MULTI-INSTRUMENT ANALYSES OF CARBONATE-BEARING MATERIALS IN JEZERO CRATER.

S. A. Connell[1], R. C. Wiens[1], S. Siljeström[2], K. Ramo[3], A. Klidaras[1], T. Fornaro[4], A. Steele[5], E. Scheller[6], W. Abbey[7], E. A. Cloutis[8], Y. Phua[9], K. Hand[7], K. Uckert[7], J. Hurowitz[3], A. Allwood[7], M. Cable[7], M. Tice[10], E. Cardarelli[11], E. Clavé[12], A. Cousin[13], J. R. Johnson[14], B. Garczynski[15], T. Fouchet[16], L. Mandon[17], A. Brown[18]. [1]Purdue University, [2]RISE Research Institutes of Sweden, [3]Stony Brook University, [4]INAF-Astrophysical Observatory of Arcetri in Florence, [5]Carnegie, [6]Heising-Simons, [7]NASA JPL/Caltech, [8]University of Winnipeg, [9]Caltech, [10]Texas A&M University, [11]University of California Los Angeles, [12]DLR-OS, Berlin, [13]IRAP Toulouse, [14]Johns Hopkins University Applied Physics Laboratory, [15]Western Washington University,[16]Observatoire de Paris, [17]IPAG, [18]Plancius Research, MD. connel47@purdue.edu

Introduction: On the Mars2020 Perseverance rover, the SuperCam [1, 2] and Mastcam-Z [3] instruments collect a variety of remote sensing data, while the Scanning Habitable Environments for Raman and Luminescence for Organics & Chemicals (SHERLOC) [4] and Planetary Instrument for X-ray Lithochemistry (PIXL) [5] instruments acquire proximity science observations on natural surfaces and abrasion patches.

Co-located instrument observations among these data sets aid in identifying specific minerals, ensuring a thorough and rigorous approach to understanding their characteristics and implications for origin and evolution. This is enabled by cross-correlating data points for specific regions of interest (ROIs). Here, we discuss spatially co-registered products of overlapping spectral points of SuperCam rasters and grids, SHERLOC scans, and PIXL elemental maps.

This study's key component was investigating abrasion patches in various rover campaigns. These abrasions allow the instruments to observe the mineral heterogeneity, grain size, distribution, and true color of the exposed rock [6]. Two abrasion patches, Thornton Gap (Sol 482, in the Skinner Ridge region during the Delta Front Campaign [7]) and Castle Geyser (Sol 1080, in the Bunsen Peak area during the Margin Campaign), are used as case studies to investigate how each instrument identifies the presence of carbonates. By observing two abrasion patches, this study aims to provide constraints on whether carbonates are authigenic or detrital, providing crucial insights into the history of aqueous alteration.

Figure 1 shows overlapping SuperCam and SHERLOC observations from Sol 498 at the Thornton Gap abrasion patch on a co-registered image for three out of four instruments. Mastcam-Z multispectral images were also registered with these data sets. SuperCam and PIXL targets on Castle Geyser overlap with Mastcam-Z multispectral (not shown here). Here, we use the Thornton Gap data sets to illustrate the presence of carbonates. Previous work [8] used Bellegarde and Dourbes abrasions as case studies to examine the efficacy of co-located analyses by proximity instruments PIXL and SHERLOC, highlighting the importance of paired observations to complete the picture of small-scale in-situ observations.

Data sets: SuperCam is a remote-sensing instrument with laser-induced breakdown spectroscopy (LIBS), visible (0.40-0.85 µm; 0.74 mrad) and near-infrared (1.3-2.6 µm; 1.15 mrad) (VISIR) reflectance spectroscopy, Raman spectroscopy, and a remote micro-imager that provides ~50 µrad resolution color context imaging [1, 2]. **Mastcam-Z** is a multispectral zoomable stereo imaging system covering 442-1022 nm [3]. **SHERLOC** is a proximity instrument with a deep ultraviolet (DUV) Raman and fluorescence spectrometer (~100 µm spot size) that includes the WATSON context microscopic imager with a resolution of 10.1 µm/pixel [4]. **PIXL** is a proximity instrument with a micro-focus X-ray fluorescence spectrometer (120 µm beam size) and a micro-context camera with a 52 µm/pixel resolution. [5].

Co-registered analyses: Co-registration techniques were used to overlay high-resolution images from the SuperCam, SHERLOC, and PIXL instruments on abrasion patches to correlate spectra from overlapping or co-located observations. ROIs were selected based on overlapping data points and extracted and replotted to correlate the mineralogy observed by each instrument.

Results: The Thornton Gap abrasion patch (Fig. 1) was acquired near the bottom of a cliff of resistant pebbly layered sandstone at the delta front [9]. Multi-instrument observations indicated a lithology of clastic medium-to-coarse-grained material [9]. The abrasion patch showed the presence of carbonates, as seen by other instruments discussed below. The Castle Geyser target also has strong carbonate signatures; however, the co-registration is in progress and will be discussed during the conference.

The Sol 498 SuperCam raster points 1 and 2 (blue crosses in Fig. 1) nearly overlap the SHERLOC 10x10 (green and orange crosses) and 36x36 scans (purple).

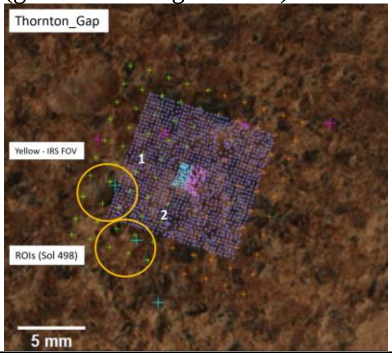

Figure 1. Co-registration of Thornton Gap: SuperCam and SHERLOC targets. SuperCam LIBS data points are 1 and 2 (blue crosses), the SHERLOC 10x1 HDR scans (green and orange data points), and the SHERLOC 36x36 survey scan (purple). The ROI represents a location where all spectral points are either co-located or overlapping (yellow circles). These circles represent the field of view for 68% of the SuperCam IR signal.

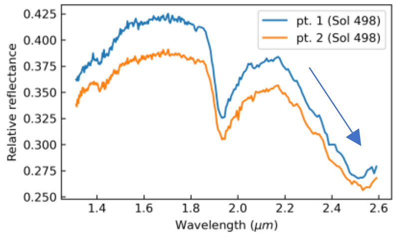

Figure 2. SuperCam IR spectra at a 1.3 – 2.6 µm wavelength range for raster locations 1 and 2 (Sol 498, scam01498).

The SuperCam IR spectra (Fig. 2) show a relatively steep upward slope from 1.3 – 1.8 µm, indicative of an Fe^{2+} absorption consistent with olivine and/or Fe-carbonates, and a downward slope from 2.2 – 2.6 µm possibly attributable to sulfate-carbonate mixing [10]. Other features are a very weak 1.4 µm OH band, strong 1.9 µm (H_2O) band, very weak 2.3 µm (Mg/Fe phyllosilicate/carbonate), and strong 2.5 µm (carbonate) absorption bands.

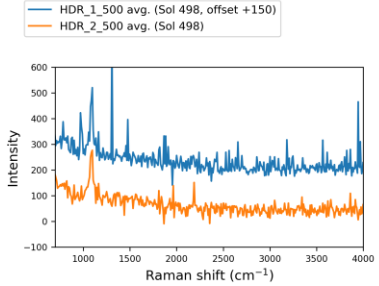

Figure 3. SHERLOC DUV Raman. HDR_1_500 avg. (blue) and HDR_2_500 avg. (orange) indicate averages of 500 laser shots per point for Sol 498. The spectra comprise specific data points extracted from the HDR scans overlapping with SuperCam (visible within the yellow circled ROIs).

The SHERLOC spectra (Fig. 3) show a strong 1077 cm^{-1} peak indicating carbonate.

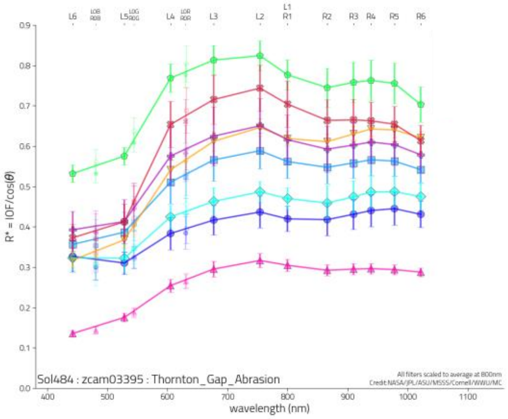

Figure 4. Mastcam-Z spectra of Thornton Gap abrasion (Sol 484, zcam03395) show various ROIs created on or near the abrasion patch.

The Mastcam-Z multispectral image covered the entire abrasion patch. The multispectral data (Fig. 4) are consistent with weathered olivine +- Fe-bearing carbonate (green), as evidenced by a 750-800 nm peak and strong downturns at longer wavelengths. The downturn in the last two wavelengths (green ROI) could be consistent with hydration if not related to photometric effects [11].

Discussion and conclusion: The Thornton Gap abraded surface exhibits sedimentary petrology with aqueous alteration due to the presence of hydration seen by SuperCam [12] and carbonate identified by or consistent with all three rover instruments. SuperCam sees strong hydration within the abrasion patch by showing the 1.9 µm H_2O absorption band. However, the Mastcam-Z multi-spectral lacks a strong hydration signal, and the SHERLOC DUV Raman does not show any peak in its 3200-3500 cm^{-1} hydration region. SuperCam IR spectra of raster locations 1 and 2 exhibit a weak 2.3 µm and stronger 2.5 µm bands, suggestive of possible carbonate, consistent with the SHERLOC DUV Raman 1077 cm^{-1} peak.

Various instruments possess the capacity to infer or identify carbonates. Mastcam-Z cannot uniquely identify Fe-carbonate, but distinguishing between phases such as weathered olivine and Fe-bearing carbonate is challenging. SuperCam can detect carbonate with LIBS, Raman and VISIR but can face challenges due to mineral mixing, which can often subdue absorption bands in the VISIR. SHERLOC can detect and constrain the carbonate species but may only show one of several mineral peaks or peaks at lower intensity, including hydration.

Similarly, PIXL infers carbonates based on their major elements suggested by low totals (~85 wt.%) since they do not detect carbon directly. However, PIXL's diffraction map reveals crystalline or amorphous phases, which can constrain the history of aqueous alteration of carbonates.

This multi-technique approach leverages each instrument's strengths, which can increase confidence in more robust mineral identifications, such as carbonates, and achieve a holistic understanding of Mars's geochemistry, mineralogy, textures, and hydration for astrobiological potential [8, 13].

Acknowledgements: We acknowledge the support of NASA's Mars Exploration Program, CNES, CNRS, and others, as well as the scientists and engineers on the mission; NASA grant: NNH13ZDA018O and JPL contract 1688677 to Purdue.

References: [1] R.C. Wiens et al. (2021) SSR 217, 4. [2] S. Maurice et al. (2021) SSR 217, 47. [3] J.F. Bell et al. (2021) SSR 217, 24. [4] R. Bhartia et al. (2021) SSR 217, 58. [5] A.C. Allwood et al. (2020) SSR 216, 134. [6] R.C. Moeller et al. (2021) SSR 217, 5. [7] K. Stack et al. (2024) JGRP 129, e2023JE008187. [8] J.R. Hollis et al. (2022) Icarus 387, 115179. [9] A.E. Murphy et al. (2024) 55th LPSC, 1935. [10] C. Quantin-Nata et al. (2024), this meeting. [11] Rice et al. (2023) JGRP 128, e2022JE007548 [12] E. Dehouck et al. Submitted. [13] Mars2020 Science Description (2013).