

INVESTIGATING THE ORIGIN AND ALTERATION HISTORY OF THE MARGIN UNIT IN JEZERO CRATER, MARS, WITH THE SUPERCAM INSTRUMENT. C. C. Bedford¹, E. Ravanis², R. C. Wiens¹, E. Clavé³, O. Forni⁴, J. Madariaga⁵, J. Aramendia⁵, S. A. Connell¹, A. Jones⁶, B. H. N. Horgan¹, K. Williford⁷, C. Royer⁸, B. Garczynski⁹, E. Moreland¹⁰, P. Beck¹¹, L. Kah¹², L. Mandon¹¹, A. Cousin⁴, Wolf¹³, A. Brown¹⁴, E. Dehouck¹⁵, O. Beyssac¹⁶, ¹Purdue University, USA (cbedford@purdue.edu), ²University of Hawai'i at Mānoa, USA, ³DLR, Germany, ⁴IRAP, France, ⁵University of the Basque Country, Spain, ⁶Imperial College, UK, ⁷Blue Marble Space Institute of Science, USA, ⁸LATMOS, France, ⁹Western Washington University, USA, ¹⁰Rice University, USA, ¹¹IPAG, France, ¹²University of Tennessee, USA, ¹³LANL, USA, ¹⁴Plancius Research, USA, ¹⁵University of Lyon, France, ¹⁶IMPMC, France.

Introduction: The Margin Unit was identified from orbit as an olivine and carbonate-bearing region situated along the inner western margin of the Jezero crater rim, suggesting the existence of a potentially habitable ancient lake system [1]. Several origin hypotheses exist, including in-situ carbonation of an olivine-rich igneous deposit (pyroclastic or cumulate) [e.g. 2]. The Perseverance rover investigated several locations of the Margin Unit (East, West, North, and Rim) between sols 910-1282. We aim to constrain the origin and geological history of the Margin Unit using a combined textural and chemical analysis.

Methods: SuperCam Remote Micro-Imager (RMI) images were used to broadly classify the rocks based on textures and identify alteration features. ImageJ was used to analyze grains coarser than very fine sand [3] in select RMI images across each textural type.

Quantified elemental data from the Laser Induced Breakdown Spectrometer (LIBS) is used for targets between 2 and 6.5 m from the rover mast [4,5]. We have applied a hierarchical agglomerative cluster analysis on the quantified LIBS data to constrain the relative proportions of mineral groups across each textural type and alteration feature. Cluster memberships were tested using silhouette scores and data with low scores were placed into a "Mixed" cluster category.

Results: Seven clusters were identified:

1. Olivine-rich; Characterized by moderate SiO₂ (44.1 ± 4.6 wt%) and high MgO (31.5 ± 5.2 wt%) and FeO_T (24.0 ± 3.4 wt%), stoichiometric calculations estimate that this group has 57.5 ± 3.9 wt% olivine with minor pyroxene, iron-oxides, and feldspar.
2. Pyroxene-rich; Characterized by elevated SiO₂ (63.9 ± 4.2 wt%) with high MgO (25.1 ± 5.0 wt%) and FeO_T (16.4 ± 6.4 wt%), this cluster is stoichiometrically dominated by pyroxene (57.8 ± 5.5 wt%) with minor olivine, silica and feldspar.
3. Silica-rich; Defined as having high SiO₂ (up to 82.1 wt%) and low abundances of other major elements, this likely relates to silica cement identified by PIXL [6].

4. Carbonate-rich; Defined as having low SiO₂ abundances (<30 wt%) with high MgO (30.4 ± 9.6 wt%) and FeO_T (31.1 ± 8.3 wt%), this likely relates to Mg/Fe carbonates mixed with mafic material [7]
5. High FeO_T; This cluster is defined by elevated abundances of FeO_T (up to 82.0 wt%).
6. Dust/Coatings. Defined as having relatively high abundances of Al₂O₃ (8.5 ± 2.0 wt%) and TiO₂ (0.7 ± 0.2 wt%). Compositionally like Mars dust [8], this correlates to the presence of coatings.
7. Sulfate-rich; Has high abundances of CaO (up to 47.5 wt%), and low abundances of all other major elements. S and F lines are high, identified with LIBS [9].

The main textural groups include Tabular Granular, Rubbly, Rounded Granular, Matrix-supported, and Pebbly Sandstone. Tabular Granular rocks consist of a grain-supported texture with minimal cement/interstitial material and tabular, dark and light green euhedral grains. Interlocking grains are identified in some targets. This texture is dominated by the Olivine-rich cluster (88%) with minor contributions of Pyroxene-rich (3%) and Carbonate-rich (9%). The Tabular Granular texture is largely seen on the Rim Margin, extending up the crater rim with an average grain size of coarse sand (0.97 ± 0.65 mm).

Rubbly textures are only identified in 4 targets in the East and West Margin. These targets are present in recessive, poorly consolidated layers with composite pebble to granule-sized grains up to 7.52 mm in size that themselves have a Tabular Granular texture. Cluster results also have a large proportion of the Olivine-rich (76%) composition but with a slightly greater abundance of Carbonate-rich (14%) and Silica-rich (5%) compared to the Tabular Granular texture.

Rounded Granular textures are abundant in the East Margin Unit, containing a similar grain-supported texture to the Tabular Granular group but with mostly rounded grains. Grain size distributions show a bimodal distribution with an average of 0.42 ± 0.24 mm (medium sand). Laminations and layering can be present in Rounded Granular rocks and cluster results show that

these are 48% Olivine-rich with a greater proportion of Carbonate-rich (32%) and Silica-rich points (11%).

Matrix-supported textures are abundant in the West Margin and contain dark grey/red, fine-grained/crystalline interstitial material between grains. The grain size of this matrix is too fine to measure in RMI images, but data from the PIXL and WATSON instruments show that this relates to silica and carbonate cement [6]. Dark and light green grains are commonly fractured and rimmed with a tan material. This textural class has the highest proportion of Carbonate-rich (37%) and Silica-rich (16%) clusters of any textural type, with Olivine-rich (36%) and Pyroxene-rich (9%) clusters with a mean grain size 0.43 ± 0.25 mm.

The Pebbly-sandstone texture is only identified above the contact with Bright Angel with some uncertainty on how it relates to the overall North Margin Unit. This texture contains a granular texture with polymict, angular to round, granule to pebble-sized clasts of a variety of colors, some of which SuperCam analyzed and are shown to contain silica [10] or high FeO_T . Cluster analysis of this textural type shows that it contains a high proportion of the high FeO_T (41%) cluster with Silica-rich (22%) and Carbonate-rich (27%) detections and few Mafic cluster detections (<11%).

The main alteration feature in the East and West Margin are ridges that are either similar in appearance to the bedrock or express a fin-like morphology. Cluster analysis shows that these ridges are mostly Carbonate-rich (68%) with detrital Olivine-rich material (24%).

Discussion: We hypothesize that the Tabular Granular texture of the Rim Margin Unit is representative of a crystalline, olivine-rich igneous rock, like the Séítah formation. These Tabular Granular rocks are exposed at a higher elevation than the hypothesized Jezero paleolake levels [11] and are unlikely to have interacted with the lake itself. Several coarsely crystalline rocks have been identified in the crater rim suggesting that it is extensively eroded, exposing the parautochthonous target rocks [12]. The erosion of the crater rim would have therefore provided a large sediment load into the Jezero crater paleolake.

The composite grains of the Rubbly textural group are indicative of reworking of the olivine-rich crater rim rocks. Their granule to pebble grain size is indicative of higher energy deposition such as by a river; however, the recessive nature of this rock type makes the environment of deposition difficult to assess. The polymict pebbly sandstone of the North Margin is indicative of a debris flow deposit from a diverse source, potentially suggesting that different lithologies are present in the crater rim north of where we have explored with Perseverance.

The Rounded Granular texture of the East Margin is possible to achieve in both sedimentary and igneous cumulate rocks and is not itself indicative of formation. However, the East Margin has several features in outcrop such as candidate cross-bedding, erosion surfaces, and low angle-inclined East and West dipping strata, which were also detected in the subsurface by RIMFAX, consistent with a lakeshore environment of deposition [13]. Grain sizes measured in the East Margin cover the expected range of grain sizes observed in nearshore lake environments on the Earth [e.g., 14] and are finer than those of the Tabular Granular source on the crater rim. A decreased grain size and increase in roundness of East Margin grains may come from physical weathering during transportation. Furthermore, the relatively high abundance of secondary alteration minerals indicates that the initial deposit has a higher porosity which is more likely in a clastic deposit.

The Matrix-supported texture of the West Margin suggests that it has experienced extensive alteration overprint. However, the grain size distribution matches that for the East Margin, indicating a similar environment of deposition. Reflectors dipping ESE identified with RIMFAX [13] suggests that the West Margin is older than the East Margin and may have experienced longer exposure to aqueous fluids, altering it more than what is seen in the East.

Conclusion: Our analysis suggests that the East and West Margin Unit are representative of a clastic, lakeshore deposit that became altered with exposure to the Jezero crater paleolake. Sediments were likely derived from the olivine-rich material of the crater rim that is itself deeply eroded. After the East and West Margin Unit were deposited and lithified, the deposit was fractured, and carbonate remobilized to form the fracture-associated ridges showing that fluids interacted with the Margin Unit post-deposition.

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