

A MULTI- AND HYPERSPECTRAL INVESTIGATION OF HYDRATED SILICA IN OXIA PLANUM, MARS. J.D. McNeil¹, P.M. Grindrod¹, L.L. Tornabene², P. Fawdon³, V.G. Rangarajan⁴. ¹Natural History Museum, London, UK (joe.mcneil@nhm.ac.uk), ²Department of Physics & Astronomy, Western University, London, Ontario, Canada, ³School of Physical Sciences, The Open University, Milton Keynes, UK. ⁴DLR, Institut für Planetenforschung, Berlin, Germany.

Introduction: Oxia Planum, Mars, is the future landing site of ESA's ExoMars Rosalind Franklin rover (EMRF, launching 2028), which will search for physical and chemical biosignatures at the surface and subsurface using its analytical suite of instruments, the 'Pasteur' payload [1]. The landing site region contains a plethora of Noachian-aged features that indicate a water-rich past with periods of extensive deposition and water-rock interaction [2], including Fe/Mg clay-bearing plains [3], a sedimentary fan [4], and mounds [5]. Amongst these features are proposed detections of deposits containing hydrated silica ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$; opal [6, 2]). Hydrated silica is important in understanding aqueous processes and habitability on Mars owing to its numerous formation pathways which invariably require liquid water, and its excellent preservation potential for physical and chemical biosignatures that may be present [e.g. 7]. Here, we present the first dedicated investigation of these potential opal-bearing deposits, using HiRISE [8] and CaSSIS [9] with DEMs to constrain their stratigraphic position, hyperspectral CRISM data [10] to investigate their geochemistry, and multispectral CaSSIS data to expand the limited available targeted CRISM data within the landing site in order to find potential opal-bearing targets for EMRF to explore in the central landing site.

Methods: Hydrated silica exhibits near-IR absorption features at 1.4 μm , 1.9 μm , ~2.21 μm , and ~2.26 μm [7]. We analyzed all available targeted CRISM data in the landing site area using survey parameters MIN2250, BD2250, and BD1900R2 [11] to identify pixels that are likely to yield a hydrated silica spectrum. Candidate regions were ratioed to a corresponding spectrally bland 'denominator' region, following the methods in [13]. Confirmed detections of hydrated silica were smoothed using a Savitsky-Golay filter, and underwent gaussian deconvolution and continuum removal, following [13]. Spectral metrics were then measured, including diagnostic band center locations [8], band depth ratios (BDRs), and concavity ratio criteria (CRCs; [13]), which can place constraints on opal crystallinity and origin. CaSSIS color band ratio composites (CBRCs) were created by manually permutating band combinations [14] using 4-band cubes that contain opal-bearing deposits based on overlapping CRISM. We found that the combination BLU-RPR-PBR highlights these outcrops (Fig. 1b), owing to their

lack of Fe-bearing phases compared to their surroundings and overall 'blueness'.

Results: CRISM data indicate the presence of opal-bearing material (hydrated silica unit; HSU) in two main physiogeographic locations within Oxia Planum. Firstly, HSU is present in a thin (~5 m), bright-toned, blueish-white unit positioned stratigraphically below the sedimentary fan, and above the phyllosilicate-bearing plains (Fig. 1). The fan body also contains exposures of meter-scale, laterally-discontinuous outcrops of bright-toned, similarly-colored strata. CaSSIS CBRCs (BLU-RPR-PBR) indicate that these outcrops are identical in color to the CRISM detections of HSU in the larger, exposed outcrops (Fig. 1). This, as well as their similar relationship to the fan, indicates that they are likely to also be HSU. Outcrops of HSU are also present infilling topographic lows south of the sedimentary fan, at the margins of Pelso Chasma [16].

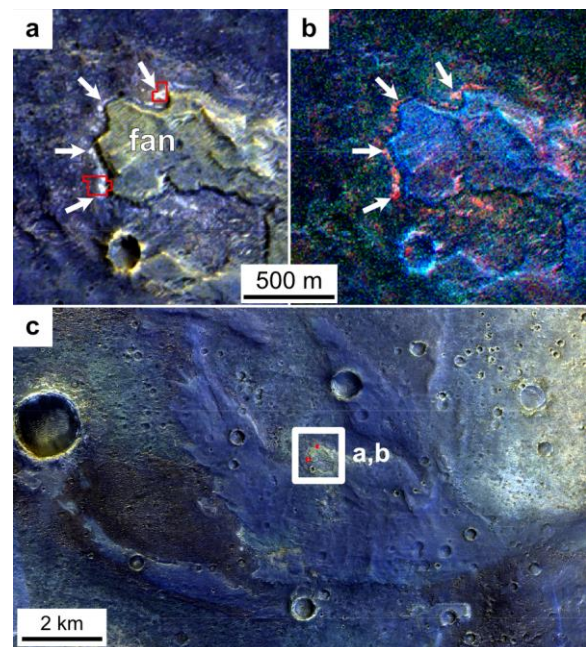


Fig. 1: Opal-bearing outcrops near the Oxia Planum sedimentary fan. a) CaSSIS image of toe of fan, showing bright white unit (HSU) aligned with CRISM detections of hydrated silica (red). b) CaSSIS CBRC highlighting the HSU in pink. c) CaSSIS mosaic of sedimentary fan.

The position of the 1.4 μm and 2.2 μm BDR values from targeted CRISM cubes indicate that the HSU in

Oxia Planum is predominantly amorphous (Opal-A); ten out of fourteen spectra plot within the Opal-A field, three plot within the crystalline opal (Opal-CT) field, and one plots in the overlap region (Fig. 2). The mean crystallinity of opal in Oxia Planum is similar to the mean crystallinity of opal in fans elsewhere on Mars. CRC values for the 1.4- and 1.9- micron features both indicate that opal in the HSU is predominantly weathering-derived, instead of hydrothermally-derived.

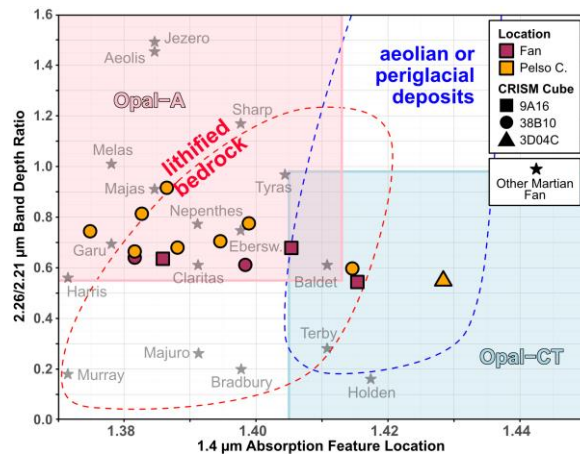


Fig. 2: Position of 1.4 μm absorption feature versus 2.2 μm BDR in Oxia Planum relative to other fan deposits across Mars [15]. Hydrated silica in Oxia Planum falls predominantly in the Opal-A/Lithified bedrock fields, indicating relative immaturity.

We have identified 78 potentially opal-bearing deposits in proximity to the EMRF landing ellipses; these are outcrops that occur at the same stratigraphic position as the HSU, have similar morphology and texture in HiRISE, and similar colors in CaSSIS (CBRC BLU-RPR-PBR). 18 candidate outcrops are present within the 2028 EMRF landing ellipses, making them prime targets for in situ investigation.

Stratigraphic position of hydrated silica-bearing deposits in Oxia Planum: Aqueous alteration of hydrated silica under martian conditions can alter its crystallinity through dissolution and reprecipitation by circulating fluid, over time converting relatively more amorphous opal (Opal-A) into relatively more crystalline opal (Opal-CT; [17]). The observation of Opal-A at Oxia Planum, situated directly above clay-bearing plains that underwent aqueous alteration [4], implies an unconformity exists between the alteration of the clay-rich plains and the deposition of the overlying hydrated silica-bearing unit, and therefore also between the plains and the sedimentary fan.

Formational hypotheses: The origin of Oxia Planum's hydrated silica deposits remains uncertain,

with detrital, authigenic, and diagenetic processes all plausible. A detrital origin would imply transport from the Coogoon Valles catchment [18], but the lack of CRISM-detected silica-bearing source rocks [19] and the immaturity of Opal-A in the HSU suggest limited transport, challenging this hypothesis. Alternatively, the HSU may have formed authigenically, with silica precipitating from highland runoff as water flow decelerated at the sedimentary fan or within Pelso Chasma. Localized deposition, driven by variable flow conditions, sediment load, or water chemistry, could explain the discontinuous opal horizons observed within the fan. These deposits may also represent silica precipitation during the final stages of water retention in the basin. A diagenetic origin, involving redistribution of silica through groundwater interaction, could account for the concentrated opal-bearing strata, with burial by fan sediments preserving its immaturity.

Conclusions: The HSU at Oxia Planum presents a valuable opportunity to study hydrated silica-bearing materials on Mars with in situ analysis. Its amorphous nature, indicative of limited water interaction compared to the more crystalline Opal-CT, suggests the preservation of relatively pristine material with an enhanced potential for biosignature preservation. Coupled with its aqueous formation conditions, the HSU represents one of the most promising outcrops within the landing site for astrobiological exploration. The formational hypotheses for the HSU, with implications for the geological history of Oxia Planum, can be directly tested using EMRF's PanCam [20] instrument suite in tandem with the "Enfys" IR spectrometer [21] and analytical 'Pasteur' payload [1].

References: [1] Vago et al. (2017) *Astrobio*. 17, 471-510; [2] Quantin-Nataf et al. (2021) *Astrobio*. 21, 345-366; [3] Mandon et al. (2021) *Astrobio*. 21, 464-480; [4] Roberts et al. (2024) *EPSC2024-1171*; [5] McNeil et al. (2022) *JGR:P*. 127; [6] Carter et al. (2022) *Icarus* 389; [7] Sun & Milliken (2018) *GRL*. 45, 10,221-10,228; [8] McEwen et al. (2007) *JGR:P*. 112, 1-40; [9] Thomas et al. (2017) *SSR*. 212, 1987-1944; [10] Murchie et al. (2007) *JGR:P*. 112, 1-57; [11] Vivano-Beck et al. (2014) *JGR:P*. 119, 1403-1431; [12] Ehlmann et al. (2009) *JGR:P*. 114; [13] Pineau et al. (2020) *Icarus*. 347, 113706. [14] Tornabene et al. (2018) *SSR*. 214, 18; [15] Pan et al. (2021) *PSJ* 2 65; [16] Fawdon et al. (2024) *J.Maps*. 17, 621-637. [17] Tosca & Knoll (2009) *EPSL*. 286, 379-386; [18] Fawdon et al. (2022) *JGR:P*. 127; [19] Turner et al. (2021) *LPSC52-2490*; [20] Coates et al. (2017) *Astrobio*. 17, 511-541; [21] Grindrod et al. (2025) *LPSC56*, #1840.