

MINERALOGY, MORPHOLOGY, AND GEOCHRONOLOGICAL SIGNIFICANCE OF THE MÁÁZ FORMATION AND THE JEZERO CRATER FLOOR. B. Horgan¹, M. Rice², B. Garczynski¹, J. Johnson³, K. Stack-Morgan⁴, A. Vaughan⁵, B. Wogsland⁶, J.F. Bell III⁷, L. Crumpler⁸, B. Ehlmann⁴, S. Holm-Alwmark⁹, K. Farley⁴, S. Fagents¹⁰, J.I. Núñez³, G. Paar¹¹, E. Ravanis¹⁰, D. Shuster¹², J.T. Simon¹³, A. Udry¹⁴, M. Wadhwa⁷, R. Wiens¹⁵. ¹Purdue Univ. (briony@purdue.edu), ²Western Wash. Univ., ³JHU/APL, ⁴Caltech/JPL, ⁵USGS/Astrogeology, ⁶Univ. of Tenn. - Knoxville, ⁷Arizona State Univ., ⁸New Mexico MNHS, ⁹Univ. of Copenhagen/Lund Univ., ¹⁰Univ. of Hawaii, ¹¹Joanneum Res., ¹²Univ. of Cal. - Berkeley, ¹³NASA/JSC, ¹⁴Univ. of Nevada - Las Vegas, ¹⁵Los Alamos Natl. Lab.

Introduction: The Perseverance rover is currently exploring the floor of Jezero crater and collecting samples for eventual Mars Sample Return (MSR). The rover landed in Feb. 2021 on a dark unit that covers much of the crater floor, mapped from orbit as the “Crater Floor - Fractured Rough” unit (CFFR) [1]. CFFR (Fig. 1) exhibits rough surface textures within lobate margins [2], as well as pyroxene spectral signatures that are distinct from olivine-dominated spectra of the Séítah formation [3]. In situ, CFFR is represented by the Mááz formation [4]. Perseverance has collected 1 sample pair from this unit, and will likely collect another in early 2022 [5]. If these samples are igneous, geochronology of returned samples has the potential to provide constraints on the absolute timing and duration of major events in Jezero through stratigraphic relationships, as well as on Mars more generally through calibration of the crater chronology [6-10]. However, from orbit, this unit has been variously hypothesized to be volcanic, fluvio-lacustrine, or aeolian in origin, and to have formed before, after, or interfingered with fluvial activity in Jezero [1-3,7-10]. Here we use morphology and mineralogy from Mastcam-Z multispectral images and orbital data to investigate the origin of the CFFR/Mááz fm. We find that the Mááz fm. is most consistent with a series of igneous units emplaced at different times, and that geochronology of returned samples may allow us to bracket the timing and duration of fluvial activity in Jezero crater.

Methods: Mastcam-Z is a pair of cameras on the rover mast with RGB Bayer and 12 narrowband filters between 445-1035 nm [11]. We apply spectral parameters [12] to detect Fe-bearing minerals. We compare our results to CRISM orbital hyperspectral images (0.35-2.6 μm ; ~ 18 m/px) and HiRISE images (25 cm/px).

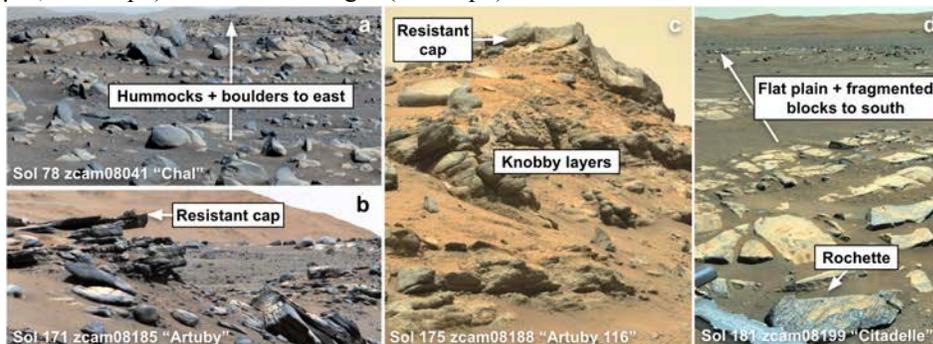


Figure 2: CFFR/Mááz formation morphotypes in Jezero crater imaged by Mastcam-Z (Z110, L0 enhanced color). (a) Chal member boulders and hummocks east of landing site, (b) Rochette member resistant layered cap, (c) Artuby member knobby layers, and (d) smooth plains and fragmented blocks to the south of Artuby ridge.

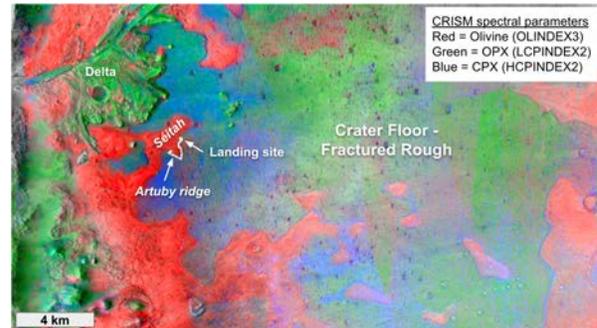


Figure 1: Jezero CRISM mafic parameter map [2] over CTX, rover traverse in white. In CFFR, CPX dominates at lobate margins and near delta, while OPX dominates in the interior.

Morphology: The Mááz fm. exhibits four morphologies across five possible members [4]. The stratigraphically highest is the *Chal* member (Fig 2a), a hummocky surface producing large round boulders with no visible layers, best exposed east of the landing site and corresponding to the rough textures of CFFR. The *Artuby* member (Fig. 2b) exhibits 1-10 cm layers with variable friability, where resistant thick layers express as knobby protrusions. This unit is exposed within Artuby ridge but has no clear orbital expression. Artuby ridge is capped by the *Rochette* member (Fig. 2b-c), a resistant blocky unit with variable thickness, planar jointing/layering, pitting, and (rarely) flow structures and large pit chains that are consistent with a lava flow. This unit also forms a resistant cap on the western margin of the Mááz fm. On the plains south of Artuby, the Rochette mbr. appears to form a smooth and fragmented surface with significant regolith, and was sampled at Rochette (Fig. 2d). Low relief “paver” surfaces with meter-scale polygonal fractures are present at multiple elevations (*Nataani/Roubion* members).

Multispectral properties: CFFR targets show spectral signatures that are due to a combination of dust [13], coatings [14], regolith [15], and rock surfaces [12]. Dark CFFR rock surfaces most commonly exhibit broad absorption bands centered near 880-980 nm that are consistent with variable pyroxene compositions (*Fig. 3a*). Chal mbr. boulders, most pavers, and Artuby mbr. layers are dominated by shorter wavelength band centers (880-900 nm) consistent with orthopyroxene (OPX), whereas Rochette mbr. cap rocks and fine sands have bands shifted to longer wavelengths (900-930 nm) consistent with Fe-rich OPX or Fe-rich clinopyroxene (CPX). These groups are distinct from coarse sands and Séítah rocks, both of which exhibit strong blue slopes from ≤ 677 -1035 nm consistent with olivine [12,15].

These different pyroxene spectral signatures are confirmed within CFFR abrasion patches, where Mastcam-Z is able to resolve individual sub-mm mineral grains (*Fig. 3c*). The Bellegarde abrasion on Rochette shows abundant brown grains with strong bands centered at ~ 890 nm consistent with Mg-rich OPX, as well as dark gray grains with strong bands centered at ~ 930 nm consistent with Fe-rich CPX, but the natural surface of the rock is dominated by these latter signatures (*Fig. 3b*). In contrast, the Guillaumes abrasion patch on Roubion shows similar OPX grains, but little CPX is resolved by Mastcam-Z, consistent with the OPX-dominated natural surfaces of the Roubion/Artuby members.

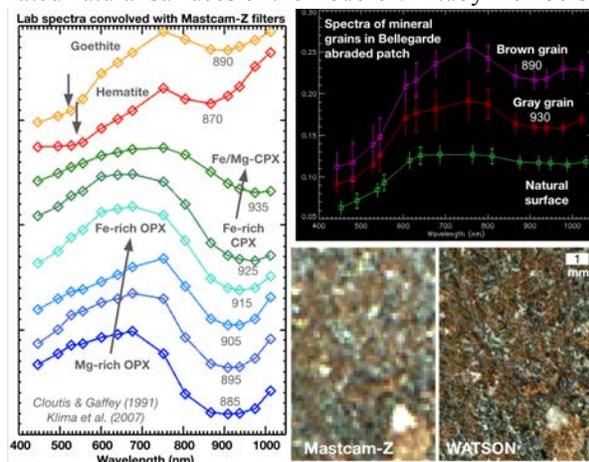


Figure 3: (a) Lab spectra convolved with Mastcam-Z filters and labeled with modeled apparent band centers. (b) Spectra of individual grains in Bellegarde abrasion patch, (c) as viewed by Mastcam-Z and WATSON.

Comparison to CRISM: CRISM spectra at the landing site are dominated by olivine (red in *Fig. 1*), which we attribute to mantling by coarse sands derived from Séítah. Outside of this area, CFFR shows variable weak signatures due to pyroxene. Rough hummocks consistent with the Chal mbr. show weak OPX signatures (green in *Fig. 1*), while the fragmented blocks and regolith south of and similar to the Rochette mbr. show

CPX signatures (blue in *Fig. 1*), both consistent with Mastcam-Z results. Extending these results across Jezero, we find that Chal-like OPX-dominated boulder-forming hummocks make up the majority of CFFR, but that the lobate margins tend to exhibit CPX signatures similar to Rochette. This suggests that Rochette-like cap rocks are responsible for the lobate appearance of the unit. In addition, the surface of CFFR near the delta and delta remnants is noticeably devoid of the boulder-forming hummocks, and is instead dominated by the fragmented blocks similar to Rochette and CPX or mixed pyroxene signatures (*Fig. 1*).

Discussion: We hypothesize that the lobate margins of CFFR are composed of Rochette mbr. cap rocks, which are petrologically and texturally consistent with a lava flow [14-15]. However, the rough texture and weak OPX signatures of much of the interior of CFFR is more similar to Chal mbr. boulders. While the petrology of this unit is not yet known, it displays no clear sedimentary features and may be another, younger lava flow.

These CFFR units show different relationships with the delta and delta remnants, as the Rochette-like smooth and fragmented cap rock with CPX-dominated spectra is the only unit present near the delta, while Chal-like boulder-forming hummocks with OPX-dominated spectra are widespread to the east of the delta remnants (*Fig. 1*). While the Rochette mbr. likely underlies and thus predates the delta [10], the relationship between the Chal mbr. and the delta is less clear. Given their resistant character, it seems unlikely that the Chal boulders were preferentially eroded back from the delta. Instead, we hypothesize that the Chal mbr. was never present near the modern delta front, possibly because it was emplaced after fluvial activity when the delta was more extensive. If this is true, samples from Rochette and a future Chal mbr. boulder may allow us to bracket the timing and duration of fluvial activity in Jezero. The Chal mbr. also appears to best preserve the crater population on the crater floor [6,19] and thus a crystallization age of this unit determined by sample return geochronology may ultimately be used for calibrating the Mars crater chronology functions.

References: [1] Stack *et al.* (2020) *SSR* 216:127 [2] Sun & Stack (2020) *USGS SIM* 3464 [3] Horgan *et al.* (2020) *Icarus* 339, 113526 [4] Sun & Hand *et al.*, this vol. [5] Simon *et al.* this vol. [6] Calef *et al.*, this vol. [7] Shahrzad *et al.* (2019) *GRL* 46, 2408 [8] Werner (2019) *M&PS* 54, 1182 [9] Goudge *et al.* (2015) *JGR* 120, 775 [10] Holm-Alwmark *et al.* (2021) *JGR* 125, e2021JE00-6840. [11] Bell *et al.* (2021) *SSR* 217:24 [12] Rice *et al.*, this vol. [13] Johnson *et al.*, this vol. [14] Garczynski *et al.*, this vol. [15] Cardarelli *et al.*, this vol. [16] Nuñez *et al.*, this vol. [17] Schmidt *et al.*, this vol. [18] Udry *et al.*, this vol. [19] Quantin *et al.* (2021) *LPSC* #2034.