MINOR MINERALS ANALYZED BY PIXL – A MAJOR PART OF IGNEOUS ROCK PETROGENESIS AT JEZERO CRATER. T. V. Kizovski[1], M. E. Schmidt[1], Y. Liu[2], B. C. Clark[3], M. Tice[4], C.D.K. Herd[5], J. Hurowitz[6], S. VanBommel[7], T. Henley[1], and A. Allwood[2]. [1]Brock U. (St. Catharines, ON L2S 3A1 Canada, tkizovski@brocku.ca), [2]JPL-Caltech (Pasadena, CA 91125), [3]Space Sci. Inst. (Boulder, CO 80301), [4]Texas A&M (College Station, TX 77843), [5]U. Alberta (Edmonton, AB T6G 2E3 Canada), [6]SUNY Stony Brook (NY 11794), [7]Wash. U. (St. Louis, MO 63130)

Introduction: On February 18, 2020 the Mars 2020 Rover "Perseverance" landed on the floor of Jezero crater, an ancient, ~45 km diameter impact crater than once contained a lake [1]. Since landing, the rover has traversed ~2.4 km across the crater's floor, analyzing various outcrops in order to piece together the area's geological history, search for preserved evidence of habitable environments and biosignatures, and collect samples.

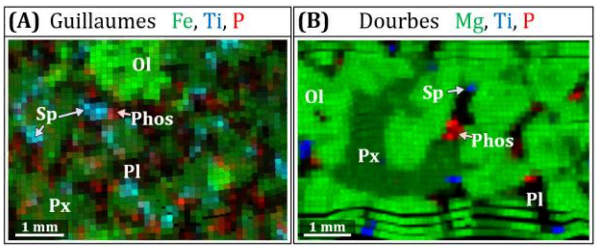

Figure 1: Red-Green-Blue (RGB) element maps for abraded patches Guillaumes (A), and Dourbes (B). Ol = Olivine, Phos = Phosphate, Pl = Plagioclase, Px = Pyroxene, Sp = Spinel.

The Planetary Instrument for X-ray Lithochemistry (PIXL; an X-ray fluorescence [XRF] spectrometer on-board the rover) is crucial for this purpose, producing elemental abundance maps on rock targets at scales comparable to a 10x magnifying hand lens [2] (Figure 1). At the time of this writing, Perseverance has analyzed four abraded targets with PIXL across two different geologic units. These units were delineated based on previous orbital observations [3], and are known as the Crater Floor Fractured Rough unit (Cf-fr) (PIXL targets Guillaumes and Bellegarde), and the olivine-carbonate bearing Séítah region (Cf-f-1) (PIXL targets Dourbes and Quartier).

The chemical and textural data from PIXL has been critical for classifying these rocks and understanding their geologic history [4]; allowing us to examine the minerals within them at a precision and scale not possible in previous missions. Here, we focus on PIXL analysis of minor mineral phases (specifically oxides and phosphates), and show that through detailed examination of their compositions and spatial distribution, the entire geologic histories of the rocks that contain them can be assessed.

Method: Prior to XRF mapping by PIXL, a 50 mm circular area of each rock target was abraded in order to provide a smooth surface. The XRF maps range in size from 35 to 50 mm^2. A step size of ~0.125 mm was used for all maps (the size of the beam), resulting in high resolution continuous maps with total analysis points/map ranging from 2344 to 3341. The X-ray signals were integrated for 10 s at each point on PIXL's two detectors. Phosphates and oxides were identified as points with P_2O_5 >5 wt.%, and TiO_2 and/or Cr_2O_3 >2 wt.%, respectively.

Results & Discussion: XRF element mapping for the four abraded targets shows that phosphate minerals and Ti-rich oxides are typically observed within the interstices of mafic minerals and feldspars (Figure 1). Cr-rich oxides are only observed within mafic phases in the Dourbes and Quartier targets (Figure 2). This spatial distribution of the phosphates and oxides is consistent with typical igneous crystallization. While this was not the predominant interpretation at landing [3]; these results support that the Cf-fr unit and region are igneous (including major mineral chemistry, textures, and bulk compositions [see 4 & 5 for more details]).

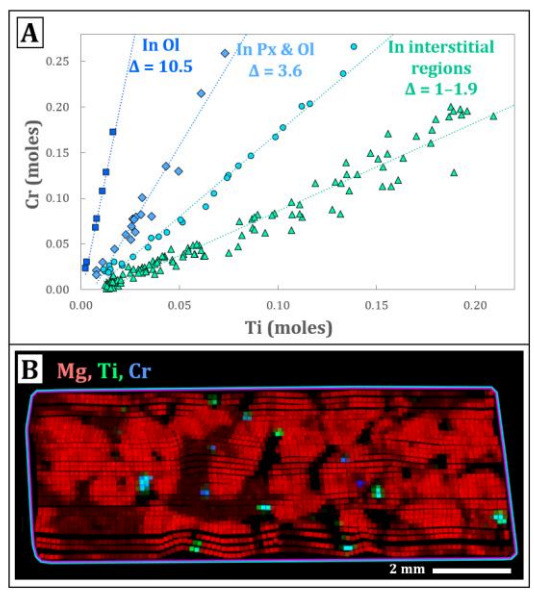

Figure 2: (A) Cr and Ti compositional trends observed for oxides in Dourbes; trend line slopes noted with Δ. (B) RGB element map for Dourbes illustrating the spatial occurrence of Cr-rich oxides (blue - in red and dark-red mafic minerals) and Ti-rich oxides (turquoise to green - in black mesostasis regions).

Oxide Minerals. The oxides' chemistry varies across the abraded patches, with Ti-rich compositions in the Cf-fr targets, and significant Cr in Cf-f-1 (Figures 2&3). The Ti-rich, Cr-poor oxides in the Cf-fr rocks are similar to titanomagnetite and ilmenite observed in late-stage mesostasis in martian meteorites such as evolved (Fe-rich) basaltic shergottite Los Angeles [6].

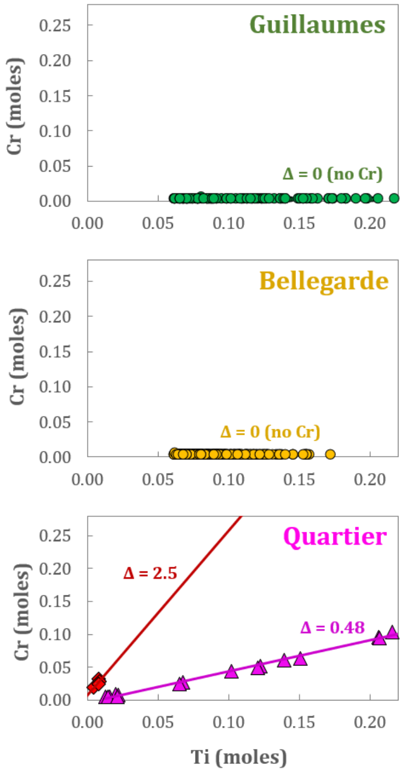

Figure 3: Cr and Ti compositional trends observed for oxides in Guillaumes (CF-Fr), Bellegarde (CF-Fr), and Quartier (Cf-f-1).

The Cr-rich oxides observed in the Cf-f-1 rock targets are similar to the chromites enclosed within mafic phases in cumulate martian meteorites such as chassignites and poikilitic shergottites (Cr/Ti molar range = 6-51 [7,8]). Higher Ti-oxides (typically ilmenite) are also observed within the chassignites' mesostasis, but typically contain negligible Cr [7]. Oxide trends in poikilitic shergottites are similar to chassignites, but also include spinels with intermediate Cr/Ti compositions (Cr/Ti molar ratios of ~1), similar to those in the Séítah targets [8].

Phosphate Minerals. Abundant phosphate minerals were observed in all four abraded patches. The average molar Ca/P ratio for the phosphates in the Séítah region is ~1.2, consistent with merrillite; while the average Ca/P ratios for Cf-fr phosphates range from 1.7 for Bellegarde to 2.1 for Guillaumes, likely consistent with apatite. The Ca/P ratios for all targets range between apatite (Ca/P = 1.7) and brushite (Ca/P = 1.0), and should be interpreted with caution, especially for the Cf-fr phosphates due to their small grain sizes and the resulting spectral mixing. In addition, merrillite and apatite are commonly intergrown in martian meteorites at length scales below the PIXL spot size [9], making it difficult to confirm the absence of either phase.

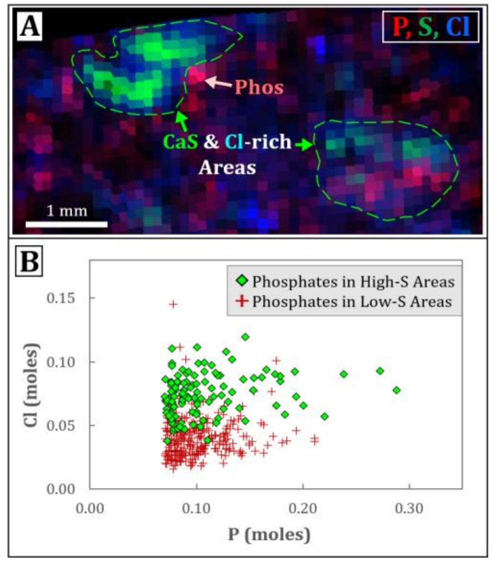

Figure 4: (A) RGB map for Bellegarde showing phosphates in proximity to secondary high-S regions. (B) Cl and P abundances for phosphates in Bellegarde illustrating higher-Cl phosphates are observed in proximity to secondary high-S regions (points with P_2O_5 > 5 wt.%, and SO_3 >2 wt.%).

It should be noted that in the Bellegarde (Cf-fr) abraded patch, several phosphates were observed in proximity to sulfates interpreted to be secondary alteration products (Figure 4). These phosphates contain slightly more Cl than those in low-sulfate areas, possibly preserving evidence of secondary aqueous alteration processes.

The results of this investigation showcase the power of PIXL, where micron-scale analyses can be used to gain insights into regional-scale processes. The compositions and spatial distribution of the phosphates and oxides provide strong supporting evidence that the Cf-fr and Séítah rocks are igneous, distinct from each other, and have undergone secondary alteration processes. More detailed analyses of these phases is planned for future work including estimating fO_2 from the oxides, and spectral deconvolution for the phosphates. Results will allow for more detailed comparison with known martian igneous lithologies and important context for samples collected by the rover for eventual return to Earth.

References: [1] Farley K. A. et al. (2020) *Space Sci. Rev. 216:142*. [2] Allwood, A. C. et al. (2020) *Space Sci. Rev.* 216: 314. [3] Sun, V. & Stack, K. (2020) *USGS Sci. Invest. Map* 3464. [4] Schmidt, M. et al (2022) *LPSC LIII*. [5] Liu et al. (in Prep) *Science*. [6] Herd et al. (2001) *Am. Miner* 86, 1015-1024. [7] Hewins et al. (2020) *GCA* 282, 201-226. [8] Kizovski et al. (2019) *MAPS* 54:768-784. [9] McCubbin F. et al. (2015) *MAPS* 51(11):2036-2060.