Regolith at Jezero crater, Mars: spectral diversity, textures, and implications for provenance. E.L. Cardarelli[1], A. Vaughan[2], M.E. Minitti[3], L. Beegle[1], M. Rice[4], J.R. Johnson[5], B. Horgan[6], A. Cousin[7], L.C. Kah[8], E.M. Hausrath[9], and S. Siljeström[10]. [1]Jet Propulsion Laboratory, California Institute of Technology, CA (emily.cardarelli@jpl.nasa.gov). [2]Arizona State University, Tempe, AZ; [3]Framework, Silver Spring, MD; [4]Western Washington University, Bellingham, WA; [5]Johns Hopkins University Applied Physics Laboratory, Laurel, MD; [6]Purdue University, West Lafayette, IN; [8]University of Tennessee; [9]UNLV, Las Vegas, NV; [10]RISE Research Institutes of Sweden, Stockholm, Sweden.

Introduction: The Perseverance rover successfully landed in Jezero crater, Mars in February 2021 at the Octavia E. Butler landing site and began its mission to explore and sample an ancient crater lake basin, seeking signs of ancient microbial life. After rover commissioning activities (~100 sols), Perseverance began the Crater Floor Campaign to explore and sample the crater floor units of Jezero. Here, we present a multi-instrument investigation of the regolith (i.e. unconsolidated sediments ranging in grain size and rock fragments) encountered during the campaign in the Máaz and Séítah geologic units [1]. Coordinated observations on regolith illuminate the primary properties of the rocks found in Jezero crater and may provide insight into provenance. Cross-scale characterization within these units enables investigation into the regolith chemistry and mineralogy as well as into the mechanisms of transport and weathering, which is informative for sample cache selection.

Methods: For this study, we determined regolith grain size, distribution, and texture using images from Mastcam-Z [2], SuperCam RMI [3], and the WATSON imaging subsystem of SHERLOC [4]. Texture characterization and grain size measurements made with Mastcam-Z were limited to images acquired at the highest zoom setting (110 mm focal length) to maximize resolving power (e.g., resolving features down to ~0.5 mm at 2 m working distance) on regolith grains and clasts. Measurements made in RMI observations were limited to images acquired from ~2-4 m from the target, resolving features down to 0.16-0.32 mm [3]. Measurements with WATSON were made in images acquired from 4-25 cm working distance, yielding pixel scales between ~22-100 μm/pixel.

Additional compositional information was assessed with SuperCam spectroscopy techniques (VISIR, LIBS) [3] and Mastcam-Z multispectral imaging [2]. Mastcam-Z multispectral observations were made using the instrument's 14 narrow band filters ranging from 442 to 1022 nm distributed across the pair of stereoscopic cameras atop the mast. Multispectral surface observations are accompanied by a Mastcam-Z calibration target observation enabling the conversion from radiance to reflectance for the unique time of sol and viewing conditions the in which the observations were acquired [5]. Spectra are extracted from sunlit surfaces to avoid shadowing effects, and are analyzed in a spectral database software developed for Mastcam-Z called 'multidex' to investigate spectral trends and characteristics [6].

Grain characteristics and texture: Regolith observed in the Crater Floor Campaign can be grouped in three major classes: coarse, dark sand grains; fine, redder grains; and pebble-to-cobble fragments of rocks breaking down (Fig. 1).

Coarse, dark sand grains are gray, sub-rounded, exhibit a small range of grain sizes (1.3-1.7 mm), and are found both within the Máaz and Séítah formations. They occur on top of bedrock slabs, collect around the base of bedrock slabs and isolated rock targets, and armor bedforms. Their distribution indicates they have been historically mobile. The size of the grains overlaps with gray grains found in situ in bedrock of the Bastide member [1] of the Séítah formation, which range from 1-1.5 mm in size. Preliminary observations suggest the grains found in the Máaz formation decrease in size with distance from Séítah.

The finer regolith endmember is distributed on and around bedrock in the Máaz and Séítah formations, intermixed with and underlying the other two regolith endmembers, and also comprises bedforms. As Mastcam-Z is limited to resolving objects coarser than ~0.5 mm (medium sand, Wentworth grain scale), grain size measurements of this endmember presented here are limited to WATSON images. Preliminary observations indicate this endmember has 100-350 μm grains (very fine to medium sand) with a range of grain colors (gray, red, black), and rounded to sub-rounded shapes (where resolved).

The coarsest regolith endmember is an immobile, indurated, poorly sorted mix of angular to sub-angular fragments from ~2-10 mm (granules to medium pebbles). This component represents the undisturbed surface not covered in eolian bedforms. It is found around bedrock slabs and isolated rocks targets, and resembles these rock targets in color and surface texture.

Mineralogy and implications for provenance: Mastcam-Z multispectral observations support the division of regolith observations into two broad classes (Fig. 2). Coarse, gray sand grains are bluer in color with a peak reflectance that occurs at the 678 nm band. They also have negative NIR slopes consistent with a broad ~1000 nm absorption. The 1000 nm absorption, when combined with a peak reflectance at 678 nm is consistent with the presence of olivine. The fine fraction is red in color, with peak reflectance at 754 nm

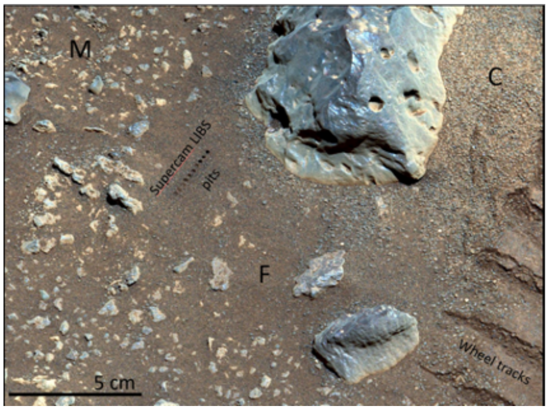

Fig. 1: Examples of the coarse gray grains (C), fine (F) and mixed (M) regolith endmembers observed in the Jezero crater floor units. Wheel tracks and SuperCam LIBS laser spots are visible in the martian soil frame, ZLF_0067_0672896411_239FDR_N0032208ZCAM08027_110085J01 imaged by Mastcam-Z.

and a broad 908 nm absorption. This endmember is consistent with pyroxene or a secondary ferric oxide bearing phase, which could be contributed by airfall dust. The coarsest regolith component is a mixture of the fine grained regolith spectral class and pebbles, spectrally similar to local rocks.

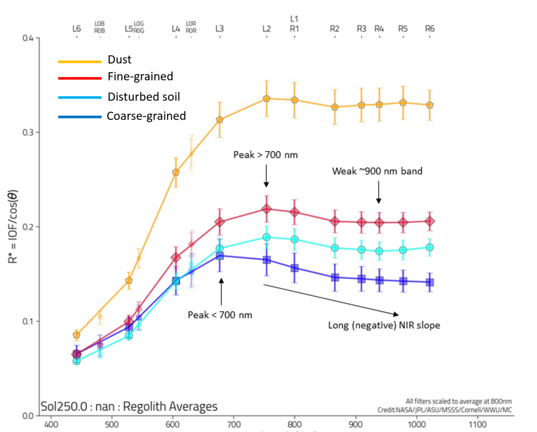

Fig. 2: Representative Mastcam-Z spectra from regolith endmembers and dust in the Máaz formation.

The Mastcam-Z spectral characteristics of the dark gray sand grains are consistent with olivine. SuperCam VISIR observations (1.3-2.6 μm) of these grains also indicate the presence of olivine, as do the Mg-rich materials suggested by the SuperCam LIBS chemical analyses of these grains [7, 8]. Olivine-bearing rocks are not observed in the Máaz formation, but are observed in the Séítah formation. This mineralogic link and similarity in grain size between in-situ Séítah bedrock grains and the gray sand grains suggest they are sourced from Séítah.

The fine-grained component is consistent with pyroxene and ferric iron bands, with spectral similarity to rocks from the Máaz formation and the Chal and Artuby members [9,10] as well as the disturbed soils and regolith crusts (Fig. 2). There is a wide-distribution of this fine-grained component, though it may be locally derived. In comparison, the coarse, poorly sorted regolith endmember has a mixed spectral signature that is a combination of the fine-grained component and rock fragments. The fragments are similar to flat local rocks with a light-colored coating suggesting they are comminution products that are the result of in-situ weathering of rocks and dust accumulation [11]. SuperCam VISIR spectra suggest that the rock surfaces in the Máaz formation exhibit strong hydration features in the 1.9 μm absorption region, possibly due to alteration processes and supporting the aforementioned; whereas the regolith fractions exhibit variable but overall weaker absorptions [7].

SHERLOC WATSON specific textural observations coupled with SuperCam LIBS analyses support grain size distribution gradients and chemical compositional transitions over rock-regolith boundaries where indurated rock surfaces are adjacent to regolith [12]. Local grain-scale based examinations suggest chemical weathering could be related to a variably distributed coating or rind on mafic rock targets. However, differences in the regolith spectra across the traverse indicate that local mixing may also be an important factor in regolith formation within these units.

Overall, cross-scale documentation of regolith encountered over Perseverance's traverse provides a robust and holistic roadmap of primary properties in each geologic unit and insights into the provenance of multiple regolith types -- elucidating the ultimate regolith candidates for sampling and return.

Acknowledgments: We thank the Mars 2020 engineering, operations, and science teams for collectively making the observations within possible.

References: [1] Sun V.Z., et al. (2022) LPSC 53. [2] Bell, J.F. III, et al. (2020) *SSR, 216*. [3] Wiens, R.C., et al. (2020) *SSR, 216*. [4] Bharita, R., et al. (2020) *SSR, 216*. [5] Kinch, K.M. et al. (2020) *SSR, 216*. [6] Million, C. et al. (2022) LPSC 53. [7] Mandon, L., et al. (2022) LPSC 53. [8] Cousin, A., et al., (2022) LPSC 53, [9] Rice, M. et al. (2022) LPSC 53. [10] Horgan, B.N. et al. (2022) LPSC 53. [11] Beck, P., et al. (2022) LPSC 53. [12] Cardarelli, E.L., et al. (2021) AGU.