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New constraints on the “Marginal Carbonates” from in situ observations with SuperCam, Mars2020

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Introduction: Jezero Crater lies in one of the most extensive carbonate-rich regions on Mars [1, 2], and diverse carbonate-bearing units were detected from orbit within the crater [3-6]. In particular, a unit along the Western rim of the crater stands out with especially strong carbonate signatures in CRISM data. Several origins have been considered for these “Marginal Carbonates”, including a lacustrine beach-deposit, altered igneous or pyroclastic deposits, aeolian or fluvial-deltaic origins [4]. Since September 2023 (Martian day or “sol” 910), the Perseverance rover has been exploring this so-called Margin Unit (Fig. 1A) [7].

Method: We use data collected with the SuperCam instrument [8, 9] during the Margin Campaign (up to sol 1124), with three complementary spectroscopy techniques for chemical (laser-induced breakdown spectroscopy, LIBS) and mineralogical characterization (Raman and infrared reflectance spectroscopy, IRS) of rocks along the rover traverse. Additionally, the Remote Micro-Imager (RMI) provides high-resolution color images to contextualize the spectroscopic analyses.

In particular, we derive abundances for major elements (MOC) from LIBS [10], and identify specific minerals, in particular olivine and pyroxene, based on stoichiometric analyses [11]. Carbonates (above ~50 vol% [12]) can be identified based on a combination of MOC and carbon signal characterization [12, 13]. With Raman, the position of the carbonate mode can be used to derive the composition of Fe-Mg carbonates (Mg# defined as $Mg/(Fe+Mg)$) [14].

Results:

LIBS – The Margin Unit shows the highest concentration of both carbonate-bearing and high silica

points along the entire traverse (49% of carbonate detections and 73% of points with $\text{SiO}_2 > 65$ wt.% for 22% of LIBS analyses). Besides these, rocks in the Margin Unit are generally of mafic composition, including multiple detections of olivine and pyroxene (Fig. 1 C-F, [11]). Although all the carbonates are Ca-poor and Fe-Mg rich, their composition is variable. In particular, before sol 1027, carbonates covered a large range of composition (Mg# varying between ~ 0.3 and 0.8); since sol 1027, the Mg# of identified carbonate-bearing points are clustered in the 0.6 - 0.8 range (Fig. 1D, F). Since these compositional changes are correlated with changes in rock morphologies and textures [7, 15, 16], we defined two sub-units: the Eastern Margin (EM) before sol 1027 and the Western Margin (WM) afterwards (Fig. 1B).

IRS – With IRS, the Margin Unit is characterized by three main signatures: i) the $1.9 \mu\text{m}$ hydration band, comparable to what is observed in the vast majority of targets in Jezero Crater [17, 18]; ii) a $2.2 \mu\text{m}$ band, more frequent and deeper than in previous units and attributed to Si-OH based on the correlation with LIBS data; iii) absorption bands at 2.3 and $2.5 \mu\text{m}$ corresponding to carbonates, with a possible contribution of clays. Most spectra also show a positive slope between 1.3 and $1.8 \mu\text{m}$, attributed to Fe^{2+} in either olivine or carbonate. Additionally, a small band at $2.39 \mu\text{m}$ indicates the presence of Fe-phyllosilicates in some targets, but their precise characterization is complicated by the strong carbonate signatures.

Raman – For the first time in the mission, carbonates were detected not only in all three abraded patches (Fig. 1B) but also on six different targets with natural surfaces in the Western Margin. Some significant variability in Mg# is observed (median values: EM= ~ 0.45 ; WM= ~ 0.6).

With Raman, olivine was also detected in the first abrasion patch in the EM. No high-silica phase was detected with SuperCam Raman, which however is challenging due to an instrumental artifact.

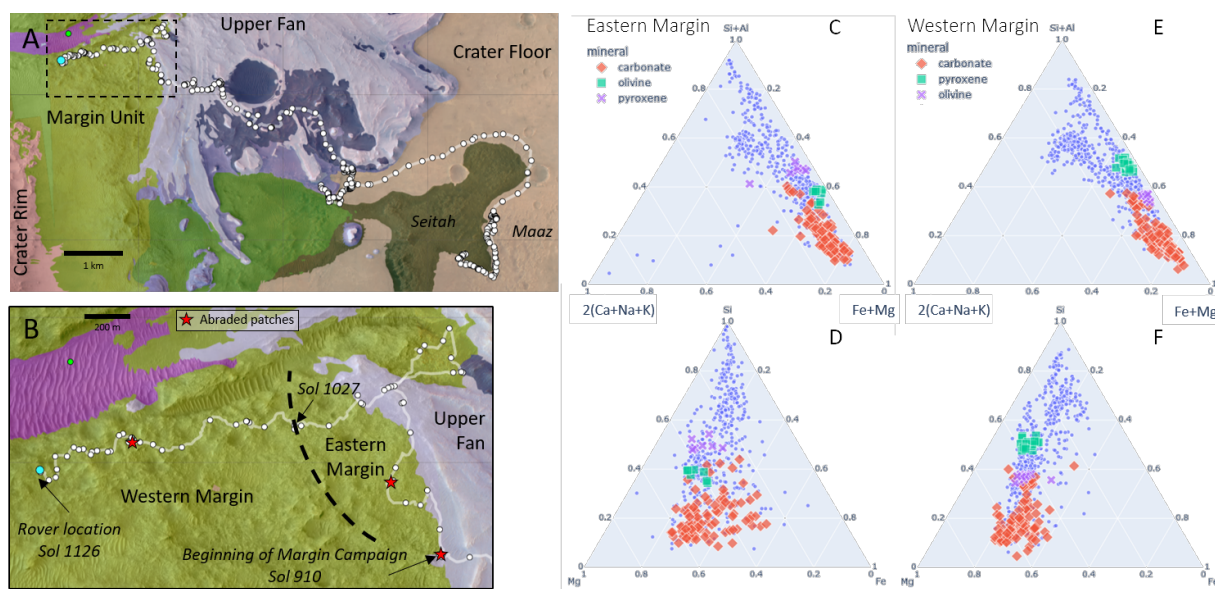


Figure 1 – Context of the Margin (A) and Eastern and Western Margins (B). Compared compositions (MOC) of EM (C-D) and WM (E-F), including minerals of interest.

Summary & Discussion: Several lines of evidence indicate that the Eastern and Western Margins may be distinct. Observations of layering and clastic textures show that the EM is likely of sedimentary origin. The WM lacks clear structure to conclude confidently [7, 15, 16].

The Margin Unit is uniquely enriched in both Fe-Mg carbonates and a silica-rich phase (LIBS, Raman and IRS). The silica is at least hydroxylated based on the IRS, but its hydration state is not well constrained. Additionally, points with mafic compositions in LIBS, including olivine and pyroxene grains, are also omnipresent in this unit. Beyond these general observations, we note some variability within the Margin Unit, and in particular between the Eastern and Western parts. Based on LIBS data, the WM presents a more restrained range of carbonate compositions, with only Mg-

rich carbonates, covering the same range of composition as the primary minerals identified in this sub-unit (Fig. 1F). Raman data confirm the higher Mg# in carbonates in the WM. In the EM, the range of carbonate composition is wider, and wider than the range of primary mineral compositions (Fig. 1D).

The combination of mafic minerals, high-silica points and carbonates is consistent with altered mafic/ ultramafic rocks, possibly analog to carbonated peridotite [e.g. 19, 20]. The SuperCam data do not enable to confidently conclude regarding the presence of serpentine or talc in these rocks, although some phyllosilicates are detected with IRS. Nonetheless, the match between the compositions of carbonates and primary minerals in the WM is consistent with in situ alteration of olivine-rich lithology with CO₂-rich fluids in a closed-system. However, the original process of emplacement of this mafic material is still poorly constrained. In the EM, the more diverse compositions – in particular of carbonates – and layering could indicate additional reworking of this altered-mafic material, possibly including Ca-enriched fluids.

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