COARSE-GRAINED OLIVINE-RICH REGOLITH AT JEZERO CRATER, MARS: NATURE, SOURCE AND TRANSPORT.

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Introduction: Since its landing in February 2021 at Jezero crater (Mars), the NASA Perseverance rover has explored two formations of the crater floor, Máaz and Séítah, as well as the front part of the western delta in the crater. Along the traverse, the SuperCam instrument onboard Perseverance has analyzed rocks as well as regolith, from very fine to coarse grained material. In this study, we focus specifically on the coarse grained fraction of the regolith analyzed by SuperCam since the landing. A companion study by [1] provides a complete overview of the SuperCam data for all regolith targets. The objective of this study is to characterize the physical properties (grain size, density) of coarse grains and test if they can be transported by present winds at Jezero [2]. Then, a second objective is to assess the source for this coarse grained regolith. Finally, we compare these in situ observations with observations from orbit to better understand the distribution of olivine-rich regolith on the crater floor.

Methodology: The SuperCam instrument analyzes remotely (up to 7 m) the elemental chemistry of regolith targets by LIBS, and their mineralogy by VISIR and Raman spectroscopy, as well as it provides high-resolution context images with a Remote Micro Imager (RMI). Associated with LIBS, a microphone records the laser-induced acoustic signal, which provides constrains on the hardness for rock targets, but also on the granulometry for regolith targets [3]. SuperCam is described by [4,5]. LIBS provides a quantitative estimate of major elements present in the fraction of rock ablated by the laser within a ~350 μm wide spot [6], as well as qualitative information on many light and/or minor elements such as H or C. Some regolith grains are larger than the LIBS spot size, making possible single crystal analysis and stoichiometric analysis [7-8]. VISIR spectroscopy has a much larger analytical footprint (in the mm range) and it generally samples several grains.

What is coarse-grained regolith? Figure 1 provides an image of coarse-grained regolith. It is representative of observations along the traverse on the crater floor and the base of the delta. Grain size varies from 0.5 mm to a few mm, yet it is clustered in the range of 1-2 mm [9]. Most grains are rounded and roughly isotropic in shape. Some rock fragments are identified locally based on colour, size and angular shape. In the Wentworth classification, this corresponds to coarse- and very coarse sands and granules. Coarse-grained regolith was found either on meter-scale sand ripples as well as directly on the crater floor, either topping local rocks or fine-grained regolith.

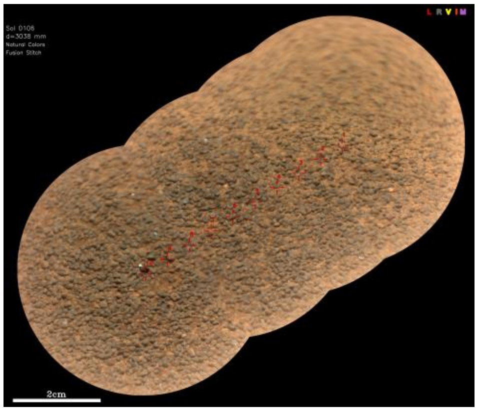

Fig.1: Coarse-gained regolith at target Hastaa (sol 106). Most of the coarse grains are olivine.

Source of coarse-grained regolith:
Figure 2 depicts a geochemical diagram based on LIBS data comparing the molar Al/Si versus (Fe+Mg)/Si of coarse-grained regolith with local rocks explored so far by the rover.

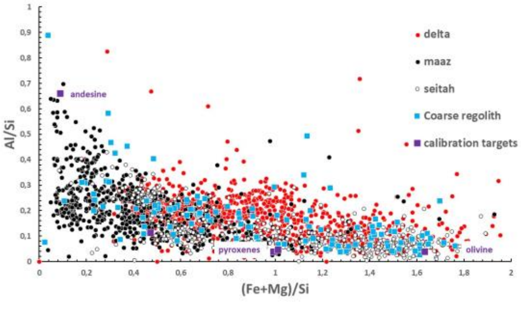

Fig. 2: Molar Al/Si versus (Fe+Mg)/Si for coarse grained regolith (blue) compared to Jezero rocks.

At first order, coarse-grained regolith is richer in MgO and lower in Al_2O_3 compared to Máaz. The same trend is observed when comparing with the Delta rocks but to a lesser degree.

In addition, some LIBS points sampled essentially pure minerals, e.g., 1-2 mm olivine grains with Fo# consistent with olivine from the Séítah unit [7-8]. The presence of olivine in the coarse-grained regolith is further confirmed by VISIR spectroscopy (Fig. 3, see [10]). Last, the grain size of olivines matches those in the Séítah cumulate rocks [7-8]. These grains are observed East from the Séítah unit. Some olivine is detected in the Delta rocks yet with much smaller grain size. However, the distance for transport is much longer (and complicated by the high topography in Séítah) to consider them as a source for olivine grains in regolith close to the landing site. Altogether, we consider that the most likely source for coarse-grained regolith is the igneous Séítah unit.

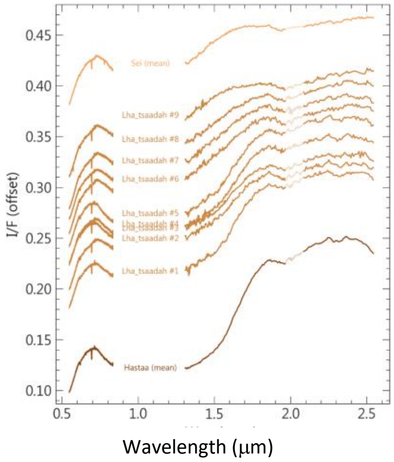

Fig. 3: VISIR spectra in coarse-grained regolith targets showing all a broad band centered at 1 um indicative of olivine.

The orbital view: [11] provides detailed maps for the distribution of olivine in Jezero crater based on CRISM data (Fig. 4). Although Séítah rocks have the strongest olivine contribution, some olivine is also locally detected in the Máaz unit. Yet in situ observations of Máaz rocks do not detect olivine in these rocks [12], so these olivine detections reflect the presence of olivine in the regolith covering the rocks (see also [10]). In Figure 4, it is possible to estimate a rough minimal transport distance of a km, but also possible transport up to several km, by taking the minimum distance between the orbital olivine detections in regolith and the closest Séítah rocks. Olivine is transported eastward in that region, consistent with the dominantly eastward transport observed elsewhere on the crater floor.

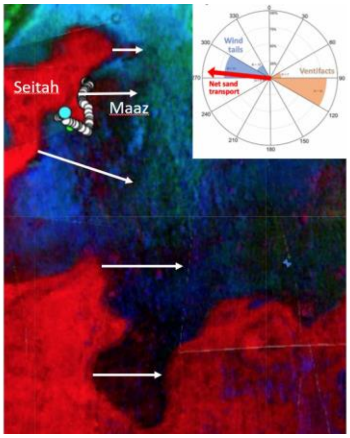

Fig. 4: Mineralogical map from [11] showing the presence of olivine (red) and pyroxene (blue). Olivine grains are transported eastward from Séítah (white arrows) in the opposite direction of present day dominant wind estimated from wind tails (inset from [2]).

Aeolian transport of coarse-grained regolith: Because olivine in the coarse grained regolith is only weakly altered by fluid-rock interactions, and the coarse-grained regolith is mainly observed in aeolian sand ripples, we assume that most of the transport was done by aeolian and not hydrological processes. In such a context, transport of these grains can be done by saltation for smaller grains, and reptation for larger grains [13], or a combination of both. For the olivine grains we have the grain size/shape as well as density estimates which makes possible testing for aeolian transport. This is ongoing work.

The eastward transport of olivine-rich grains hypothesized here is opposite to the dominant wind direction of today’s climate (determined from regolith wind tail observations, and predicted by numerical climate modeling), but aligns with older dominant wind directions responsible for ventifact orientations observed on the Jezero crater floor [2,14]. [14] suggested that ventifacts were likely created under a different climate regime with opposite wind directions.

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References: [1] Cousin et al., this meeting; [2] Newman et al. Sci. Adv. 2022; [3] Noah et al., this meeting; [4] Wiens et al. SSR 2021; [5] Maurice et al. SRR 2021; [6]Anderson et al. SAB 2022; [7] Wiens et al., Sci. Adv. 2022; [8] Beyssac et al., JGR subm.; [9] Vaughan et al., JGR subm. [10] Mandon et al. JGR in press [11] Horgan et al. Icarus 2020 [12] Udry et al. JGR in press [13] Kok et al. 2012 [14] Herkenhoff et al. JGR, subm.