SUPERCAM FIRST SHOTS: DUST COMPOSITION AND VARIABILITY.

J. Lasue[1], P.Y. Meslin[1], A. Cousin[1], O. Forni[1], R. Anderson[2], P. Beck[3], O. Beyssac[4], A. Brown[5], S.M. Clegg[6], E. Dehouck[7], J. Frydenvang[8], P. Gasda[6], O. Gasnault[1], E. Hausrath[9], S. Le Mouélic[10], S. Maurice[1], P. Pilleri[1], W. Rapin[1], R.C. Wiens[11], and the SuperCam team.
[1]IRAP-CNRS, Toulouse, France, (jlasue@irap.omp.eu) [2]USGS, Flagstaff, AZ, USA, [3]Univ. Grenoble Alpes, IPAG, France, [4]IMPMC, Paris, France, [5]Plancius Research, MD, USA, [6]LANL, Los Alamos, NM, USA [7]Univ. de Lyon, LGL-TPE, France, [8]Univ. Copenhagen, Denmark [9] Univ. Nevada, Las Vegas, USA, [10] LPG, Nantes, France

Introduction: The NASA Perseverance rover has been exploring Jezero crater on Mars for the past two years. Since its arrival, the rover has driven about 14 km along the bottom surface of the crater, including the Máaz formation, the Artuby ridge and Séitah formation, and the different outcrops located at the foot of the delta. The formations found in the crater floor are of igneous origin with local aqueous alteration. The main upper unit is of basaltic origin while the deepest formation is probably an olivine-rich cumulate [1, 2].

Instruments: SuperCam is a multi-technique remote sensing instrument able to acquire high resolution color images, passive visible/near-infrared, Laser-Induced Breakdown Spectroscopy (LIBS) and Raman spectra, and includes a microphone [3, 4]. The LIBS technique was already developed to survey the surface of Mars with ChemCam (e.g. [5]).

In a typical analysis, a series of 30 powerful laser pulses at 1064 nm ablates the surface of targets at a distance of few meters, inducing a plasma spark. The elements constituting the target are excited by the laser energy and emit photons at characteristic wavelengths, which can be analyzed by spectroscopy to determine their quantification [6, 7]. During such an analysis, the several spectra obtained by the first laser shots are typically contaminated by the dust deposited on the surface of every rock target on Mars (unless it was preliminary cleaned by abrasion or another technique). The first five spectra are typically removed before calculating the composition of each target [6, 7].

The first spectra acquired on each target location present a very homogeneous composition, different from the one of the underlying target. The average first shot compositions have therefore been interpreted to represent an analysis of eolian dust deposited over time on the surface of Mars and previous studies have shown the compositional similarity between the dust detected at Jezero by SuperCam and at Gale by ChemCam [8, 9].

In this study, we confirm the similarity in composition between the eolian dust deposited at Jezero and that previously described at Gale crater. We further assess the possible locational variability of the first shots dust signal, and its eventual thickness variation to determine the effectiveness of dust removal by the LIBS technique.

Method: We have used all the LIBS shot-to-shot data acquired since the landing of Perseverance (643 sols). In this dataset only the data corresponding to natural undisturbed target surfaces have been selected, by removing abraded targets, drill holes, drill tailings and calibration targets from the analysis. This corresponds to ~2900 different spectra processed by denoising, background removal, wavelength calibration, and correction for instrument response.

The average spectrum obtained from these data can then be appropriately compared with the average first shot spectrum obtained by ChemCam at Gale crater, which was built over 1500 sols (~ 8500 spectra). Further statistical analysis include time series variations and depth removal analysis as described below.

Results on composition: We have verified for the first time that the average of the very first LIBS shots for all targets can be superposed, indicating strong similarities in their Major Oxides Composition (MOC) [9]. Comparing the cloud of MOC in a ternary diagram highlights the similarity between the SuperCam and ChemCam datasets as shown in Figure 1.

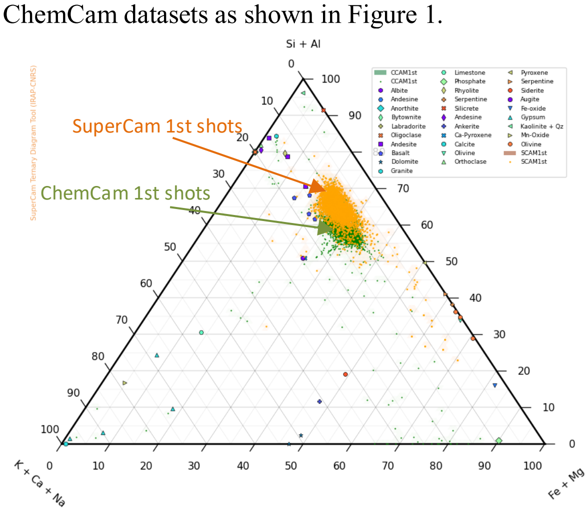

Figure 1: Comparison of LIBS spectra first shots of ChemCam at Gale ([10] in green) and of SuperCam at Jezero (in orange).

Some disparities were observed in Mg and Ca lines in the SuperCam signal, possibly due to a contribution from local rocks. The alkali do not present very strong differences. The minor elements (H, Li, Ba, Sr, Rb, Mn, S, Cl, etc.) are essentially similar for both instruments, indicating a similar level of hydration and minor-elements contents of the dust fraction at Jezero and at Gale [8]. This is consistent with the study of local soils at Jezero indicating a transition from locally derived composition in coarse grains to a more homogeneous composition for fine grained materials [10]

Locational variation of dust compositions: The time series of MOC predictions can be studied to detect if any variations in first shots composition could be linked to environmental changes (dust storms) or possible local contributions. No significant variations in the composition are detected with time for most major elements, except possibly the MgO content, which shows an increase around the Séitah area, which could be linked to a local contribution of this formation with a higher rock Mg# (Figure 2).

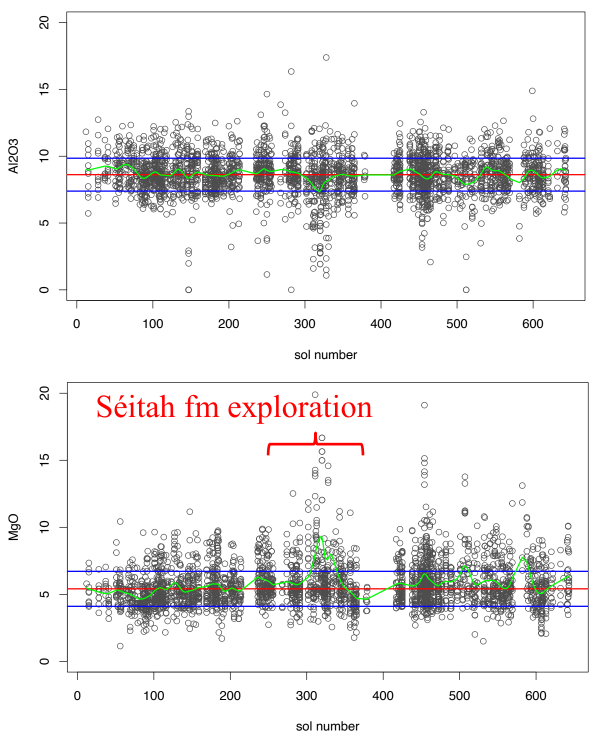

Figure 2: Time variations in the MOC predictions of the first shots for Al2O3 and MgO data with the median value indicated in red, median absolute deviation in blue and spline smoothed curve in green.

Thickness of the dust cover: We use a continuous piecewise linear fit to data with residual sum of squares to detect changes in slope for the MOC composition as a function of shot number at each point [11]. This allows us to assess the shot number at which the composition contaminated by dust transitions to the main rock composition (Figure 3a). Using this automated slope change detection algorithm, it is possible to assess the average change of slope for each target (selecting those natural surface targets which have a composition significantly different from the eolian dust). The distribution of slope changes thus obtained indicates that most of changes occur at or below 5 shots (median = 4.4 shots; mad = 1.5 shots). This validates the data processing defined for LIBS (removal of first 5 shots), and gives a minimum estimate of the dust cover of only a few microns, consistent with the typical Mars dust size.

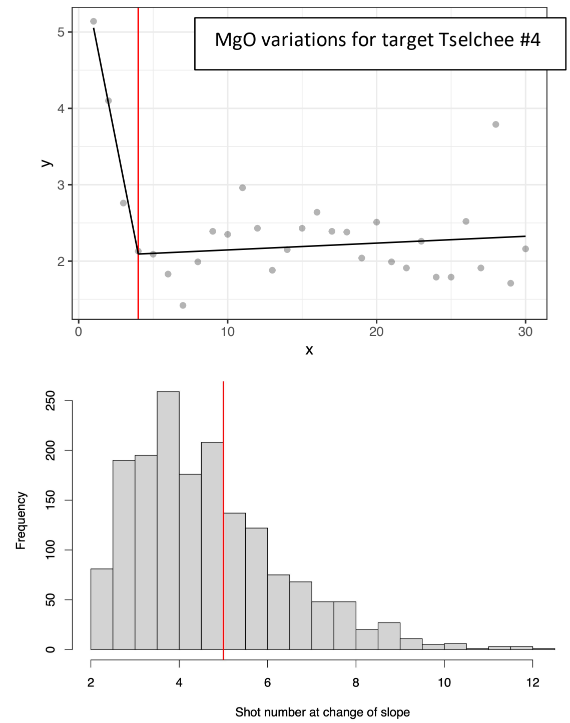

Figure 3: a. Slope change detection for MgO for target Tselchee #4 **b.** Histogram of slope change detection indicating that most of the changes occur at or below 5 shots.

Conclusions: Our analysis indicates that the dust cover studied at Jezero corresponds to a thin homogeneous material similar in composition to the eolian dust studied at Gale. This result is consistent with a global mixing of the eolian dust on Mars, or possibly a single origin for the eolian dust on Mars as proposed in previous studies (e.g. [12, 13]).

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References: [1] Farley et al. (2022) *Sci. 377.6614 (2022).* [2] Wiens et al. (2022) *Sci. Adv. 8.34 (2022).* [3] Maurice et al. (2021) *SSR, 217(3),* 1–108. [4] Wiens et al. (2021) *SSR, 217(1),* 1–87. [5] Maurice et al. (2016) *JAAS, 31(4),* 863–889. [6] Clegg et al. (2017) *Spectrochim. Acta B, 129,* 64–85. [7] Anderson et al. (2022) *Spectrochim. Acta B 188 (2022).* [8] Lasue et al. (2018) *GRL, 45(20),* 10968–10977. [9] Lasue et al. (2021) *LPSC, 53,* #1758. [10] Cousin et al. (2023) *LPSC, this meeting*. [11] Fearnhead et al. *J. Comput. Graph. Stat.* 28.2 (2019): 265-275 [12] Berger et al. (2016) *GRL, 43(1),* 67–75. [13] Ojha et al. (2018) *Nat. Comm., 9(1),* 1–7.