions and vertical dotted line indicate absorption bands specific to hydrated silica. Surface temperature and atmospheric pressure for martian data are derived from GCM model at the time of spectral acquisition. For terrestrial examples, all samples were measured at terrestrial ambient atmospheric pressure. **B.** Band minima positions. Minima at high-wavelengths indicate the presence of (semi-)crystalline silica (e.g., opal-CT/chalcedony), whereas minima at low-wavelengths mostly indicate the presence of amorphous silica (e.g., opal-A/glasses). Terrestrial frozen opal-A/CT fields are also reported. Error bars are equal to the CRISM resolution (~6.56 nm). **C.** Concavity-Ration-Criterion. High CRC values tend to indicate a high-T opal formation (e.g., hydrothermal activity), whereas low-CRC values mostly favor a low-T opal formation (e.g., continental weathering). Terrestrial frozen opal-A/CT field is also reported. Confidence degree for spectral criteria (SC) calculation is based on the S/N of CRISM spectra. Error bars are twice the calculated standard deviation.