Diversity of carbonates in Jezero Crater, Mars, as seen with the SuperCam instrument. E. Clavé[1] (elise.clave@dlr.de), P. Beck[2], E. Dehouck[3], O. Beyssac[4], O. Forni[5], S. Schröder[1], N. Mangold[6], C. Royer[7], L. Mandon[2], S. Le Mouélic[6], C. Quantin-Nataf[3], S. Bernard[4], J.A. Madariaga[8], G. Lopez-Reyes[9], A. Ollila[10], J. Johnson[11], S. Clegg[10], A. Cousin[5], R.C. Wiens[12], S. Maurice[5] & the SuperCam Team, [1]DLR-OS, Berlin, [2]IPAG, Grenoble, [3]LGL-TPE, Lyon, [4]IMPMC, Paris, [5]IRAP, Toulouse, [6]LPG, Nantes, [7]LESIA, Meudon, [8]University of Basque Country, [9]ERICA group, University of Valladolid, [10]LANL, NM, [11]JHUAPL, Laurel, [12]Purdue University

Introduction: Jezero Crater lies in the most extensive carbonate-rich region on Mars [1, 2], and carbonates were detected from orbit in several locations within the crater [3, 4]. Since February 2021, the Perseverance rover has been exploring the crater and characterizing a variety of carbonate minerals. The SuperCam instrument [5, 6] is particularly well suited to carbonate detection and characterization along the rover traverse, thanks to three complementary techniques, which enable direct detection of carbonate (Raman and infra-red reflectance spectroscopy – IRS) or carbon (laser-induced breakdown spectroscopy – LIBS) in the rocks. Additionally, the Remote Micro-imager (RMI) provides high resolution color images to contextualize the spectroscopic analyses. These techniques can be used to characterize geologic targets up to several meters around the rover, and SuperCam is thus used on an almost daily basis.

Dataset: We explore the LIBS, Raman and IRS (not included in this abstract) datasets acquired on Mars with SuperCam over the first 1000 Martian days (sols) of the Mars2020 mission.

Overview of the units explored by Perseverance over the first 1000 sols: Over the first 420 sols of the mission, Perseverance explored two igneous units constituting the floor of Jezero Crater: Máaz, interpreted to originate from lava flows [7] and Séítah, interpreted as an olivine cumulate [8, 9]; both these units show signs of aqueous alteration [10]. The rover then went on to explore the sedimentary rocks of the Western Fan from bottom (Fan Front) to top (two main units called Skrinkle Heaven – SH – and Carew Castle – CC), interpreted as deltaic and fluvial deposits [11, 12]. Finally, the rover has been investigating the Margins Unit since sol 910.

Carbonate diversity: Using conservative criteria (similar to [13], limit of detection ~20-25 wt.% carbonate based on [14]), we've identified 280 out of 5546 LIBS points as being carbonate-bearing. The chemical compositions derived from LIBS data [15] indicate that these carbonates are all Fe-Mg carbonates (Ca poor). With Raman, carbonate signatures were identified in eight out of xxx abrasion patches along the traverse; we use the position of the main carbonate mode to estimate the Mg# (Mg/(Fe+Mg)) of the carbonate [16] (Figure 1).

Siderite in Màaz: In Mg-poor felsic rocks of the crater floor, we've identified siderite, mixed with Fe and Ti oxides [13].

In-situ carbonation in Séítah: The igneous mafic rocks of Séítah were shown to have been aqueously altered, resulting in Fe-Mg carbonates. For the most part, this alteration appears to have involved low water-to-rock ratios [13], except for the outer portion of Séítah, directly beneath the Fan, which could have been altered through interaction with lake water [17].

Mg-rich coatings: In addition to those previously identified in Máaz [13], we've identified Mg-rich (Mg#~0.8) carbonate coatings in the Fan front and upper Fan both; as in the crater floor, they are often associated with Fe-Mg sulfates.

Carbonate vein in the Fan front: In the same area of the Fan front where we identified Mg-rich carbonate coatings, we also analyzed a Fe-Mg carbonate vein, with a Mg# ~0.7 [18].

Carbonates in the Fan: Fe-Mg carbonates were identified from orbit in the Western Fan, but only locally at its top [e.g. 3, 4, 19], in the curvilinear deposits [20] (corresponding to SH), interpreted as prodelta deposits (foreset beds) using in situ imaging [11]. With SuperCam, we've identified Fe-Mg carbonates in bedrock targets everywhere in the upper Western Fan, in both SH and CC deposits, with no significant difference in the carbonate detections (density or composition) in these two units. We note a significant variability in Mg# of the carbonates along the traverse, with for example a lower Mg content in some SH deposits South of Belva Crater (Mg# possibly as low as 0.2-0.3), and higher Mg contents in both SH and CC deposits to the West of this crater (Mg# ~0.65-0.7).

The Marginal Carbonates: The Margin unit was identified from orbit as associated with one of the strongest carbonate signal in Jezero; Horgan et al. [19] hypothesized that at least part of these carbonates could be of lacustrine origin, with possibly very high astrobiological potential. With SuperCam, we were able to identify carbonates in the bedrock of this unit, which is composed of clastic deposits of uncertain origin [21, 22], at almost every stop of the rover. The carbonates appear Fe-Mg rich, with Mg# ranging between ~0.3 and ~0.7, comparably to other detections in Jezero crater, with a higher density of lower Mg# detections (in the

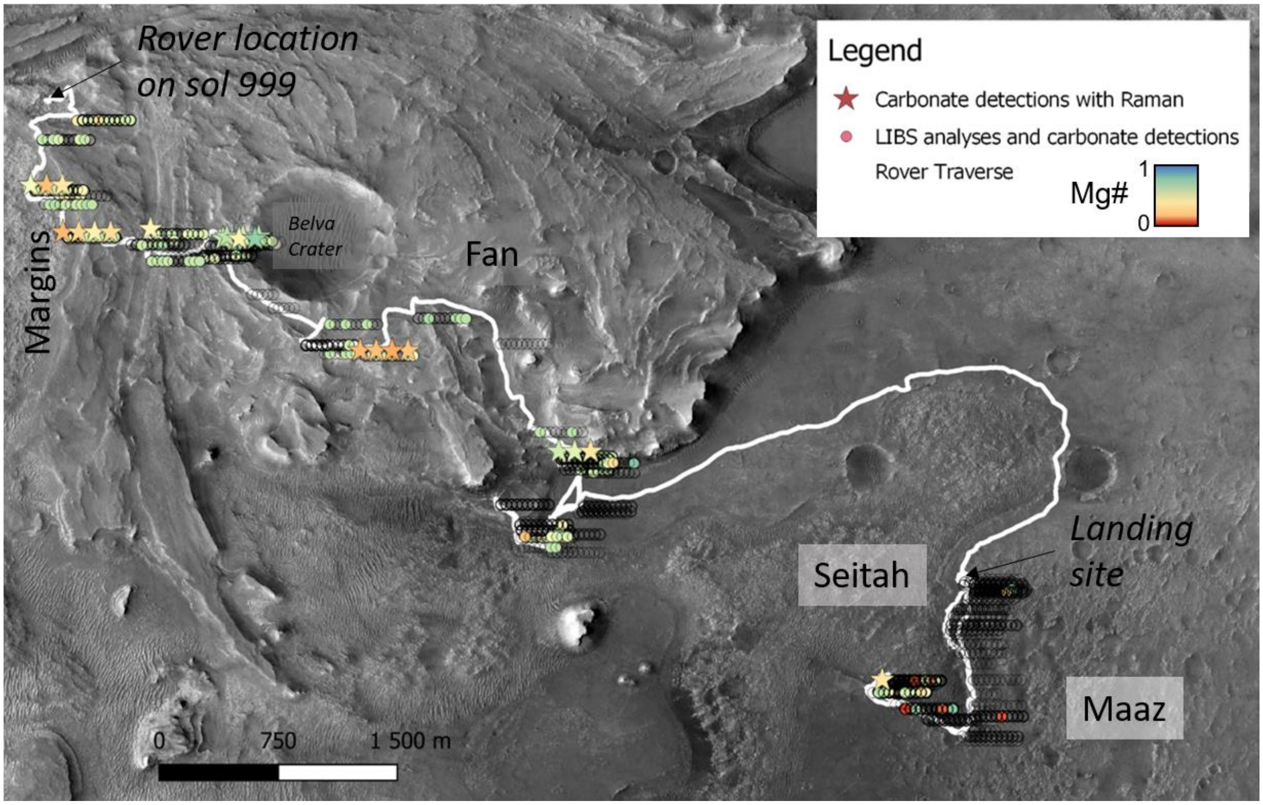

Figure 1 – Overview of carbonate detections in Jezero Crater with SuperCam LIBS and Raman. All LIBS analyses are represented with black circles (5 to 10 points per target), filled when carbonates were identified. The Raman detections of carbonates are represented with stars. The color code shows the Mg#.

0.3-0.4 range). At some locations in the Margins, the density of detections with LIBS appears higher than in the Fan.

Discussion & Perspectives:

Combining multi-technique detections: We are systematically comparing data with the different SuperCam techniques to take advantage of their different sensitivities to characterize the composition of the carbonates, the mineral phases they're mixed with and the textural information provided by RMI images.

Orbital vs in situ detections: Carbonates were detected with SuperCam in all units of the upper fan (fluvial and deltaic both), even though they had only been detected in the curvilinear deposits from orbit. This difference could possibly be due to different carbonate concentrations, compositions, mineral mixtures, grain size effects or dust cover; in any case, this may indicate that carbonates are present on the Martian surface in more places than currently assumed from orbital studies. Additional carbonates detections were also achieved in situ, in the coatings and carbonate vein in Màaz and the Fan Front, that were not visible from orbit. Moreover, in situ analyses enable a higher resolution characterization of carbonate composition, textures, mineral mixtures, etc., which are crucial to derive the formation processes of the carbonates.

Implications for the story of aqueous alteration at Jezero: The detections presented here trace a complex alteration history at Jezero; the SuperCam data, using the observed variability of carbonate composition, mineral mixtures and textures, will help us constrain the different episodes, and associated characteristics.

Nature of the Marginal Carbonates? Based on in situ observations, the carbonates observed in the Fan and Margins do not appear significantly different, as opposed to orbital studies. We're investigating the implications for the nature of the Marginal Carbonates (see also Wiens et al., this conference [22]).

References: [1] Ehlmann B., J.F. Mustard et al. (2008) *Nature geoscience;* [2] Mandon L. et al. (2020). [3] Goudge T. et al. (2017) [4] Tarnas J. et al. (2021). [5] Maurice S. et al. (2021) *SSR*. [6] Wiens R.C. et al. (2021) *SSR*. [7] Udry A. et al. (2022) *JGR*. [8] Liu Y. et al. (2022) *Science*. [9] Wiens R.C. et al. (2022) *Sci. Adv*. [10] Farley K.A. et al. (2020) *SSR*. [11] Stack K. et al. (sub.) [12] Caravaca G. et al., *this conf*. [13] Clavé E. et al. (2023) *JGR*. [14] Beck et al. (sub.); [15] Anderson R. et al. (2021) *SAB*. [16] Boulard et al. (2012) *Phys Chem Minerals*. [17] Beyssac O. et al. (2023) *LPSC*. [18] Nachon et al. (2023) LPSC. [19] Horgan et al. (2020). [20] Stack et al. (2020). [21] Horgan et al., *this conf*. [22] Wiens et al., *this conf*.