INVESTIGATING THE ORIGIN OF BOULDERS IN THE JEZERO DELTA USING MULTISPECTRAL OBSERVATIONS OF FLOAT ROCKS.

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Introduction: During the NASA Mars 2020 Perseverance rover's exploration of the lower Jezero delta, it has documented bedrock and float rocks (not attached to outcrop) with varying lithologies, morphologies, and spectral properties. The float rocks could be derived from mass wasting of local rock units or detrital blocks from more distant units deposited by floods, glacial activity, or impacts. Thus, the diversity of float rocks, and their relationship to adjacent bedrock, can give insights into the provenance of the delta sediments and their post-depositional erosion. Examining float rocks can also help reconstruct the local paleoenvironment and constrain the overall depositional history of the delta.

In this study, we aim to answer three key questions: (1) What are the compositions and morphologies of float rocks found in the delta vicinity? (2) How are they distributed across the lower delta, and how do they relate to the in-place delta stratigraphy? (3) Ultimately, what can the float rocks tell us about the provenance of delta sediments and the evolution of the Jezero fluvio-deltaic system?

Here, we present initial results from a survey of float rocks in Mastcam-Z multispectral observations of the lower Jezero delta. We find three distinct float morphologies (conglomerates, layered, and massive) and describe their corresponding spectral properties, mafic compositions, and distribution within the Cape Nukshak and Hawksbill Gap areas of the delta.

Methods: Mastcam-Z is a stereoscopic, zoom-enabled, multispectral imager that can acquire true color images with red, green, and blue (RGB) color filters, and visible to near-infrared images with 11 narrowband science filters between 400 and 1100 nm [1]. Key absorption bands in the reflectance spectrum can help constrain the mineralogy of rock targets [2].

We complied a Mastcam-Z database of multispectral observations taken on sols 415-628 during the Delta Campaign of Perseverance's traverse. We filtered the database to only include spectra of float rocks. We avoided spectra from dusty and/or coated surfaces to more accurately represent the mineralogy of the float rocks.

Using radiometric calibration targets on the rover, Mastcam-Z data were converted into units of relative reflectance (R*) [3]. Various products were then generated to highlight spectral variability in a scene, such as true and false color images and decorrelation stretch products. [4]. Regions of interest (ROIs) were manually selected, and R* values across pixels were averaged to derive reflectance spectra. To extract a spectrum with minimal noise that best captures the geologic diversity in each scene, we chose ROIs on homogeneous surfaces without specular reflections or shadows [5]. We modified the spectral parameters of Rice et al. (2022) [5] to best evaluate the compositional diversity of the float rock population.

Results: *Morphology.* We find that most float rocks can be categorized morphologically into three distinct categories: conglomerates, layered, and massive (Fig. 1). Conglomerate float rocks can be best described as coarse-grained and poorly sorted with pebble to cobble sized clasts. Layered float rocks are fine to medium grained, well sorted, and have weak or thin to thick laminations. Massive float rocks are sub angular to rounded and vary in size from cobbles to boulders and larger.

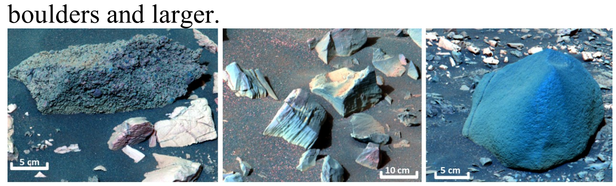

Figure 1. Morphologies of float rocks in Mastcam-Z enhanced color. From left to right: conglomerate (sol 464, zcam03380), layered (sol 425, zcam03357), and massive (sol 607, zcam03470).

Spectroscopy. Previous studies have identified eight major Mastcam-Z spectral classes of rocks on the Jezero crater floor [5]: Dusty, Hematite-like, Coated, Low-Ca Pyroxene-like, Olivine-like, Weathered Olivine-like, Fe-rich Pyroxene-like, and Dark Oxide-like [5]. These classes are distinguished by absorptions near 528 nm (Fe-oxides), 866 nm (hematite), 908 nm (low-Ca pyx), peak reflectance positions near 600 nm (Fe-rich pyx) and broad, negative NIR slopes (olivine). A parameter space of the 978 nm / 1022 nm ratio vs. 800 nm / 978 nm ratio (e.g., Fig. 2) characterizes the broad NIR profile and separates spectra consistent with dust and/or hydration (upper left) from Olivine-like spectra (upper right), Low-Ca Pyroxene-like spectra (lower right), and Hematite-like spectra (lower left) [5].

All float rocks are plotted in this parameter space in Fig. 2. Conglomerates are clustered in the middle of the plot, indicating relatively flat NIR profiles. Layered float rocks are clustered towards the top left of the parameter space, and some have 1022 nm features possibly consistent with hydration. Massive float rocks occupy regions of the parameter space more consistent with low-Ca pyroxenes and olivine. The other float rocks plotted in Fig. 2 (green dots) represent targets for which morphology cannot be resolved (e.g., pebbles or distant rocks). We note that some spectral variation captured in this parameter space may be due to differences in texture, dust cover, illumination conditions and viewing geometries, and other factors [6].

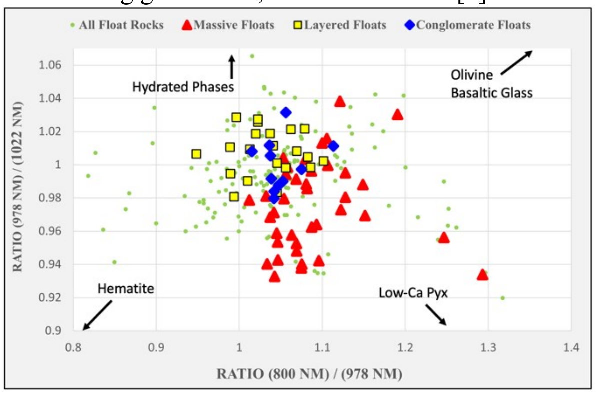

Figure 2. Mastcam-Z spectra of all float rocks plotted as 978 nm / 1022 nm ratio vs. 800 nm / 978 nm ratio. Mineralogic interpretations for different quadrants of this parameter space are indicated [5].

Stratigraphy. Different morphologies of float rocks appear to correlate with respective stratigraphic members of the lower Jezero delta as observed in Mastcam-Z multispectral data (Fig. 3). Conglomerates are found only in the Hogwallow Flats and Hughes River Gap members of Hawksbill Gap. Layered float rocks are mainly present in the Lower Rockytop and Hughes River Gap members of Hawksbill Gap, and the Yori Pass and Amalik-Kaguyak members of Cape Nukshak. Massive float rocks are ubiquitous throughout Cape Nukshak, but at Hawksbill Gap they mostly occur below the Devil's Tanyard member.

Discussion: Both conglomerate and layered float rock spectra do not have strong mafic iron signatures, and their spectra are controlled by varying amounts of Fe-oxides, consistent with the in-place delta stratigraphy [e.g., 8]. These float rocks have most likely been eroded locally from adjacent and/or overlying delta strata and are comprised of reworked sediment that has undergone varying degrees of diagenesis [e.g., 9].

Massive float rocks may have multiple compositional populations: those with low-Ca Pyroxene-dominated spectra, those more consistent with weathered olivine, and those without clear mafic signatures. Compared to the other rocks at the delta front, massive float rocks have the weakest Fe-oxide signatures and may represent the least altered mafic materials encountered. Massive float rocks encountered at lower Hawksbill Gap may have eroded from the Boston Knob member, which is spectrally similar. Others likely derive from boulder conglomerates at the delta top [e.g., 10], and thus may represent fragments of catchment outcrops that have undergone minimal alteration in transit. Ongoing work will compare massive float rock spectra to orbital observations of the upstream bedrock mineralogy [11], which can constrain the provenance of the float rocks. We will also survey additional float rock classes, such as light-toned cobbles, seen in Navcam and Mastcam mosaics.

To date, no float rocks have been observed with spectra indicative of iron meteorites. However, some massive float rock spectra could be consistent with impact-derived glasses (Fig. 2, upper right), so an ejecta hypothesis for all rocks cannot be ruled out.

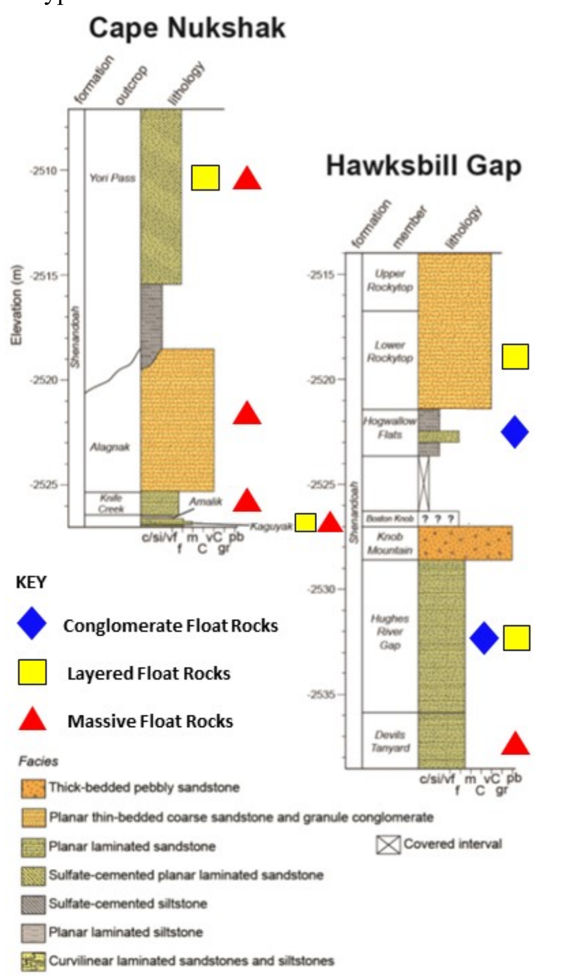

Figure 3. Stratigraphic columns of the Cape Nukshak and Hawksbill Gap areas of the lower delta [7], with occurrences of Mastcam-Z multispectral observations of float rocks indicated.

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References: [1] Bell J. F. et al. (2021) *Space Sci. Rev. 217,* 24. [2] Clark R. N. et al. (1999) *JGR, 95,* 12653. [3] Kinch K. M. et al. (2020) *Space Sci. Rev. 216,* 141. [4] Million C. et al. (2022) *LPSC,* Abstract #2533. [5] Rice M. S. (2022) *JGR, 127*. [6] Bell J. F. et al. (2022) *Science Advances, 8,* eabo4856. [7] Stack K. M. et al. (2023) *LPSC*, this issue. [8] Núñez J. I. et al. (2023) *LPSC*, this issue. [9] Broz A. P. et al. (2023) *LPSC*, this issue. [10] Mangold N. et al. (2023) *LPSC*, this issue. [11] Horgan B. et al. (2023) *LPSC*, this issue.