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**COMBINING SUPERCAM LIBS AND VISIR: CONSTRAINING THE MINERALOGY IN JEZERO CRATER.** O. Forni (olivier.forni@irap.omp.eu)<sup>1</sup>, P. Beck<sup>2</sup>, J. R. Johnson<sup>3</sup>, E. Dehouck<sup>4</sup>, C. Quentin-Nataf<sup>4</sup>, O. Beyssac<sup>5</sup>, A. Udry<sup>6</sup>, A. Cousin<sup>1</sup>, R. B. Anderson<sup>7</sup>, L. Mandon<sup>8</sup>, C. Royer<sup>9</sup>, E. Clavé<sup>10</sup>, F. Poulet<sup>11</sup>, S. Le Mouélic<sup>12</sup>, P.-Y. Meslin<sup>1</sup>, P. Pilleri<sup>1</sup>, V. Debaille<sup>13</sup>, S. Maurice<sup>1</sup>, R. C. Wiens<sup>9</sup>, S. M. Clegg<sup>14</sup>, T. Fouchet<sup>15</sup>, A. J. Brown<sup>16</sup> <sup>1</sup>Institut de Recherche en Astrophysique et Planétologie, Toulouse, France, <sup>2</sup>IPAG, Grenoble, France. <sup>3</sup>JHUAPL, Laurel, USA. <sup>4</sup>LGL-TPE, Lyon, France, <sup>5</sup>IMPMC, Paris, France. <sup>6</sup>University of Las Vegas, Las Vegas, USA. <sup>7</sup>USGS, Flagstaff, USA. <sup>8</sup>JPL-Caltech, Pasadena, USA, <sup>9</sup>Purdue University, Lafayette, USA, <sup>10</sup>CELIA, Bordeaux, France, <sup>11</sup>IAS, Orsay, France, <sup>12</sup>LPG, Nantes, France, <sup>13</sup>ULB, Bruxelles, Belgium, <sup>14</sup>LANL, Los Alamos, USA, <sup>15</sup>LESIA, Meudon, France, <sup>16</sup>Plancius Research, USA.

**Introduction:** Since the landing at Jezero in February 2021, the NASA Perseverance rover has visited the crater floor units, which are the structurally deepest and consist of stratified rocks [1]. Onboard Perseverance, SuperCam is a versatile remote-sensing instrument providing chemical and mineralogical information from the same spot on a target at a sub-mm to mm scale by combining Laser Induced Breakdown Spectroscopy (LIBS), time-resolved Raman and visible and infrared spectroscopy (VISIR), a microphone and a remote micro-imager (RMI) [2], [3]. In this abstract, we present results combining LIBS and VISIR techniques. SuperCam Laser-induced breakdown spectroscopy (LIBS) obtains emission spectra of materials ablated from the samples in electronically excited states. SuperCam passive reflectance spectra cover the 0.39–0.85  $\mu\text{m}$  (VIS) and 1.3–2.6  $\mu\text{m}$  (NIR) ranges, which allow the identification of a wide variety of minerals, especially hydrated species [4], and hence can help to constrain past environmental conditions at Jezero crater. We found that all of the floor units are igneous, with lava flows apparently comprising the upper units as part of the Mááz formation, while the lower formation [5], Séítah, is an olivine cumulate, produced by gravitational settling of olivine crystals in a large melt body [6, 7]. After exploring the floor, Perseverance drove to the edge of the delta formation and began a reconnaissance traverse style of observations starting at Enchanted Lake, just below an arm of the delta formation, and then moving into Hawksbill Gap, climbing between Devil’s Tanyard and Hogwallow flats. This approach, combining the chemical information from the LIBS data and the mineralogical information from the VISIR can provide additional constraints on the formation of the detected phases and/or the alteration processes in Jezero rocks.

**Data and methodology:** To achieve our analysis objectives we used a dimensionality reduction of the initial data. For LIBS we use the Major Oxide Composition (MOC) data derived from multivariate regression methods [8]. For VISIR, we use some diagnostic spectral parameters computed using the formalism described in [9] that generally are similar to those compiled by [9] for CRISM and by [10] for

ChemCam on board the Curiosity Rover, as well as some custom parameters adapted to the SuperCam data.

We selected all the LIBS spectra jointly acquired with VISIR data and removed all suspect data based either on the quality of the LIBS signal or the quality of the VISIR data. The magnitude of a specific spectral parameter is plotted into a classical ternary diagram in which pure minerals can be localized, such as the Wo-En-Fs diagram for pyroxenes. Additionally, a diagram can be displayed for each type of unit that has been identified.

**Results:** We analyzed several parameters with this approach, as discussed below.

*1.3 – 1.8  $\mu\text{m}$  slope:* This slope is indicative of the presence of olivine [9, 11]. Olivine has mainly been identified with SuperCam data in the Séítah unit [6, 11]. On a Si-Fe-Mg diagram, the highest slopes (between 0.4 and 0.7 radiance/ $\mu\text{m}$ ) cluster in two regions, one corresponding to the olivine but another that corresponds to the presence of orthopyroxenes which have a different molar (Fe + Mg) / Si ratio (Fig. 1.). Note that some points with low Si have also high slopes and may trace the presence of Mg-Fe carbonates [12].

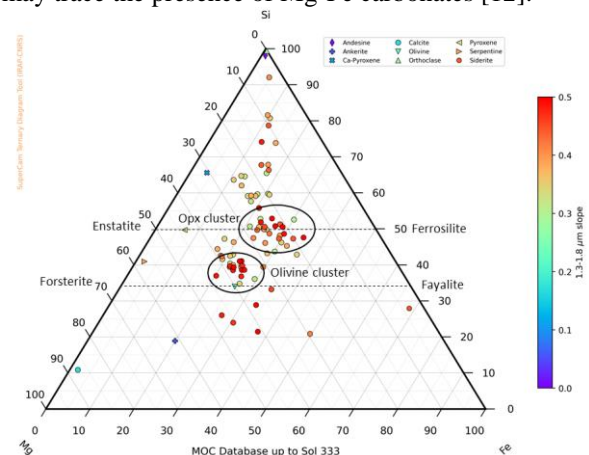


Figure 1: Si-Fe-Mg ternary diagram representing the magnitude of the 1.3 – 1.8  $\mu\text{m}$  slope that concentrates in two clusters, one close to orthopyroxenes (Si<sub>50</sub>-Fe<sub>25</sub>-Mg<sub>25</sub>) and one close to olivine (Si<sub>40</sub>-Fe<sub>25</sub>-Mg<sub>35</sub>).

This ratio equals two for olivine and equals to one for orthopyroxene. Consequently, the slopes are

dominated by the presence of olivine and the spectra are apparently insensitive to the presence of pyroxenes. However, selecting the highest slope spectra in both clusters and ratioing their mean suggests the presence of orthopyroxenes in the spectra corresponding to the LIBS orthopyroxenes spectra (Fig. 2.). Not only are the strong values of this slope interesting, but the lowest values are diagnostic of some particular phases like the coatings that cluster at a  $Wo_{20}$ - $En_{25}$ - $Fs_{55}$  composition in the pyroxenes diagram, or the sulphates that generally have low Si content, relatively high Mg content, and high H content based on the H line area at 655 nm [13].

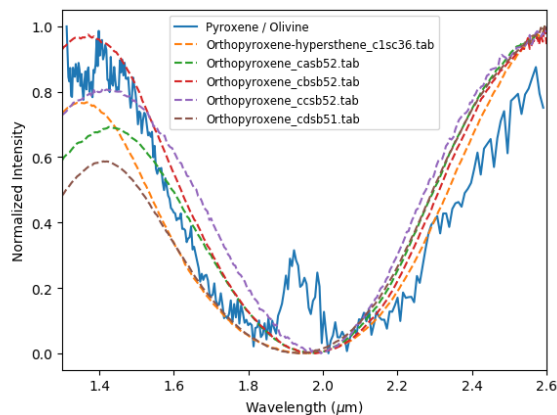


Figure 2: Ratio of the mean spectra in the two cluster exhibiting the good match with RELAB experimental orthopyroxenes spectra (dashed lines). The bump in the 1.9-2.0  $\mu\text{m}$  corresponds to variation of the water band at 1.9  $\mu\text{m}$  and atmospheric residuals.

**Absorption band at 2.28-2.32  $\mu\text{m}$ :** This spectral parameter traces the Fe/Mg-OH vibration and is diagnostic of Fe/Mg-phyllsilicates like Fe-smectite (e.g. nontronite) Mg-smectite (e.g., saponite), serpentine, talc-bearing material, chlorite, and prehnite. The absorption band moves from the lower to higher wavelengths with increasing Mg content. It is generally associated with structural  $H_2O$  and OH absorption features at 1.4  $\mu\text{m}$  and a 1.9  $\mu\text{m}$  feature. It sometimes traces the alteration of olivine and pyroxene. Strong absorption at 2.32  $\mu\text{m}$  (Mg-OH) are found in the Seftah formation and are correlated with olivine. This would mean that the olivine is altered, but this observation is in contradiction with the images, which exhibit apparently fresh crystals, and that the H signal is relatively low. The alteration might be related to secondary phases at the grain boundaries [8]. The strongest absorptions are found in the Amalik outcrop in the Delta unit. They are found in mainly three targets: Chiniak (Sol 565), Novarupta (Sol 572) and Hook\_Glacier (Sol 424). These infrared signatures

coupled to chemistry might indicate the presence serpentines. From the stoichiometry they can represent alteration of olivine and orthopyroxene. It is worth to note that all those targets are very much enriched in Cr at the percent level. The presence of Cr can be primary at least for the olivine or can come from the substitution of Al or Fe in phyllosilicates in the octahedral sites (Hisingerite, Bedeilite) [14]. Their chemical composition is very similar to the Seftah unit composition and may reflect high temperature deep hydro-thermalism [15]

**Discussion and future work:** The combined analysis of chemical data from the LIBS and mineralogical data from the VISIR provides good agreement between the two sets of data. However, some discrepancies were noticed. At least three causes can explain these differences. The first is related to the differing footprint sizes of the two techniques (LIBS spot size is of the order of 300  $\mu\text{m}$  while the VISIR footprint size is much larger of the order of 0.11 mrad i.e. 3.3 mm at 3m). The second is related to the small spatial offset between the centers of the two observations. This means that, while the LIBS technique can sample very tiny grains, the VISIR integrates signals from a much broader area and the mixing of phases is more likely. The third cause is related to the mineralogical response to the VISIR signal: Strong absorptions mainly due to the  $Fe^{2+}/Fe^{3+}$  can easily dominate the spectra and mask the presence of other phases even if the latter dominates the mixture. We have analyzed other spectral parameters like the absorptions at 1.4  $\mu\text{m}$  and 1.9  $\mu\text{m}$  as well as a sulphate index [9]. Other spectral indices will be investigated in the VIS and joint LIBS/VISIR multivariate reduction techniques will be used to better constrain endmembers.

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