OVERVIEW OF THE BEDROCK GEOCHEMISTRY AND MINERALOGY OBSERVED BY SUPERCAM DURING PERSEVERANCE'S DELTA FRONT CAMPAIGN. E. Dehouck[1*], O. Forni[2], C. Quantin-Nataf[1], P. Beck[3], N. Mangold[4], C. Royer[5], E. Clavé[6], O. Beyssac[7], J. R. Johnson[8], L. Mandon[9], F. Poulet[10], S. Le Mouélic[4], G. Caravaca[2], H. Kalucha[9], E. Gibbons[11], G. Dromart[1], P. Gasda[12], P.-Y. Meslin[2], S. Schroeder[13], A. Udry[14], R. B. Anderson[15], S. Clegg[12], A. Cousin[2], T. S. Gabriel[15], J. Lasue[2], T. Fouchet[16], P. Pilleri[2], C. Pilorget[10], J. Hurowitz[17], J. Núñez[8], A. Williams[18], P. Russell[19], J. I. Simon[20], S. Maurice[2], R. C. Wiens[5], and the SuperCam team. [1]LGL-TPE, Lyon, France; [2]IRAP, Toulouse, France; [3]IPAG, Grenoble, France; [4]LPG, Nantes, France; [5]Purdue Univ., West Lafayette, IN; [6]CELIA, Bordeaux, France; [7]IMPMC, Paris, France; [8]JHUAPL, Laurel, MD; [9]Caltech, Pasadena, CA; [10]IAS, Orsay, France; [11]McGill Univ., Montréal, Canada; [12]LANL, Los Alamos, NM; [13]DLR, Berlin, Germany; [14]UNLV, Las Vegas, NV; [15]USGS, Flagstaff, AZ; [16]LESIA, Meudon, France; [17]Stony Brook Univ., Stony Brook, NY; [18]Univ. Florida, Gainesville, FL; [19]UCLA, Los Angeles, CA; [20]NASA JSC, Houston, TX. *erwin.dehouck@univ-lyon1.fr

Introduction: In February 2021, the *Perseverance* rover landed in Jezero crater, Mars. The crater floor was found to be composed of lava flows and cumulate rocks [1-5]. These magmatic rocks appear to have undergone some limited aqueous alteration; however, it is not clear whether this alteration is related to the lacustrine phase of the crater [1,3,6,7].

After completing its exploration of the crater floor, *Perseverance* reached the foot of the Jezero western fan in late April 2022 (sol ~422). Long-distance images acquired earlier in the mission had already confirmed the deltaic nature of the fan [8], which had long been suspected from orbital observations [9,10]. Between April and December 2022, *Perseverance* investigated the basal layers of the delta at two locations named Hawksbill Gap and Cape Nukshak, which are ~400 m apart [11]. Here, we present an overview of the geochemistry and mineralogy of the delta rocks as observed by SuperCam, and show that these rocks record a diversity of past aqueous alteration environments.

Dataset: SuperCam is a remote-sensing instrument that combines five different techniques to study various properties of the rocks and soils encountered along the rover's traverse [12,13]. Here, we use the major-element oxide compositions derived from the laser-induced breakdown spectroscopy (LIBS) data [14] to assess the chemical composition of the targets. We also use visible (0.40–0.85 µm) and near-infrared (1.3–2.6 µm) reflectance spectra (collectively referred to as VISIR data) to assess their mineralogical composition [6,15]. The data shown here include only bedrock targets, i.e., observations of regolith, veins or rock coatings were set aside.

Results: *Hawksbill Gap section.* The lowest exposed rocks along the Hawksbill Gap section are the planar laminated fine sandstones of the Devils Tanyard (DT) member. These rocks have relatively elevated SiO_2 and Al_2O_3 contents, and relatively low FeO and MgO contents (Fig. 1). Their VISIR spectra display absorption bands at 1.4, 1.9, 2.31 and 2.39 µm (Fig. 2) that we attribute to Fe/Mg-bearing phyllosilicates. More specifically, the asymmetry of the 2.31-µm band indicates the presence of Mg-rich vermiculite or a mixed-layered vermiculite-smectite. In addition, some DT rocks show spectral shapes in the visible range consistent with the presence of iron oxides such as hematite.

The overlying Hughes River Gap (HRG) member is also composed of fine sandstones. This member was not explored in depth by the rover, but the available LIBS and reflectance data suggest that its chemical and mineralogical composition is similar to DT.

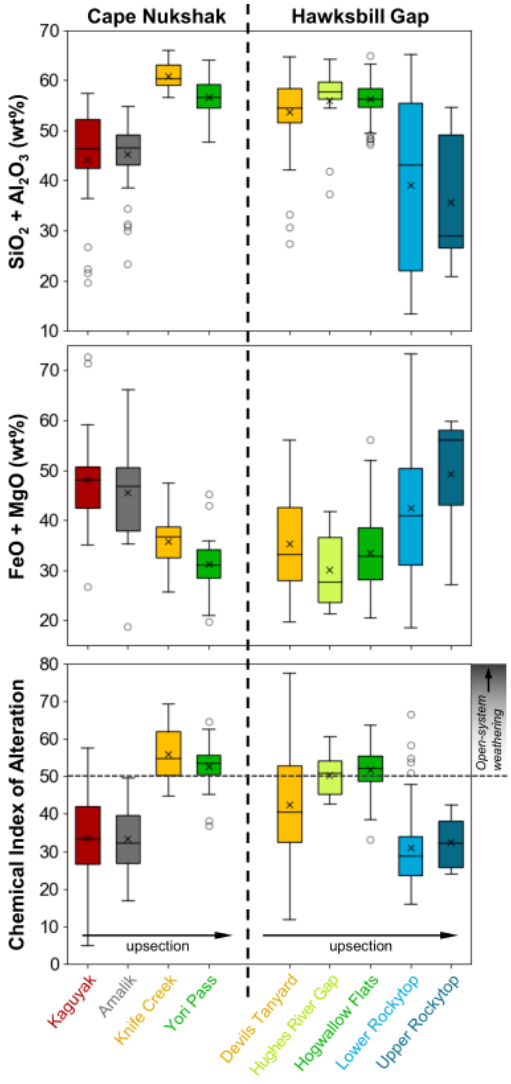

Figure 1 – Geochemistry of the main geologic units of the delta front, from SuperCam LIBS data.

The Hogwallow Flats (HWF) member is composed of siltstones to fine sandstones that are distinctly lighter toned than the rest of the delta front. Their chemical composition is in line with the underlying DT and HRG members (Fig. 1). However, their VISIR spectra show variable but generally shallower 2.3-µm bands, suggesting a reduced abundance of phyllosilicates. On the other hand, a sharp drop of reflectance just shortward of 2.4 µm is observed in all the spectra (Fig. 2), indicating the presence of hydrated sulfates. An absorption at 433 nm suggests that these sulfates are, in part, Fe^{3+}-bearing [16].

Finally, the Rockytop (RT) member is composed of coarse sandstones to pebble conglomerates. The coarse grain size results in a larger dispersion of the LIBS chemical measurements (Fig. 1), but this member is overall more mafic than the underlying ones. The VISIR spectra somewhat resemble those of the HWF member.

Cape Nukshak section. The base of the Cape Nukshak section was studied extensively at a location named Enchanted Lake, where two main outcrops were analyzed by SuperCam. The lowest one is named Kaguyak and is composed of thinly bedded sandstones, whereas the upper one is named Amalik and is composed of distinctly grey-toned siltstones. Both have relatively low SiO_2 and Al_2O_3 contents, and relatively elevated FeO and MgO contents compared to the rest of the delta front (except RT; Fig. 1). Pyroxene and olivine grains are detected with LIBS in these rocks [17]. In terms of VISIR data, Kaguyak is most similar to HWF, whereas Amalik has a unique spectral signature among all the delta rocks (Fig. 2). Indeed, the Amalik spectra display slightly reduced 1.4 and 1.9-µm bands, as well as a strong 2.33-µm band, shifted longward compared to the vermiculite-like spectra of DT. The most likely candidate to explain these features is a Mg-rich serpentine (e.g., antigorite).

Stratigraphically above Enchanted Lake, the Knife Creek (KC) interval was found to have chemical compositions and reflectance spectra similar to those of the DT member, while the light-toned rocks of the Yori Pass (YP) interval appear compositionally similar to those of the HWF member.

Implications: *Local geologic history.* The observed chemical and mineralogical similarities between DT and KC, as well as between HWF and YP, suggest that these intervals could be lateral equivalents of one another, even though their thicknesses seem to differ [11]. If true, this would mean that the deposition of the Hawksbill Gap and Cape Nukshak sediments was coeval (or roughly so), and that *Perseverance* has explored a single lobe (or closely related lobes) of the delta so far. In addition, the putative correlation between DT and KC would imply that any lateral equivalent of Enchanted Lake is not exposed in the Hawksbill Gap section (either because it does not exist, or because it is covered by regolith).

Aqueous alteration. The LIBS data collected by SuperCam show slightly elevated values of the Chemical Index of Alteration (>50) in several locations on the delta front (Fig. 1), indicating some degree of mobile element removal. In addition, the VISIR spectra provide evidence for widespread and diverse secondary phases. At least two main types of phyllosilicates are identified: vermiculite (or mixed-layered vermiculite-smectite) at DT, and serpentine at Amalik. Hydrated sulfates are found in the HWF and RT members, as well as in the Kaguyak interval. Carbonates are also likely present at HWF and RT [18].

In turn, the presence of varied secondary phases records a diversity of past aqueous environments: vermiculite is indicative of mild, likely near-surface alteration [19]; serpentine implies hydrothermal alteration; and sulfates suggest evaporitic conditions (expected in a closed lake system [8]). However, it is important to keep in mind that some secondary phases may be detrital. For example, vermiculite-like signatures are found extensively in the Jezero watershed [20]. Thus, not all the environments listed above need to have existed within the lake itself. Nevertheless, the observed diversity implies that the rock samples collected by *Perseverance* for a future return to Earth will cover a range of paleoenvironments and organic preservation potentials, which was a primary consideration when selecting Jezero as the landing site.

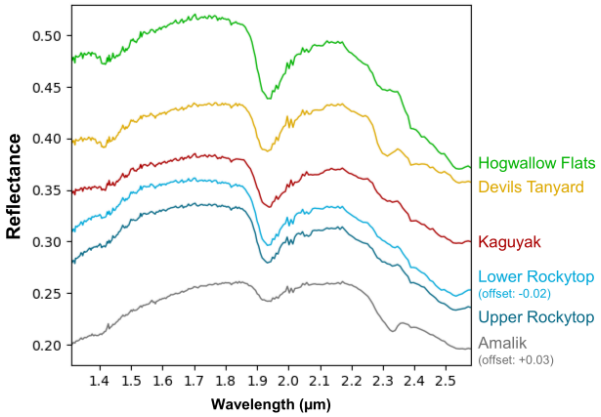

Figure 2 – Average near-infrared reflectance spectra of the main geologic units of the delta front.

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