IGNEOUS PROCESSES AT JEZERO CRATER AND COMPARISON TO OTHER MARTIAN IGNEOUS COMPOSITIONS.

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Introduction: The Mars 2020 *Perseverance* rover landed in Jezero crater on February 18th, 2021, and explored different units, including the crater floor, the delta, and the margin units, consisting of various igneous and sedimentary lithologies. By analyzing the compositions and textures of igneous rocks and minerals (detrital or not) in the different Jezero units, which possibly vary in age from early Amazonian to Noachian, we can better constrain the martian igneous history over an extended and critical time window. Here we focus on the SuperCam (SCAM) results of igneous rocks and detrital igneous minerals found at Jezero crater and compare them to the martian meteorites. All of the martian meteorites are igneous, or represent igneous processes, and they are currently our only samples that we possess from Mars. However, most of these rocks are all relatively young (<2.4 Ga) and none have any field context [1]. Mars 2020 is the first step of the Mars Science Return Campaign and has collected 24 samples so far. The complementary study of returned samples and meteorites will help constrain the evolution from the Noachian to the Amazonian of the martian interior.

SuperCam LIBS analyses: The SCAM instrument is a mast-based, remote science instrument that measures rock chemistry with Laser Induced Breakdown Spectroscopy (LIBS) [2]. Because the LIBS beam size varies from 170 to 350 µm depending on the distance of measurement (1.5–6.5 meters), we can analyze single minerals, which have a larger grain size than the LIBS beam. Pyroxene is recognized by: (4 (±0.2) total cations with 6 O; $0.85 < (Fe+Mg+Ca)/Si < 1.15$); $Al/Si < 0.13$; $Na/Si < 0.05$; $1.7 < Ti+Fe+Mg+Ca+Na+K < 2.21$; Totals ≥80 wt.%; $3.95 < \text{Total cations} < 4.15$). Olivine is identified with: (3 (±0.2) total cations with 4 O; $1.5<(Fe+Mg)/Si <12.0$); $Al/Si < 0.12$; $Na/Si < 0.05$; Totals ≥85 wt.%; $2.8<\text{Total cations}<3.2$).

The Crater floor is igneous: *Perseverance* first encountered the Máaz formation (Sols 1 to 201 and then from Sols 343 to 382) and the Séítah formation (Sols 201 to 342) in the crater floor unit. Using textural, mineral, and chemical SCAM analyses, it was evidenced that the Máaz formation represents different thick lava flows with possible pyroclastic layers [3, 4]. The Séítah formation represents an olivine-rich cumulate. Both formations are the only ones observed at Jezero with a confirmed igneous origin [5, 6], but it is not clear if they are petrogenetically linked [3].

Texture is a good indicator of igneous origin: The ophitic textures and basaltic mineralogy observed in the Máaz lithology are extremely common in martian meteorites, especially shergottites, the most common type of martian meteorites [1]. However, no recovered martian meteorites show vesicular textures like those found in the Máaz rocks. Séítah rocks have an interlocking or poikilitic cumulate texture, similar to the poikilitic shergottites and chassignites [3–6].

Séítah rocks are more primitive than the Máaz rocks: Máaz rocks resemble basaltic shergottites in regard to their CaO and Al_2O_3 contents, but they have lower MgO and Mg# when compared to most martian meteorites (Fig. 3): They are most similar to Fe-rich meteorites, such as the basaltic shergottite Los Angeles and the gabbroic shergottite Northwest Africa (NWA) 7320 [3]. Séítah rocks, however, have a higher MgO and lower alkali content and show compositions similar to olivine-phyric and poikilitic shergottites [3, 4].

The Máaz pyroxenes vary from augitic to Fs-rich compositions and resemble basaltic and gabbroic shergottite pyroxenes, especially the Fe-rich compositions (Fig. 1). However, these Fe-rich compositions are quite rare in meteorites [7]. One plagioclase grain was analyzed in the Content mb (resembling the Máaz fm) ($An_{28}Ab_{66}Or_6$), but no olivine was detected in any rocks of the Máaz fm.

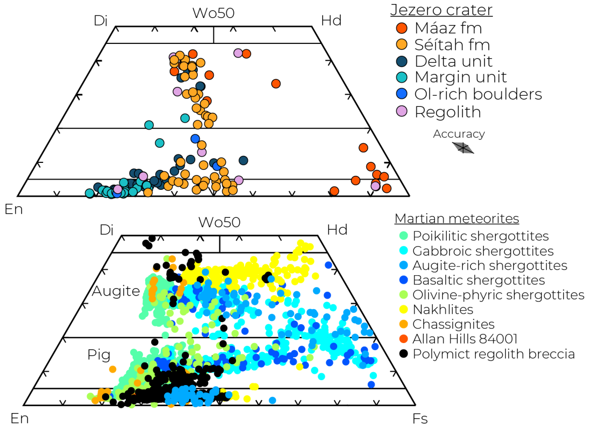

Figure 1. *Pyroxene single mineral composition in Jezero crater with martian meteorite compositions with references within [3].*

The Séítah pyroxenes vary in composition from orthopyroxene to augite and resemble the pyroxene trend of the least primitive poikilitic shergottites (Fig. 1). Séítah shows cumulate olivine with compositions varying from Fo$_{57}$ to Fo$_{73}$ (with Fo=100 modal MgO/(MgO+FeO), compositions common in olivine-bearing meteorites [1].

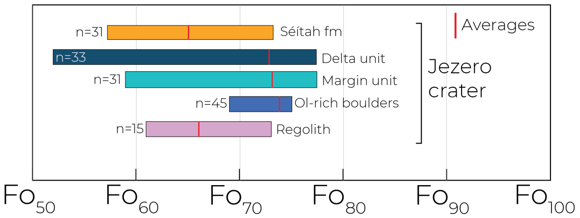

Figure 2. *Olivine single mineral forsterite composition in Jezero crater.*

Variable mineral compositions in the delta and margin units: The origin of rocks (igneous or sedimentary) from the delta unit (Sol 420–910) and the margin unit (Sol 910–1115) is not clear. However, single minerals, likely detrital, were detected in both. Delta pyroxenes overlap with the Séítah pyroxene and the Máaz high-Ca pyroxene compositions. These compositions are similar to the core of nakhlite meteorite pyroxenes (Fig. 1).

The delta pyroxene compositions (n = 38) range from orthopyroxene to augite and overlap all pyroxene compositions. The margin unit pyroxenes are primitive (high Mg), and overlap with the delta pyroxenes. The margin pyroxene and low-Ca delta pyroxenes overlap the pyroxene compositions found in the polymict regolith breccia NWA 7034 [8].

Thirty-one single olivines were found in the delta unit, and represent the largest range of compositions (from Fo$_{52}$ to Fo$_{78}$), including the most primitive olivines which were found in the crater (in AEGIS_0873A and AEGIS_0897 targets).

Boulders: Pyroxene and olivine-rich boulders [9-10] were identified throughout the rover traverse. LIBS did not detect single pyroxene within pyroxene-rich pyroxene, but infrared spectra show diagnostic pyroxene absorption. Pyroxenes and olivine compositions found in the olivine-rich boulders overlap compositions of margin mineral compositions, but are more primitive.

Discussion and summary: The Máaz and Séítah formations from the crater floor unit are both igneous, and are thick lava flows as well as olivine-rich cumulate rocks. Séítah shows more primitive compositions, and resembles olivine-bearing martian meteorites. Igneous minerals are found in all of the delta units explored by *Perseverance*, including pyroxenes and olivines. The delta pyroxene and olivine compositions span the compositions of Séítah and margin minerals. Overall, the margin pyroxenes are more primitive than all of the other minerals found in Jezero crater. The margin pyroxenes resemble pyroxene from Northwest Africa (NWA) 7034, a meteorite containing the oldest clasts (~4.5 Ga) in our martian meteorite collection. If detrital, the margin minerals could originate from the outside crater rim or similar lithologies that represent older, more primitive Noachian crust. The delta detrital pyroxenes and olivines could have originated from lithologies with Séítah-like compositions as well as possibly from the margin unit. The olivine-rich boulders could have also originated from a lithology resembling Séítah or some exhumed primitive lithology.

The investigation of the crater rim, our next step on the traverse, will further unravel the origin of igneous rocks and detrital minerals found in in the delta and the margin spanning a critical time in martian history.

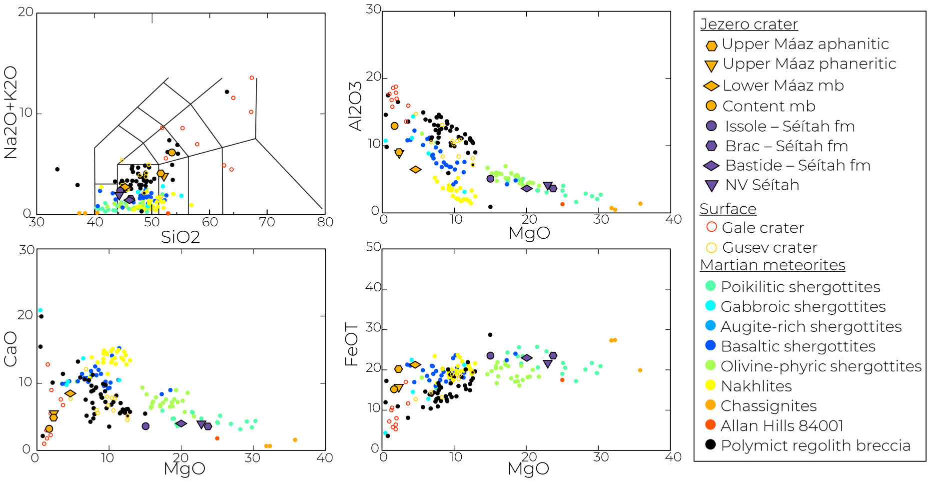

Figure 3. *Major element compositions for the Máaz fm and Séítah fm: (a) Na$_2$O + K$_2$O versus SiO$_2$, (b) Al$_2$O$_3$, (c) CaO, (d) FeO versus MgO [from 3-4].*

References: [1] Udry A., *et al.* (2020) *JGR Planets* e2020JE006523. [2] Maurice S., *et al.* (2021) *Space Sci Rev* **217**, 47. [3] Udry A., *et al.*, (2023) *JGR Planets* **128**, e2022JE007440 [4] Wiens R. C. *et al.*, (2022) *Sci. Adv.* **8**, eabo3399. [5] Beyssac O., *et al.*, (2023) *JGR Planets* **128**, e2022JE007638. [6] Liu Y., *et al.*, (2022) *Science* **377**, 1513–1519. [7] Udry A., et al. (2017) *GCA* **204**, 1–18. [8] Santos A. R., *et al.*, (2015) *GCA* **157**, 56–85. [9] Dehouck et al., (2024) LPS LV, Abstract #1967 [10] Beyssac O., et al. (2024) LPSC LV, Abstract #1493.