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**HYDROGEN IN ROCKS FROM JEZERO CRATER INVESTIGATED WITH SUPERCAM LIBS.** P. Beck<sup>1</sup>, O. Forni<sup>2</sup>, P.-Y. Meslin<sup>2</sup>, K. Benzerara<sup>3</sup>, O. Beyssac<sup>3</sup>, J. Lasue<sup>2</sup>, C. Quantin-Nataf<sup>4</sup>, F. Poulet<sup>5</sup>, C. Royer<sup>6</sup>, L. Mandon<sup>6</sup>, W. Rabin<sup>2</sup>, E. Clavé<sup>7</sup>, A. Cousin<sup>2</sup>, S. Schröder<sup>8</sup>, S. Le Mouélic<sup>9</sup>, O. Gasnault<sup>2</sup>, A.M. Ollila<sup>9</sup>, E. Hausrath<sup>10</sup>, S. Maurice<sup>2</sup>, R.C. Wiens<sup>9</sup> and the SuperCam team. <sup>1</sup>IPAG, Univ. Grenoble Alpes, CNRS, IPAG, France ([pierre.beck@univ-grenoble-alpes.fr](mailto:pierre.beck@univ-grenoble-alpes.fr)) <sup>2</sup>IRAP, Univ. de Toulouse Paul Sabatier, CNRS, CNES, Toulouse, France. <sup>3</sup>IMPMC, CNRS, Sorbonne Université, MNHN, Paris, France. <sup>4</sup>Univ Lyon 1, ENSL, CNRS, LGL-TPE, Lyon, France. <sup>5</sup>IAS, Univ. Paris Saclay, Orsay, France. <sup>6</sup>LESIA, Obs. Paris, CNRS, Sorbonne Univ., Univ. Paris-Diderot, Meudon, France. <sup>7</sup>CELIA, Bordeaux, France. <sup>8</sup>DLR, Berlin, Germany. <sup>9</sup>Université de Nantes, France. <sup>9</sup>Space and Planetary Exploration Team, Los Alamos National Laboratory, Los Alamos, USA. <sup>10</sup>Department of Geosciences, University of Nevada, Las Vegas, USA.

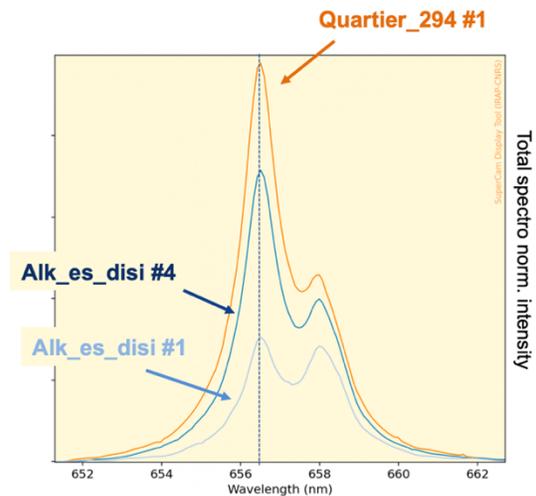
**Introduction:** The SuperCam instrument offers the capability to investigate the aqueous history in and around Jezero crater through chemical and mineralogical phase identification: major and minor element abundances can be determined by LIBS, Raman and VISIR spectroscopies, enabling us to remotely identify mineral phases. Finally, SuperCam's color imaging (RMI) can be used to investigate rock textures.

Of major interest is the capability of SuperCam LIBS to detect light elements, including H and C. Carbon atom emission lines can be used to search for carbonates or organic matter [1], while looking at the hydrogen line permits detection of OH or H<sub>2</sub>O bearing phases, as well as H-bearing organic compounds.

**Background on hydrogen in LIBS, and Methods:** There is one hydrogen line that can be used in SuperCam LIBS data, at 656.5 nm and was previously used in ChemCam data [2]. This line has been used at Gale crater in order to investigate alteration and diagenetic processes. The hydrogen line partially overlaps with a doublet of ionic carbon lines (Fig. 1), but the H and C emissions can well be separated with ChemCam spectral resolution, and are even better separated given the improved spectral resolution of SuperCam compared to ChemCam (Wiens et al., 2020). Hydrogen atoms have a particular behavior in LIBS, including being strongly impacted by surface roughness. An absolute calibration of H abundance may be possible based on LIBS data, as was done for ChemCam [3]. Such a calibration has not been done yet for SuperCam but should be pursued in a near future and requires a full apprehension of possible matrix effects. In the present study, we used a metric related to hydrogen abundance, which is the hydrogen ICA score. Independent Component Analysis (ICA) is a powerful source separation techniques, that has already been used for H in LIBS data (e.g., [4]). Results are presented based on LIBS for rocks targets. Analysis of soils are presented in [5].

**Results:** Figure 1 presents the hydrogen signal detected for two particularly rich hydrogen points (Alk\_es\_dis #4 and Quartier\_294 #1) as well as a more

standard Martian target in terms of hydrogen ICA score (Alk\_es\_disi #1).

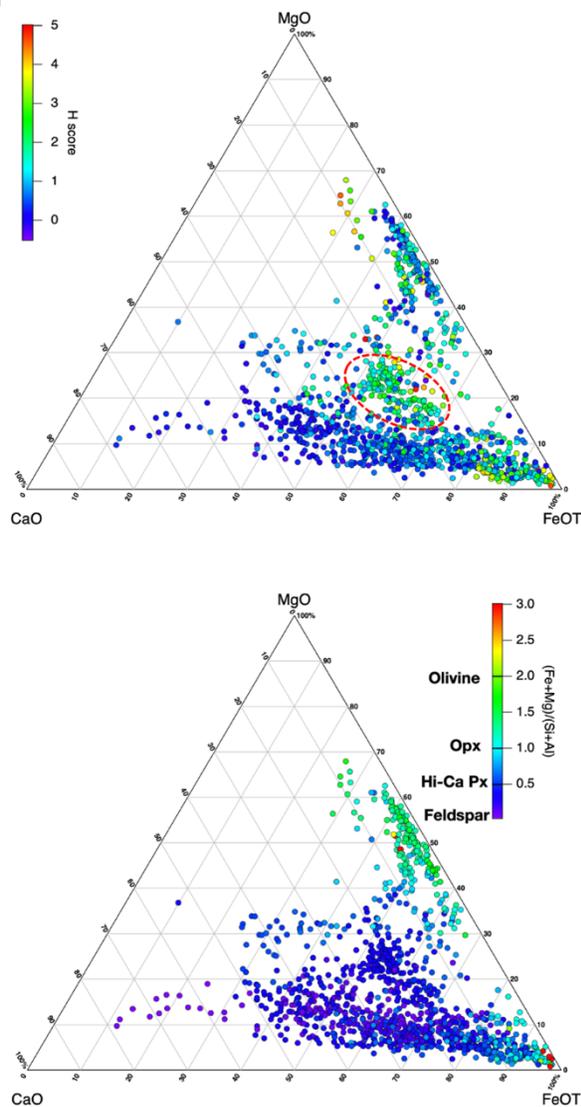


**Figure 1:** Example of hydrogen signatures (656.5 nm) in SuperCam data at Jerero crater. The smaller peak on the right of the H line is related to carbon (doublet, from atmospheric CO<sub>2</sub> decomposition).

*Hydrogen distribution among phases analyzed by SuperCam.* As was the case in Gale crater, the first shot of the series of laser bursts (typically 30 shots) always shows an enrichment in hydrogen [6]. This behavior is explained by an enhanced contribution of fine-grained aeolian dust in the first laser shot [7], before being blown away by the laser-induced shock wave.

Inclusion of hydrogen ICA scores with bulk chemistry derived from SuperCam reveals a heterogeneous distribution of hydrated products within rock targets (Fig. 2). Elemental abundances corresponding to felsic compositions are typically associated to low hydrogen scores suggesting mild to moderate alteration of the felsic component. On the other hand, several points rich in Fe and Mg do show an increase in their H-score. Some points show an elevated Mg and an elevated hydrogen concentrations, and are attributed to

hydrated Mg sulfate [8]. This is the case for example of Alk\_es\_dis #4 and Quartier\_294 #1 (Fig. 1). In addition, several points show increased Fe abundances and elevated hydrogen and can be attributed to Fe-rich clays, Fe oxy-hydroxide, or hydrated Fe-carbonates (Fig. 2).



**Figure 2:** Ternary composition diagrams derived from SuperCam Mean Oxide Composition (MOC). Points are color-coded according to hydrogen ICA score (upper panel) or  $(Fe+Mg)/(Si+Al)$  atomic ratio (lower panel). Note the presence of a chemical cluster (red dashed ellipse) enriched in hydrogen.

*Hydrated chemical cluster.* Of interest is the identification of a chemical cluster (Fig. 2 upper panel) that presents an increased hydrogen score. This initially suggested the presence of an hydrated phase with a rather constant stoichiometry, or the presence of a sim-

ilar phase assemblage. Comparison of the chemistry of points from this cluster to that of aeolian dust as probed from the first LIBS shot reveal a strong chemical similarity. This points to the fact that several points from several targets are covered by a relatively thick solid layer with a chemical composition similar to aeolian dust. Analysis of the color RMI images confirms the presence of such a coating in points from the chemical cluster, but also shows that its appearance is different from aeolian dust, being darker, often glossy and compact.

**Discussion:** Hydrogen distribution provides hints on alteration of rocks at Jezero, confirming the presence of various hydrated phases (Fe-rich clay, oxy-hydroxide, hydrated Fe-carbonate or sulfate) but also reveals that many of the targets are coated by a layer that appears to be somehow compacted dust. The association to Mg-rich sulfate points shows that it is not pure hydrated dust [8]. Reflectance spectra obtained with SuperCam's Infrared (IR) spectrometer confirm that this layer is hydrated according to the presence of a clear absorption at  $1.9 \mu\text{m}$  and a dip toward  $2.5 \mu\text{m}$ ; both can be explained by the presence of molecular water. The spectra are also showing a generally blue slope over the IR spectral range.

The infrared optical appearance of this layer is different from the red-“orange aeolian dust, in the fact that the latter do not show such hydration bands as seen from orbit. On the other hand, the presence of an -OH or  $\text{H}_2\text{O}$  component in aeolian dust is attested by the ubiquitous  $3 \mu\text{m}$  band over the Martian surface [9]. Compaction effects may explain why absorption bands are more visible in the coating layer than in the hyper-fine grained aeolian dust (see [10]). The question that now arises is how to form such a layer that seems to be well-indurated. It is not clear at the moment if aeolian processes alone may be able to produce such a layer. On the contrary, chemical processes may have played a role. Perchlorate salts have been detected by SuperCam, and deliquescence processes may help in compacting and then sintering such a layer upon evaporation of the brines. Some of these coating materials are likely present in the already cored samples.

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