IGNEOUS COMPOSITIONS IN THE RIM OF JEZERO CRATER USING SUPERCAM DATA

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Introduction: The Mars 2020 *Perseverance* rover landed in Jezero crater on February 18th, 2021. After exploring the crater floor and some crater fill, including the delta and the margin unit, *Perseverance* entered the crater rim campaign on Sol 1252. We started to encounter outcrops of the crater rim on Sol 1293. The goal of this campaign is to better understand the geological diversity of the Jezero rim, and targeting the pre-Jezero Noachian basement. The investigation of the crater rim, including its igneous minerals and rocks, will allow to better constrain the igneous history of Mars during the Noachian and pre-Noachian. It will also help to unravel the origin of igneous rocks and detrital minerals found in the delta and the margin. In the first ~100 sols of the crater rim campaign, we have already encountered various textures, mineralogies, and bulk lithologies, including pyroxenites, gabbros, and silica (Si)-rich rocks, and were able to analyze single igneous minerals of pyroxene, olivine, and plagioclase. Here we present data from sol 1293 until sol 1357.

SuperCam LIBS analyses: In this study, we used SuperCam (SCAM) data [1]. The SCAM instrument is a remote science instrument that measures rock chemistry with Laser Induced Breakdown Spectroscopy (LIBS) [1]. The *Remote Microimager (*RMI) provides visible color images (using RGB filters) from 1 m to infinity. Because the LIBS beam size varies from 170 to 350 µm depending on the distance of analysis (1.5–6.5 m), we can measure single minerals that have a larger grain size than the LIBS beam. Here, we mostly focus on the mineralogy and compositions found using the LIBS technique. 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; 1.9<Si+Al<2.2. Totals≥80 wt.%; 3.95<Total cations<4.15). Olivine is identified with 3 (±0.2) total cations with 4 O; 1.5<(Fe+Mg)/Si<2.0; Al/Si<0.12; Na/Si<0.05; Totals≥85 wt.%; 2.8<Total cations<3.2). Plagioclase is identified by 20 (±0.2) total cations with 32 O; 15.5<Si+Ti+Al+Fe<16.5; 0.8<Al/(2Ca+Na)< 1.2; 0.21<(Ca+Na)/(Al+Si)<0.30; Totals>80 wt.%; 19<Total cations<21.5). The selection of a stoichiometric target is based upon two criteria: 1) the mean composition of the point analysis given by the MOC needs to fulfill the stoichiometric criteria; and 2) the composition of at least 12 shots within one point analysis needs also to fulfill the stoichiometric criteria.

Texture and mineralogy: Various textures have been observed from sol 1293 until sol 1357, including phaneritic coarse-grained textures, fined-grained texture, and pitted textures throughout the current campaign. Many pyroxene-bearing rocks, including pyroxenites, were encountered (see below).

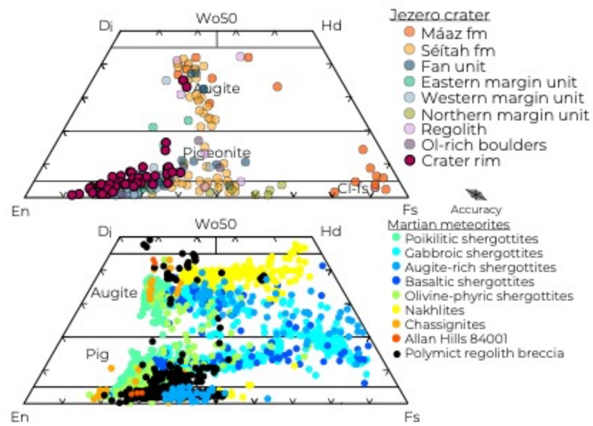

Fig. 1: Pyroxene quadrilateral with pyroxenes found throughout the Jezero traverse and crater rim in purple, compared to the martian meteorite pyroxene compositions [2].

Pyroxenes were found throughout the entire campaign and their presence was confirmed by Raman analyses. Most pyroxenes found in the crater rim are low-Ca pyroxenes with compositions varying from $Wo_1En_{87}Fs_{12}$ to $Wo_{16}En_{55}Fs_{29}$ (n=42). In addition, two single augites were also found in different rocks ($Wo_{33–35}En_{41}Fs_{24–26}$; Fig. 1).

Four stoichiometric plagioclase grains were found in three rocks in the crater rim: plagioclase-bearing rocks show different textures, including pitted and light-toned. These plagioclases show compositions varying within $An_{45–59}Ab_{39–51}Or_{2–6}$, similar to plagioclase compositions found in the Máaz formation in the crater floor.

Only four olivine grains were found since sol 1293, in La_Gloria and Pico_Macanas targets with compositions of $Fo_{74–76}$, compositions similar to the margin unit lithologies.

Various igneous compositions in the crater rim and comparison to samples:

Possible pyroxenites on the crater rim and comparison to Allan Hills 84001: Five rocks analyzed in the crater rim are likely pyroxenites (i.e., AEGIS_1294A, AEGIS_1294B, Cress_Falls, Gobblers Knob, and Ghost_Lake targets). All are floats, except the Ghost_Lake target. These rocks are coarse-grained and consist of euhedral and subangular crystals, as well as pink veins. These textures are similar to the onse observed on the hand sample of the orthopyroxenite meteorite Allan Hills (ALH) 84001. VISIR analyses also show the evidence of low-Ca pyroxenes. Note that Gobblers and Ghost_Lake targets show phyllosilicates in the VISIR and could represent altered clastic rocks, and thus might not be igneous.

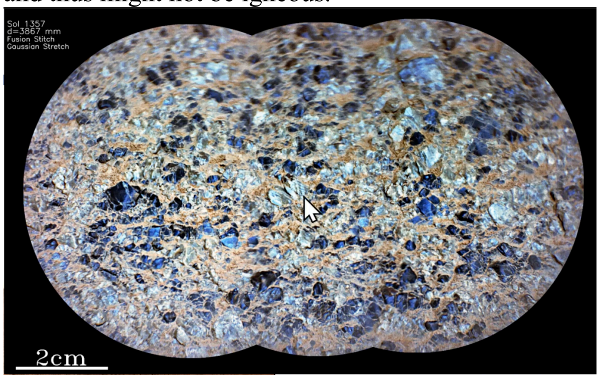

Fig. 2. Remote Microimager mosaic with Gaussian stretch of the Duran target (Sol 1357).

The pyroxenes in these rocks are all low-Ca pyroxenes (including orthopyroxene), with average compositions of $Wo_5En_{73}Fs_{22}$ (Fig. 1), varying from $Wo_1En_{87}Fs_{12}$ to $Wo_7En_{66}Fs_{24}$. The bulk rock Mg# (=molar 100*MgO/MgO+FeO) varies from 68 to 81 (average of 76), representing very primitive compositions.

Only two types of rocks are rich in pyroxenes in the martian meteorite collection: nakhlites and Allan Hills 84001. Nakhlites are not comparable to the crater rim pyroxenites, as nakhlites pyroxenes are all augites. Allan Hills 84001 bulk and pyroxene compositions are similar to the pyroxenite bulk compositions (average of LIBS MOC points of each target) and pyroxenes, although the crater rim pyroxene compositions are slightly more primitive than ALH 84001 (Mg# = 76 versus 72). Allan Hills 84001 is the oldest martian rock with a crystallization age of 4.1 Ga [3]. Pyroxenites with these compositions might be common in the pre-Noachian/Noachian martian crust and have formed from accumulation [4] and at low pressures, similar to the ALH 84001 pyroxenes (~1.5 kbar). This is consistent with the strongest signals of low-Ca pyroxenes that are focused in the ancient cratered terrains [5].

Gabbros in the crater rim. We have also found possible gabbros, containing both plagioclase and pyroxene, including the float targets AEGIS_1299A and AEGIS_1301A. These gabbros show a phaneritic texture with sometimes rounded dark grains and light-toned matrix. The pyroxene compositions in gabbros vary within $Wo_{7-17}En_{55-59}Fs_{29-34}$ and, plagioclase composition of $An_{59}Ab_{39}Or_2$ (in AEGIS_1301A point #3). Pyroxene compositions are less primitive than the pyroxenes in the pyroxenites. Preliminary results on the new Macaca and Duran targets (Sols 1357) suggest that these rocks are coarse-grained decomposed gabbros or possibly impact breccias (Fig. 2) [6;7]. The gabbro bulk compositions are similar to basaltic and gabbroic shergottites, but they are mostly similar to the mafic clasts found in the Northwest Africa (NWA) 7034 regolith breccia meteorite, which contain clasts with crystallization ages of ~4.5 Ga [8].

Olivine was found after Sol 1335 in the crater rim The lack of olivine from sols 1292 to ~1337 could be due to different magmatic compositions represented during those sols compared to the rest of the crater rim. It is also possible that the rocks that formed between Sols 1292 and 1337 crystallized at higher oxygen fugacities conditions, similar to the conditions in which NWA 7034 formed [9].

Silica-rich light-toned rocks: Four rocks with high-silica content were found at sols 1311–1317, with an average of SiO_2 of 75 wt%. Raman analyses on the Emmons_Glacier target showed strong evidence of crystallized quartz [10,11]. But we did not find the clear indication of presence of plagioclase. Numerous light-toned floats with phaneritic texture were found at sols 1319–1322, however, these rocks are not evolved with SiO_2 content of 46–52 and Mg# of 46–66. They possibly contain feldspar.

Comparison to minerals from previously analyzed units in the Jezero crater: No pyroxenites with these compositions found in the rim was previously found in the Jezero crater. Magmatic systems including pyroxenites could possibly be common in Noachian terrains around the crater. Although the low-Ca pyroxene compositions were found in the margin unit and in the fan units (a unit where pyroxenes will all likely be detrital; Fig. 1), the pyroxenes in the margin unit are less primitive than the one found in the rims (Mg# = 68 versus 74). It is possible that the protolith of some of margin unit rocks, if sedimentary, could originate from the crater rim. Olivine mineral compositions and the bulk compositions of olivine-bearing rocks are similar to those found in the margin unit [12].

The sampling of the Noachian igneous crater rim rocks would help better constrain magmatism and evolution of the primary crust, especially that meteorites of this age are very rare.

References: [1] Maurice S., *et al.* (2021) *Space Sci Rev.,* 217, 47. [2] Udry A., *et al.* (2020) *JGR Planets* e2020JE006523. [3] Lapen et al. (2010) *Science 328*, 347. [4] Righter (2024) *Metorit. & Planet. Sci.,* 1–29. [5] Poulet et al. (2009) *Icarus*, *201*, 84–101. [6] Bedford et al. (2025) 56th LPSC, Houston, TX. [7] Horgan et al. (2025) 56th LPSC, Houston, TX. [8] Bouvier et al. (2018) *Nature, 558.* [9] McCubbin et al. (2016) *Metorit. & Planet. Sci., 51*, 2036-2060 [10] Beck et al. (2025) 56th LPSC, Houston, TX. [11] Manrique et al. (2025). 56th LPSC, Houston, TX. [12] Udry et al. (2024) X Mars conference, Abstract #3052.