PROVENANCE OF SEDIMENTS IN THE JEZERO DELTA FROM PERSEVERANCE ROVER AND ORBITAL OBSERVATIONS. B. Horgan[1], L. Duflot[2], B. Garczynski[1], S. Gupta[3], J. R. Johnson[4], B. Kathir[2], C. C. Million[5], J. Núñez[4], M. Rice[2], M. St. Clair[5], A. Udry[6], A. Vaughan[7], S. Alwmark[8], E. DeHouck[9], J. Hurowitz[10], J. I Simon[11], B. Weiss[12]. [1]Purdue Univ. (briony@pudue.edu), [2]Western Washington Univ., [3]Imperial College London, [4]JHU/APL, [5]Million Concepts, [6]Univ. Nevada - Las Vegas, [7]USGS/Astrogeology, [8]Univ. of Copenhagen, [9]Univ. Lyon, [10]Stony Brook Univ., [11]NASA/Johnson Space Center, [13]Massachussets Institute of Technology.

Introduction: The Perseverance rover is exploring an ancient delta in Jezero crater to search for potential biosignatures and collect samples for return to Earth by Mars Sample Return [1]. Understanding the source (provenance) of the sediments and how it changes in the delta stratigraphy will be important for developing hypotheses for the origin and transport history of potential biosignatures, will help constrain the evolution of the delta and watershed through time, and will enable us to identify the origin of detrital grains from outside Jezero in sandstones and conglomerate samples collected by Perseverance. In this study, we constrain the provenance of delta sediments by studying the distribution of primary mafic minerals detected using spectroscopy at rover and orbital scales.

Methods: We use Mastcam-Z and SuperCam to detect mafic mineral spectral signatures in outcrop, validate these detections using SuperCam chemistry, and link to regional source units using CRISM orbital spectra. Fe-minerals exhibit broad bands between 0.4-1.3 and 1.8-2.3 μm. Mastcam-Z collects multispectral images in 14 filters between 0.41-1.01 nm. SuperCam collects point reflectance spectra between 0.4-0.85 μm and 1.3-2.6 μm [2]. We use stoichiometry [3,4] to identify single igneous minerals in SuperCam LIBS data between sols 420-644. In total we find 10 pyroxenes, two olivines, and no clear feldspars.

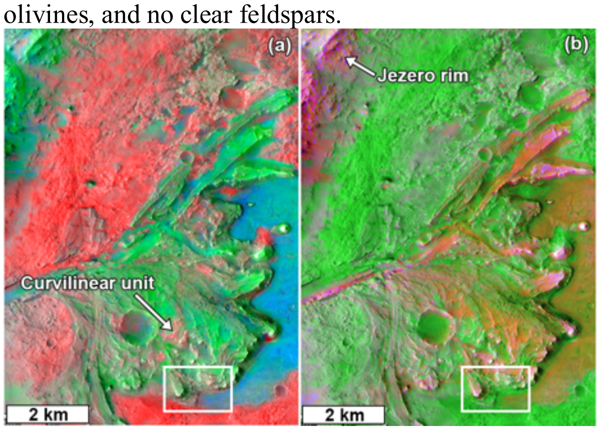

Figure 1: CRISM parameter maps of the delta, box indicates Fig 3 area. (a) RGB combo, BD1300/LCPINDEX2/HCPINDEX2. Red is olivine or Fe-carbonate, green is low-Ca pyroxene or spinel, blue is high-Ca pyroxene. (b) RGB combo, LCPINDEX2/1 μm band depth/2:1 μm band area ratio. Magenta indicates new spinel detections, orange is low-Ca pyroxene, green is other mafic minerals.

Provenance from orbit: In CRISM maps, the delta is dominated by two spectral classes: (1) low-Ca pyroxene (LCP) variably mixed with Fe/Mg-smectite, primarily associated with blocky channel deposits at the top of the delta (green, ***Fig. 1a***), and (2) olivine with carbonate and other alteration minerals, associated with curvilinear units interpreted as fluvial point bars (red, ***Fig 1a***) [5,6]. These spectral classes are similar to the two largest source units in the watershed: (1) the LCP/smectite-dominated Noachian basement (also in the Jezero rim) [7], and (2) the regional olivine/carbonate plains unit [8]. This suggests both units contribute to the delta, but vary due to hydrodynamic sorting or changes in the watershed over time [5,6].

New detection - spinel in the rim and delta: We report the first orbital detection of spinel-like signatures on Mars, based on a strong blue spectral slope between 1.2-2.0 μm, similar to lunar spinel spectra [9]. Spinel is common throughout the Jezero rim, variably mixed with LCP and smectites, and could have formed either due to excavation of deep crustal plutons or high-T impact hydrothermal alteration. Spinel is also detected on the delta (magenta, ***Fig 1b***), and appears to be concentrated in resistant sandstone outcrops along the top of the delta front. In situ detection of similar SCAM IR spectral signatures associated with Al/Si-rich float rocks in Jezero support our spinel interpretation [10].

Stratigraphic trends in mineralogy: Many delta outcrops are spectrally dominated by alteration (oxides, sulfates, phyllosilicates) [2]. However, most coarser-grained (pebbly/sandy) outcrops exhibit strong primary mafic mineral absorption bands (***Fig. 2***). These tend to be resistant, cliff forming caprocks topping many delta outcrops (***Fig. 3***). Near the base of the delta, the Alagnak caprock exhibits olivine-like blue spectral slopes >750 nm, as does the Knob Mountain outcrop in Hawksbill Gap. Stratigraphically higher outcrops like Franklin Cliffs exhibit some olivine-like signatures but more commonly exhibit spectra consistent with LCP or an olivine/LCP mixture. In some cases, these different signatures can be linked to rounded boulders in outcrop, suggesting diverse conglomerate deposits. Boulders originating at the Whale Mountain scarp also show both signatures, but rarely mixedin the same block. Whale Mountain sandstones shows uniquely strong red

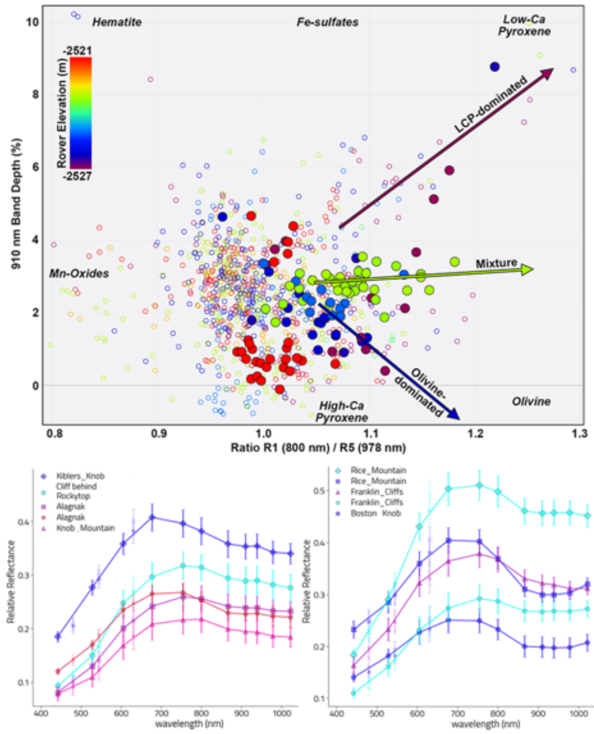

Figure 2: *(top) Spectral parameters indicating Fe-mineralogy applied to Mastcam-Z spectra of rocks, float, and pebbles at the delta (open circles, sols 400-635). Red points are largely from Whale Mountain, indicating a different composition. Large circles highlight coarse-grained caprock, color indicates rover elevation. (left) Mastcam-Z spectra of caprocks with olivine-like and (right) LCP-like signatures.*

spectral slopes between 600-750 nm, potentially consistent with the spinel that dominates from orbit at this location.

Outlier – Enchanted Lake (EL): EL contains the stratigraphically lowest exposed delta sediments [11]. The area exhibits SCAM IR signatures and SCAM/PIXL chemistries that are distinct from Hawksbill Gap [2,12]. While we do not observe mafic mineral spectral signatures in EL, LIBS suggests that this area may be unique in primary mineralogy as well, as half of the pyroxenes identified were in this area. This could suggest a distinct source for EL, such as the Noachian basement.

Outlier – Boston Knob member (BK): This member is composed of resistant meter-scale massive blocks and blocky lenses exhibiting variable but exceptionally strong olivine and LCP spectral signatures, embedded in a pebbly matrix. This unit is unlike sedimentary deposits observed elsewhere in the delta, and while a fluvial origin cannot be ruled out, we hypothesize that this member could have formed as impact ejecta from a nearby large crater, which excavated both the Noachian basement and the regional olivine/carbonate unit.

Implications for provenance: Based on orbital and in situ data, the Jezero delta and northern fan appear to exhibit a similar mineralogical stratigraphy of Noachian basement-derived sediments (best preserved in the northern part of the delta and in the northern fan), overlain by olivine-dominated sediments from the regional unit (Hawksbill Gap), overlain by delta-top deposits that appear to be a mixture of both units (Franklin Cliffs/Whale Mountain).

Implications for regional geology: We observe changing primary minerals through the Jezero delta stratigraphy in similar facies (sandstones/conglomerate), and across both the delta and northern fan. This suggests that factors in addition to hydrodynamic sorting affected the mineralogy, such as evolution of the watershed over time [5]. Olivine-rich Hawksbill Gap sediments were sourced from and thus emplaced after deposition of the regional olivine-carbonate unit, but while the watershed was still mantled in this material. In contrast, the delta top incorporates more of the underlying basement, suggesting that it was emplaced after impacts/erosion exposed more of this material. This supports the hypothesis that the delta top is a younger deposit that preserved underlying older sediments [1].

References: [1] Mangold & Gupta et al. (2021) *Science 374 711-717.* [2] Dehouck et al. this volume. [3] Udry et al. (2022) *JGR* e2022JE007440. [4] Beyssac et al. this volume. [5] Goudge et al. (2015) *JGR 120* 775-808. [6] Horgan et al. (2020) *Icarus 339* 113526. [7] Scheller et al. (2020) *JGR* e2019JE006190. [8] Mandon et al. (2020) *Icarus 336* 113436. [9] Pieters et al. (2014) *Am Min 99* 1893–1910. [10] Cloutis et al., this volume. [11] Tebolt et al. this volume. [12] Hurowitz et al this volume.

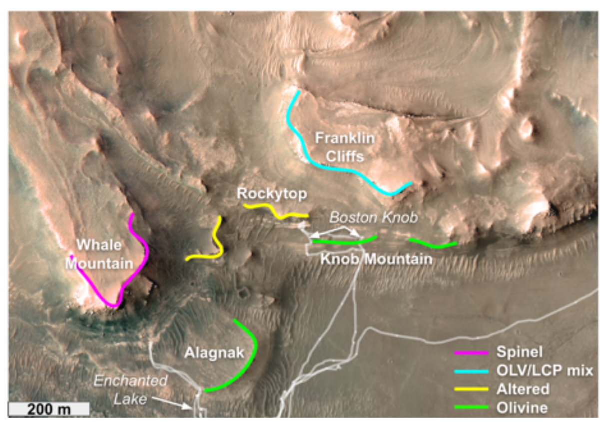

Figure 3: *Context for stratigraphic trends in mafic mineral spectral signatures in delta resistant caprocks, sandstone/conglomerate facies. White line: rover traverse sols 405-654.*