CARBONATE DETECTION WITH SUPERCAM IN THE JEZERO CRATER, MARS. E. Clavé[1] (elise.clave@u-bordeaux.fr), K. Benzerara[2], P. Beck[3], P.-Y. Meslin[4], O. Beyssac[2], O. Forni[4], A. Cousin[4], T. Bosak[5], B. Bousquet[1], K. Castro[6], S. Clegg[7], E. Cloutis[8], O. Gasnault[4], G. Lopez-Reyes[9], J.M. Madriaga[6], L. Mandon[10], S. Maurice[4], S. Le Mouélic[11], A. Ollila[7], C. Pilorget[12], P. Pinet[4], C. Quantin-Nataf[13], S. Schröder[14], R.C. Wiens[7] and the SuperCam Team. [1]CELIA, Bordeaux, [2]IMPMC, Paris, [3]IPAG, Grenoble, [4]IRAP, Toulouse, [5]MIT-EAPS, Cambridge, [6]University of the Basque Country, [7]LANL, Los Alamos, [8]University of Winnipeg, Canada, [9]Universidad de Valladolid, [10]LESIA, Meudon, [11]LPG, Nantes, [12]IAS, Orsay, [13]LGL-TPE, Lyon, [14]DLR-OS, Berlin

Introduction: The Perseverance rover (NASA) landed in the Jezero crater, Mars, in February 2021. This crater contains remnants of a paleolake [1] and shows globally the strongest carbonate signatures detected on Mars by orbital spectroscopy [2]. Carbonates on Mars are of high scientific interest for both planetary geology, climate sciences and astrobiology because they may inform us about the evolution of the Martian atmosphere and climate and its past CO_2 budget [3] as well as store textural, mineral and isotopic biosignatures [4,5]. As a consequence, carbonate detection and characterization by the Perseverance rover is particularly crucial in identifying high- priority targets for sample return.

The SuperCam instrument is part of the scientific payload of the rover and enables multi-technique characterization of the Martian surface with laser-induced breakdown spectroscopy (LIBS), time-resolved Raman and luminescence spectroscopy, visible and infrared reflectance spectroscopy (VISIR), a remote micro-imager (RMI) and a microphone [6-8].

We present an overview of carbonates detected between the landing and sol 300, in the Jezero crater, using the synergy of SuperCam investigation techniques.

Materials & Method

LIBS data: LIBS interrogates the chemical composition of the targets, and models can be trained to derive the quantitative content in some major elements [9]. Carbonate-rich targets show particularly low Si, Al, Na and K contents. However, other mineral phases share this characteristic (such as sulfates, phosphates, Fe-oxides and so on). The detection of carbon in LIBS data above the level from the contribution of atmospheric dioxide helps solve this degeneracy [10].

Raman data: The Perseverance rover carries the first extra-terrestrial Raman instruments [6,7,11]. Raman scattering spectroscopy is a very efficient technique for the detection of carbonate minerals in the laboratory, using the different vibrational modes of the carbonate ion. The spectral positions of these modes are correlated with the composition of the carbonates [12].

VISIR data: Carbonates have two main absorption bands in the near infrared wavelength range: at 2.3 μm and a 2.5 μm. The spectral position of these bands is correlated with the metallic cation associated with the carbonate ion [2].

Hardware temperature is known to affect SuperCam IR spectra taken on Mars, especially between 2.5 and 2.6 μm [13]. As a result, the carbonate identification by VISIR data is presently challenging because the 2.5-micron band of carbonates cannot be robustly detected. Improved calibration is in progress.

Results: Over the first 300 sols of the mission, SuperCam analyzed more than 200 geologic targets, using varying combinations of LIBS, VISIR and Raman spectroscopy [14,15]. Two main geologic units were sampled: first, the Maaz Formation corresponds to the unit orbitally mapped as Crater floor – fractured rough; secondly, the Seitah Formation in the Crater floor – fractured -1 unit, is characterized by a strong olivine signature from orbit [16]. Overall, Seitah is rich in olivine and Fe-Mg pyroxene, whereas the Maaz Formation is more felsic and Mg-poor [14,17].

Carbonates in the Seitah Formation: LIBS, VISIR and Raman analyses were all consistent with the presence of carbonates in some of the points investigated on the Garde abraded patch on sols 207-210. Carbonates were also detected in multiple targets (natural surfaces, abraded patches, core-holes and tailings) using LIBS and/or VISIR, all along the rover traverse in the Seitah Formation (Fig. 1). These carbonates belong to the siderite-magnesite solid solution, with Mg to (Mg+Fe) ratio between 40 and 75% and very low Ca.

Carbonates in the Maaz Formation: In contrast to Seitah, carbonates do not appear so widespread in the Maaz Formation. Shot-to-shot analyses of the LIBS spectra are ongoing to look for small amounts of carbonates; but averaged LIBS spectra indicate carbonates almost solely in the abraded patches, core-holes and/or tailings (Fig. 1). Carbonate is likely present in a target that was analyzed on sols 87-90. Definitive detection awaits accounting for possible interferences with the hydrogen content of the target.

The potential carbonates in the Maaz Formation are depleted in Mg and consistent with siderite. These trends are similar to the depletion of Mg in the Maaz Formation relative to the Seitah Formation.

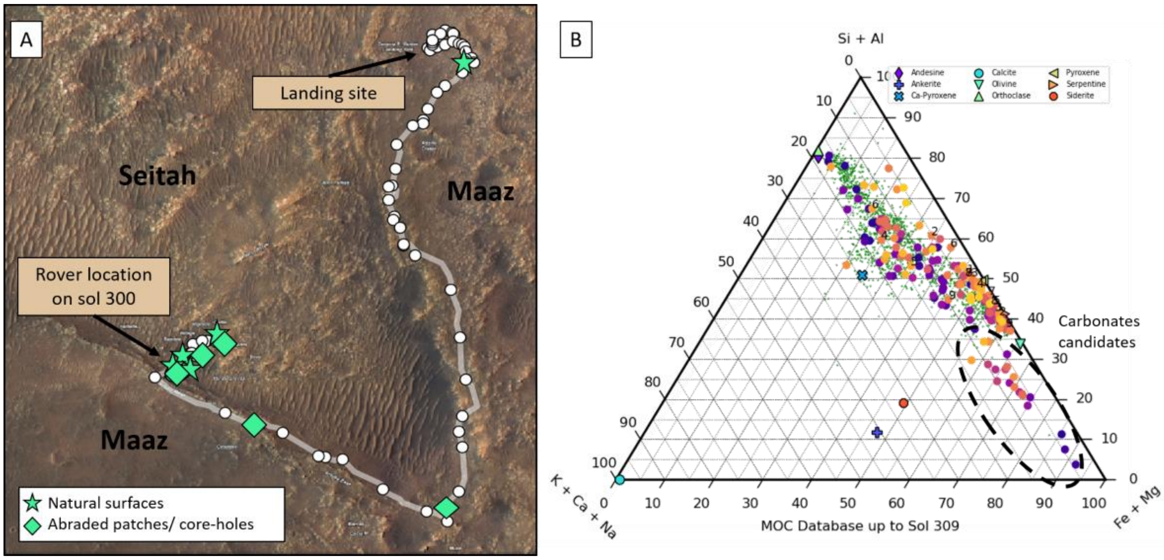

Figure 1 – Preliminary overview of the carbonate detection in the Jezero crater with SuperCam. A) Orbital view of the landing site with the rover traverse over the first 300 sols of the Mars2020 mission, and the location of our current list of carbonate candidates. B) Composition of the targets containing the carbonate candidates based on the Major Oxides Compositions [9]; note that the siderite and ankerite calibration targets shown on the plot contain 10-15% SiO_2.

Discussion and perspectives:

We detect multiple occurrences of carbonate mineral phases in the Jezero crater, though the work is still ongoing to finalize the list of detected carbonates and their characterization.

SuperCam's remote detections of carbonates in abraded patches are consistent with the results of proximity science by SHERLOC and PIXL [18]. The strength of SuperCam consists in its ability to analyze large number of targets along the rover traverse, and provide a broader view of the carbonate distribution in the Jezero crater. Additionally, the synergy of the SuperCam techniques enables non-ambiguous characterization of the carbonates. We find that Fe-Mg carbonates are ubiquitous in the olivine- and pyroxene-rich rocks of the Seitah formation, though in low quantities (probably < 5% at target scale) [13]. Comparatively, the scarce carbonates in the Maaz Formation are consistent with siderite. The detection of carbonates primarily in abraded patches and core-holes in the Maaz formation might indicate that the carbonates are mostly present in the bulk of the rocks, rather than on their surface.

The chemical composition of the carbonates detected in the Maaz Formation differs from those in the Seitah Formation and follows the variations in the Fe/Mg observed in the bulk rocks. This could be consistent with a scenario where the chemical composition of the fluids in which the carbonates form depends on the local chemistry of the rocks.

Further characterization of the distribution and composition of carbonates ion the Jezero crater may provide insight on their formation mechanisms. Currently, the carbonates are hypothesized as products of either the aqueous alteration of (ultra)mafic rocks or precipitation around the shores of the former lake. This study may also help constrain the alteration mechanisms and kinetics. Comparison between the rover and the orbital data may also help uncover the reasons why carbonates are rarely detected in the orbital data from Mars (little carbonate formation, even when the conditions were favorable? carbonates not preserved when conditions became more acidic? carbonates not directly present on the surface?). Finally, better constraining the carbon budget in the carbonate reservoir will be instrumental to better understanding the importance of carbonation in the past evolution of Martian atmospheric CO_2.

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