

CHARACTERIZING HYDRATION IN ALTERATION MINERALS OF JEZERO CRATER GEOLOGIC UNITS WITH SHERLOC ON MARS-2020 Y. Phua¹, B. L. Ehlmann¹, L. Mandon¹, S. Siljeström², J. Razzell Hollis³, R. Bhartia⁴, ¹Division of Geological and Planetary Sciences, California Institute of Technology, CA ²RISE Research Institutes of Sweden, Stockholm, Sweden, ³Museum of Natural History, ⁴Photon Systems Incorporated, CA (yphua@caltech.edu)

Introduction: The Mars-2020 Perseverance rover explored the volcanic crater floor units Séítah and Máaz, followed by sedimentary rocks in the delta front. Prior work showed Séítah and Máaz have a dominantly primary igneous mineralogy with phases such as sulfates, carbonates, phyllosilicates, and oxyhydroxides, indicating aqueous alteration of the crater floor units [e.g., 1-4]. We focused on identifying the phases responsible for hydration of these and delta rocks and examined variability in minerals across different units and abrasion patches, focusing on data obtained with the Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC), an arm-mounted Raman spectrometer with a 248.6 nm deep-ultraviolet (DUV) laser excitation source [5].

Methods: *SHERLOC targets:* We analyzed SHERLOC Raman data acquired for abraded targets (Table 1) in two types of scans, HDR (scan area 7×7 mm, step size 780 μm) and detail (scan area 1×1 mm, step size 100 μm).

Data analysis: To cast a wide net in initial analysis, all spectra analyzed were agnostically fit with a multiple Gaussian function (up to 3) in the 790-1200 cm⁻¹ region, where prominent peaks of minerals are often found (e.g., silicate, sulfate, and carbonate stretching modes) and, separately, in the 3000-3700 cm⁻¹ OH region. The median spectrum obtained on sol 413, which measured the instrument dark signal, was subtracted from each target spectrum. The noise root mean square deviation (RMSD) was calculated from 2000-2100 cm⁻¹, a spectrally quiet region. Fitted peaks of lower confidence (intensity < 3× noise RMSD for 790-1200 cm⁻¹ and intensity < 2× noise RMSD for 3000-3700 cm⁻¹) were removed in subsequent analyses. A second filter was applied to remove peaks with FWHM at the boundary of the applied

constraints (FWHM < 20 which are likely to be fitted to noise, FWHM > 120 for 790-1200 cm⁻¹ as Raman mineral features tend to be sharp, and FWHM < 50 for 3000-3700 cm⁻¹).

Results: Primary phases olivine and pyroxene, and secondary phases perchlorate/phosphate, sulfates and carbonates were detected with SHERLOC (Fig. 1; consistent with [2,3]). Hydration features are observed in some but not all targets in all three units. The hydration features observed in both crater floor units are

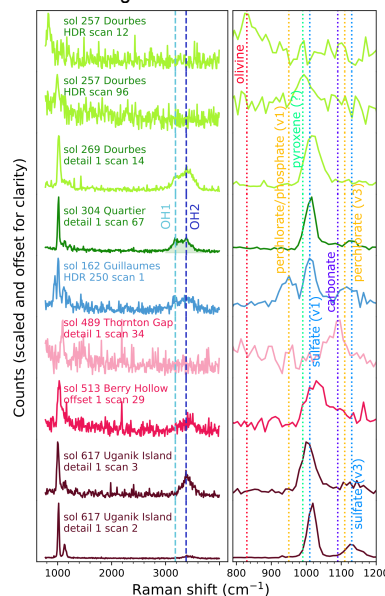
similar with a broad, bimodal feature while the hydration features observed in the delta unit have a single peak (some hydration spectra in Berry Hollow could have a less obvious second peak; Fig. 1). To identify distinctive trends across units, multiple scans in the same targets were stacked into histograms (Fig. 2).

Séítah (crater floor): Igneous minerals olivine and potentially pyroxene (in Dourbes [3]) are observed with secondary phases of sulfate and carbonate in Dourbes and Quartier and perchlorate/phosphate in Garde, as observed by [2]. Dourbes and Quartier have primary and secondary OH peaks, while Garde has little hydration. Garde has more olivine and less sulfate than the other Séítah abraded patches, potentially signaling sulfates are hydration carrier phases. Dourbes spectra have the highest OH band area of any measured and a greater OH2/OH1 peak ratio than Quartier for some points. The upshift in sulfate peak positions in Dourbes (1010-1025 cm⁻¹) relative to Quartier (1005-1017 cm⁻¹) is not directly correlated to the OH band area (Fig. 3a,b).

Máaz (crater floor): Guillaumes exhibits peaks due to sulfates and perchlorate/phosphate (as observed by [2]) as well as two hydration peaks, like Séítah rocks. While both perchlorate/phosphate and sulfates are

Unit	Target name (sol)
Séítah (crater floor)	Garde (207, 208)
	Dourbes (257, 269)
	Quartier (293, 304)
Máaz (crater floor)	Guillaumes (161, 162)
	Bellegarde (186)
	Montpezat (349)
	Alfalfa (370)
Delta	Thornton Gap (489)
	Berry Hollow (505, 513)
	Novarupta (570, 573)
	Uganik Island (614, 617, 618, 620)

Figure 1. Representative spectra from crater floor units Séítah (green) and Máaz (blue), and delta unit (pink/red) with Raman mineral detections. Vertical dashed lines indicate peak positions of likely mineral detections and lower and higher wavenumber OH1 and OH2 peaks. The shaded region for sol 304 Quartier spectra is the total OH band area, as used in Fig. 3.



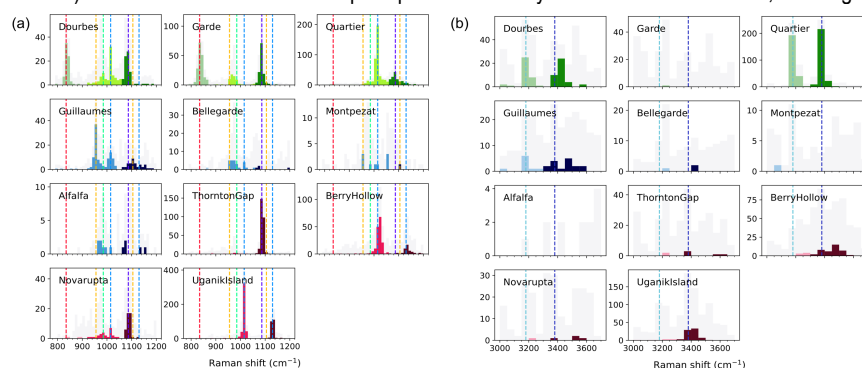
present in some hydrated Guillaumes spectra, only sulfates are present in others. Sulfate ν_1 peak intensities and OH peak area are weakly correlated (Fig. 3d) but there are relatively few hydrated Guillaumes spectra.

Delta: Carbonate and sulfate are observed in Novarupta; only carbonates in Thornton Gap; and predominantly sulfates in Berry Hollow (minimal carbonates) and Uganik Island (Fig. 2a). These mineral identifications are consistent with results from other payload instruments [6,7]. Veins in Berry Hollow and large crystal in Uganik Island show both ν_1 (1000-1025 cm^{-1}) and ν_3 (1130 cm^{-1}) sulfate peaks characteristic of anhydrite [8].

Multiple delta targets exhibit negligible OH peaks (Fig 2b) even though Uganik Island has the strongest sulfate peaks of any sample so far (Fig. 3c). The OH bands in Uganik Island and Berry Hollow both appear unimodal (Fig. 1), though the mode of the OH peak position is at greater wavenumber in Berry Hollow (3475 cm^{-1}) than Uganik Island (3425 cm^{-1}). Berry Hollow and Novarupta also have higher SO_4 peak positions (1014-1025 cm^{-1}) than Uganik Island spectra (1000-1018 cm^{-1}) (Fig. 2).

Discussion: Peaks at $\sim 1000 \text{ cm}^{-1}$ (likely sulfates) are observed in all spectra with hydration features, and polyhydrated MgSO_4 has been suggested to be present in Dourbes and Quartier [9,10]. The differences in OH band shapes and peak positions likely indicate differences in hydration states and/or phases [11]. If the hydrated materials are primarily Mg sulfate, the upshift in the SO_4 peak position in Berry Hollow (delta) relative to Quartier and Dourbes (crater floor), coupled with the unimodal OH band shape could mean that the Mg sulfate found in Berry Hollow is of lower degree of hydration than in Quartier and Dourbes [11], which is

Figure 2. Histogram plot of peaks detected in each abraded target (Séitah=green, Maaz=blue, delta=red/pink) at Raman shift positions for (a) fundamental vibrational peaks of minerals (790-1200 cm^{-1} , bin size = 10 cm^{-1}), and (b) structural OH or H_2O stretching modes (3000-3700 cm^{-1} , bin size = 50 cm^{-1}). Vertical dashed lines indicate peak positions of likely mineral or OH detections, as in Fig. 1.



consistent with the lower OH band area relative to sulfate peak intensity in Berry Hollow (Fig. 3d)

The definitive identification of hydration carriers can be complicated by coexisting materials, and varying states of hydration. Some Uganik Island spectra that show strong anhydrite signals also show a small OH peak (Fig. 1, 3c). The OH bands indicate presence of other hydrous phases. The OH bands of phyllosilicates, which are suggested to be present [6], often have peaks $>3500 \text{ cm}^{-1}$ [12,13]. While there does not appear to be many spectra with OH peak $>3500 \text{ cm}^{-1}$ (Fig. 2b), we will continue to examine the relationship between the peaks in the low wavenumber region ($\sim 1000 \text{ cm}^{-1}$) and the OH peaks to determine the hydration carrier phases, adding target rocks as more data are collected.

Acknowledgements: Thanks to the Mars-2020 science and engineering team, and the SHERLOC instrument team for advice on data analysis. **References:** [1] Farley, KA et al. (2022) Science, 377. [2] Scheller, EL et al. (2022) Science, 378. [3] Razzell Hollis, J et al. (2022) Icarus, 387. [4] Wiens, RC et al. (2022) Science Adv., 8. [5] Bhartia, R et al. (2021) Space Sci. Rev., 217. [6] Hurowitz, JA et al., this conference. [7] Nachon, M et al., this conference. [8] Wei, J et al. (2015) J. Raman Spectrosc. 46. [9] Tice, M et al. (2022) Science Adv., 8. [10] Siljeström, S et al., this conference. [11] Wang, A. et al. (2006) GCA, 70. [12] Wang, A et al. (2015) J. Raman Spectrosc. 46. [13] Fox, VK et al. (2021) Am. Min. 106.

Figure 3. Plots of (a) OH2 vs OH1 (defined in Fig. 1) peak intensity for Dourbes, Quartier, Guillaumes. (b) Total area of OH band vs sulfate ν_1 peak position for Dourbes, Quartier, Guillaumes, Berry Hollow, Uganik Island, Novarupta. (c) Total area of OH band vs sulfate ν_1 peak intensity for Dourbes, Quartier, Guillaumes, Berry Hollow, Uganik Island, Novarupta. The range marked out in the rectangle in (c) are magnified in (d).

