Alteration diversity observed in the inner part of Jezero Crater Rim

Quantin-Nataf C.1, Dehouck E.1, Beck P.2, Bedford C.3, Mandon L.2, Beyssac O.4, Clave E.5, Forni O.6, Udry A.7, Mayhew L.8, Ravanis E.9, Cousin A.6, Wiens R.3, Horgan B.3, Simon J.10, Minitti M. 11 and Poulet F. 12
(1)LGLTPE Villeurbanne Cedex, France, (2) IPAG, Grenoble, France, (3) Purdue University, USA; (4) IPMC, Paris, France; (5) DLR, Germany; (6) IRAP, Toulouse, France; (7) UNLV, USA ; (8)University of Colorado, USA; (9) *University of Hawaii, USA; (10) NASA Johnson Space Center, Houston, USA; (11) Framework, USA; (12) IAS, Orsay, France.*

Introduction: Since February 2021, the Mars 2020 rover *Perseverance* has been exploring Jezero crater on Mars to characterize the geology, assess the potential for rocks to record ancient habitable environments and/or preserve biosignatures, and collect a suite of scientifically compelling samples for return to Earth [1]. From 2021 to 2024, Perseverance explored the interior of the Jezero impact crater, and consequently the geological units post-dating its formation. In September 2024, Perseverance started the ascent of the Jezero crater rim, the first step of a multi-year campaign trough the diverse geological units identified from orbit in the rim and outside of the crater. The expectation of this campaign is to encounter rock types that represent materials from Mars' most ancient crust (Pre-Jezero and even pre-Isidis crust) and are not included in the current sample cache [2].

In this contribution, we are using the data collected by the SuperCam instrument from sol 1293 to sol 1338, which reveal a large diversity of rocks and alteration mineral assemblages in the inner side of the Jezero crater rim.

Traverse context: The crater rim campaign started when *Perseverance* reached a first group of rocks near "Faraway Rock" (Figure 1). From there, the rover was sent uphill, first passing the "Saint Elmo Pass" butte, then reaching a series of NW/SE-elongated buttes ("Curtis Ridge", "Mist Park" and "Eagle Cliff"), and finally investigating the southwestern end of the "Pico Turquino" butte.

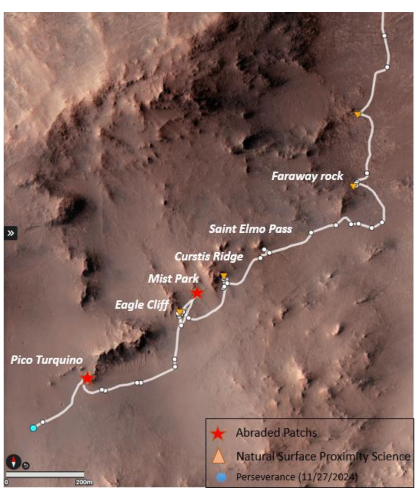

Figure 1 : Traverse map and locations of interest on the inner Jezero crater rim. All names are informal.

Dataset and method:

SuperCam: The SuperCam instrument contains a suite of techniques including passive spectroscopy in the 0.40-0.85 (VIS) and 1.3-2.6 microns (IR) wavelength ranges, Raman spectroscopy, Laser Induced Breakdown Spectroscopy (LIBS) and a camera (RMI; Remote Micro-Imager) providing high resolution context images [3,4]. In this contribution, we use both LIBS and IR data of targets with rasters from 5 to 10 points to build a classification of the rocks. We also use IR spectral parameters to evaluate the level of hydration of a target and to highlight the following alteration mineral groups: sulfates, Fe/Mg clays, Al-phyllosilicate or hydrated silica.

Data set and classification: We worked with the SuperCam targets from sols 1293 though 1338 that were analyzed with both LIBS and VISIR, thus excluding targets farther than ~10 m, for which LIBS is no longer possible or reliable. We included bedrock and float rock [5] targets, but excluded the soil targets, which are known to have compositions distinct from the local rocks [6]. Based on the LIBS data, we classified the targets according to the range of compositions observed among the raster points in terms of Si, Al, Ca+Na+K and Fe+Mg (see also paired abstract [7]). Eight classes were defined:

- HighSi: targets with >70 wt% SiO_2 (see [8], this conference)
- HighAl: targets with >30 wt% Al_2O_3
- Olivine: targets with most of the points close to the olivine reference composition [9, 7]
- Feldspar: targets with most of the points close to the Feldspar reference composition (Orthoclase or andesine). [9, 7]
- FeldsparToLCP: targets with points scattered between pyroxene and feldspar reference compositions
- LCP: targets with most of the points close to the low-calcium pyroxene reference compositions [9, 7]
- Pyroxene_Clays: points close to low-calcium pyroxene reference composition, but with a strong clay mineral signature in the VISIR spectra
- Coatings: points clustered together close to the dust reference composition [10].

Results: Along the traverse, we observed olivine-bearing lithologies several times and at different elevations up to Pico Turquino (Figure 2). Two abraded patches have been analyzed in this olivine bearing rock. A representative spectrum is displayed in red in Figure 3, as the mean spectrum of *Rust Ridge* target. The signature of Mg-rich clay minerals (paired 2.31 and 2.39 µm absorption bands) is closely associated with the olivine spectral signature (broad Fe^{2+} band centered at ~1 µm). Such association has been observed with similar spectra in the westernmost part of the Margin unit within Jezero crater [11].

Near Saint Elmo Pass, a remarkable unaltered pyroxene bearing lithology is observed. A representative spectrum (target *Cress Falls*) is displayed in Figure 3, with the typical spectral signature of low-calcium pyroxene (broad band centered at ~1.9 µm).

In the Curtis Ridge and Eagle Cliff areas, it is mainly the PyroxeneToFeldspar and Feldspar classes that are observed, with various degrees of alteration. They are represented by targets such as *Tolmie Peak* (Figure 3) with a pyroxene signature (though much less pronounced than at Saint Elmo Pass) and a weak hydration band (narrow band at 1.9 µm). There are also targets with stronger alteration signature such as AEGIS 1307A (Figure 3), with a 2.2 µm band indicative of Al-phyllosilicate associated to a drop at 2.4 µm potentially due to a mixture with sulfates. The Al-phyllosilicates are in good agreement with the primary mineralogy that includes Feldspars [7]. The strongest hydration absorption bands (Figure 2) are observed in the Eagle Cliff area, a clear NW/SE ridge.

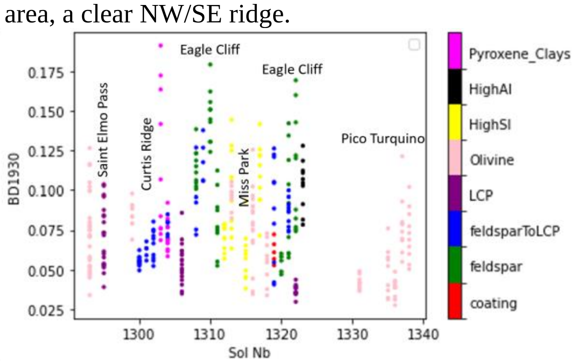

Figure 2 : Spectral parameter of the hydration band centered at 1.93 µm as a function of the sol number.

In the Mist Park area (Figure 1), the rover visited a NW/SE lag of light-toned rocks. They were notably enriched in Si with detection of quartz (ref to Beck et al, this issue). The target *Margareth Falls* show a typical IR spectrum of these rocks, with a strong absorption at 1.9 µm, a lower reflectance in the 2.1-µm region, a 2.2-µm band, a 2.3-µm band and a drop at 2.4 µm. We interpret this combination of features as a complex mixture of hydrated silica, monohydrated (and possibly also polyhydrated) sulfates, and Mg-clays. As quartz is the main component of the rocks [8] but mostly transparent in IR, this alteration assemblage is a likely minor component of the rock.

Between Eagle cliff and Pico Turquino, a few Al-rich targets were observed. A typical spectrum is shown in Figure 3 (target *Flett Glacier*). A strong Al-phyllosilicate signature is observed (2.2-µm band) [5].

A last group of rocks is observed as low-lying bedrock in the Curtis Ridge area: they show compositions close to pyroxene in LIBS together with a strong clay mineral signature in VISIR. *Fryingpan Glacier* is a good example (Figure 3). The Mg-clay signature is among the strongest observed since the beginning of the mission.

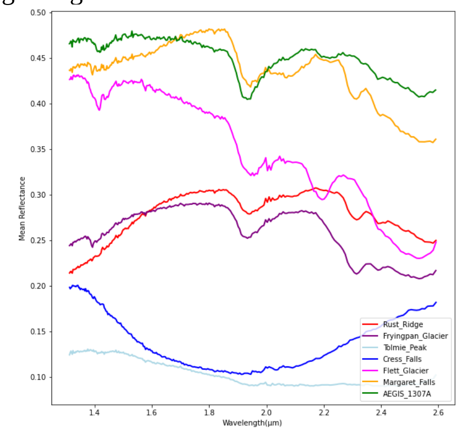

Figure 3 : Mean IR spectra of a selection of targets

Discussion:

The SuperCam data collected in the inner crater rim of Jezero crater so far reveal a diversity of lithologies with variable degrees of aqueous alteration. The pyroxene-rich rocks observed near Saint Elmo Pass appear very pristine, with both LIBS and VISIR indicating a pyroxene-rich composition with little to no alteration phases. On the other hand, the high-Si, quartz-bearing rocks found near the Mist Park butte are likely hydrothermal precipitates, and their spatial association with the NW-SE ridges suggest that the hydrothermal activity is related to the formation of Jezero crater. The other observed alteration phases (Mg-rich clay minerals, Al-rich phyllosilicates, and sulfates) may have formed at lower temperatures. Although the degraded state of the outcrops and the strong regolith cover in this part of the rim limits our ability to fully understand the timing of the alteration processes, we expect to get a clearer picture in the upcoming months, as *Perseverance* reaches better exposures of (likely) similar lithologies in the outer part of the rim.

References: [1]Farley et al., 2020; [2] Mayhew et al., this conference, [3] Wiens, et al., 2021 ; [4] Maurice et al., , 2021 ; [5] Royer et al., this conference ; [6] Cousin et al., Icarus, 2024 ; [7] Bedford et al., this conference; [8] Beck et al., this conference; [9] Udry at al., this conference; [10] Garzynski et al., this conference; [11] Bedford et al., this conference;