Mineral composition of Jezero crater western fan derived by SuperCam/Mars2020 infrared spectroscopy and spectral modeling. C. Royer[1,*], F. Poulet[2], R. C. Wiens[1], P. Beck[3], O. Beyssac[4], É. Clavé[5], E. Dehouck[6], T. Fouchet[7], J. R. Johnson[8], L. Mandon[9], S. le Mouélic[10], C. Pilorget[2], C. Quantin-Nataf[6] and S. Maurice[11] [1]EAPS, Purdue Univ., West Lafayette, IN, USA; [2]IAS, Orsay, France; [3]IPAG, Grenoble, France; [4]IMPMC/MNHN, Paris, France; [5]DLR, Berlin, Germany; [6]Univ. de Lyon, Lyon, France; [7]LESIA, Meudon, France; [8]JHU-APL, Laurel, MD, USA; [9]Caltech, Pasadena, CA, USA; [10]LPG, Nantes, France; [11]IRAP, Toulouse, France; *royer10@purdue.edu

Introduction: The western fan of Jezero crater has been explored by the rover *Perseverance* since early 2022. The timing and conditions of its origin were poorly constrained from orbital observations (*e.g.* [1]). Among the rover's instruments, SuperCam's [2, 3] near-infrared spectrometer [4] (IRS, between 1.3 and 2.6 ţm), enables the study of the mineralogy of the rocks and thus the conditions of their formation. The analysis of IR spectra collected within the fan indicates the presence of numerous aqueous alteration minerals with significant differences among geological units, along with primary minerals [5, 6]. Modeling the spectra *via* the method presented here allows for a deeper analysis by studying correlations between the measurements (projection into ternary diagrams) and the distribution of minerals in the spectral mixture (spectral deconvolution). The observations presented here were acquired between Sol 424, when *Perseverance* was at Cape Nukshak, and Sol 896, end of the Upper Fan Campaign.

Method: Our spectral modeling method consists of two main consecutive steps. First, the primary absorption bands and spectral features of each spectrum are automatically extracted and modeled using a combination of Gaussians (Multi-Gaussian Modeling, MultiGM). These include bands at 1.4, 1.9, 2.2, 2.3, 2.5 ţm, the slope between 1.3 and 1.8 ţm (an indicator of Fe^{2+}, *e.g.* in olivine and carbonates), and a criterion for sulfate detection (S_INDEX, [7]). The MultiGM analysis allows extracting the position of absorption bands with greater precision than the spectral sampling of the IRS (< 5 nm on average), and projecting the relative band areas into a well-chosen space reveals clusters that correlate with the rock composition. The second step, spectral deconvolution, relies on the use of linear combinations of reflectance spectra derived from a library of laboratory spectra. The concept involves mixing a large number of *endmembers* to account for the variability of reflectance of each species based on its state (powders of various grain sizes, slabs), observation conditions, and purity. This approach involves several successive steps, using calibrated IRS data [8] of every target.

The selection of endmembers populating the spectral library is based on the preliminary analysis provided by MultiGM and previous spectral analyses. Here, only species exhibiting absorption bands compatible with observations (1.4, 1.9, 2.3, 2.39 ţm and 2.4 ţm reflectance drop) have been retained: these include olivine, pyroxene, sulfates, Fe/Mg-smectites, vermiculite, carbonates, serpentine and Fe-hydroxides. The latter is found to correlate with the dust contamination. Finally, a correlation filter is applied to the library to eliminate duplicate endmembers more than 99 % similar. The final library contains about 100 different spectra.

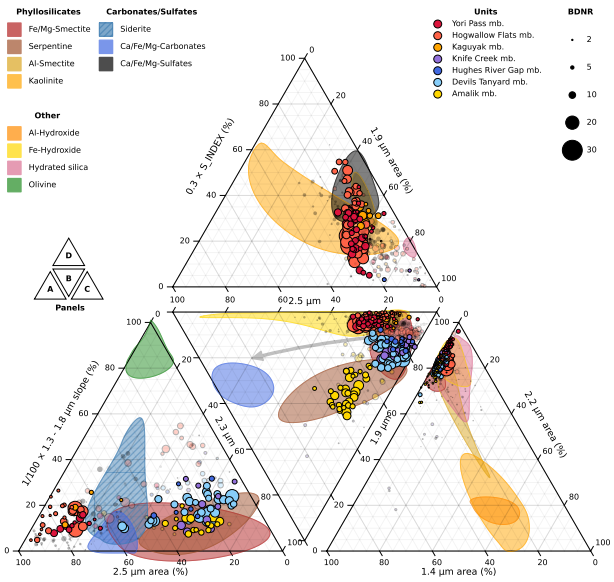

Figure 1: *Ternary projections of the Delta front observations (Shenandoah formation). The background patches are the location of lab spectra, points are the SuperCam observations. The points are colored accordingly to the geological unit and their size corresponds to the combined band-depth-to-noise ratio (the ratio of the band depth and the local noise combined among the absorption bands involved in each ternary diagram).*

The spectral modeling is then executed in two steps: 1) the spectral assemblage that best fits the data is determined by minimizing the difference between the model and the data, thereby obtaining the set of spectral mixing coefficients corresponding to each mineral family; 2) these coefficients are reinjected into a sensitivity analysis procedure based on a Markov Chain Monte Carlo (MCMC) algorithm

to determine the likelihood of each family. This latter parameter represents the sensitivity of the mixture to the presence of a mineral family. If the likelihood is lower than 1, then the presence of that mineral has little impact on the quality of the fit and thus is unlikely to be present.

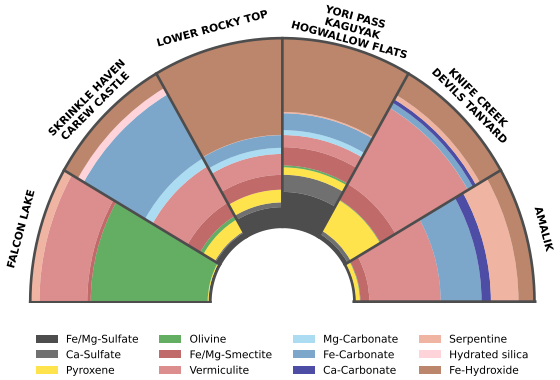

Figure 2: *Representation of the average mixing coefficients for each cluster identified in the Triforce plot. The units are sorted accordingly to their order in the stratigraphy, from top (left) to bottom (right).*

Results: The application of this method to the observations of the delta shows a wide diversity of aqueous alteration minerals. The projection of the observations in the Triforce plot (Fig. 1) reveals three clusters of points in the delta front and three in the upper fan. They correspond to mineral assemblages rich in serpentine (Amalik member), mixtures of Fe/Mg-phyllosilicates and sulfates (Hogwallow Flats, Yori Pass, Kaguyak, Rocky Top), a composition strongly marked by Fe/Mg-phyllosilicates (Devils Tanyard, Hughes River Gap, Knife Creek), carbonate-phyllosilicate mixtures with varying carbonate enrichment (Carew Castle, Skrinkle Haven), and rocks richer in primary, less altered minerals forming the Falcon Lake boulder field. Linear modeling of rocks from these clusters further identifies the mineral families composing the rocks. The sulfates of Hogwallow Flats and Rocky Top appear to be mainly composed of Fe/Mg-sulfates with some occurrences of anhydrite (Ca-sulfate) in veins (independently confirmed by Raman analyses see, [9]). Similarly, modeled carbonates are primarily rich in Fe with a transition from Ca/Fe (Amalik, Devils Tanyard groups) to Mg/Fe (higher up in the stratigraphy, Fig. 2), also documented by SHERLOC/Mars 2020 [10]. Detected phyllosilicates are also dominated by a composition rich in Fe/Mg with high mixing coefficients in vermiculite and lower ones in smectites. Modeling of altered boulders from Falcon Lake reveals the absence of carbonates in the spectral mixture but a strong presence of olivine, Fe/Mg-phyllosilicates, and serpentine.

Discussion/Conclusion: The geological units of the Jezero sedimentary delta display a wide variety of primary and aqueous alteration mineral assemblages. These minerals are present in different depositional contexts, suggesting a complex evolution of the delta and, by extension, the lake during its formation. The presence of sulfates in the middle of the delta front stratigraphy would indicate that the lake underwent a significant evaporation phase prior to the formation of the subsequent layers. The upper layers are richer in carbonates, which would also indicate a change in the nature of the filling fluid. Finally, the presence of less altered boulders at the top of the stratigraphy suggests a more energetic flow regime, and a contact with water short enough to alter small amounts of olivine into serpentine and vermiculite. These boulders could also be the remnant of an igneous flow that has largely eroded away.

References:

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