Soil diversity on Mars: comparison between Gale and Jezero craters A. Cousin[1], O. Beyssac[2], O. Forni[1], P.Y Meslin[1], N. Martin[3,9], B. Chide[3], E.M. Hausrath[4], R. Sullivan[5], F. Poulet[6], E. Dehouck[7], J. Lasue[1], S. Schröder[8], O. Gasnault[1], P. Pilleri[1], R. Wiens[9], S. Maurice[1] and the SuperCam science team. [1]IRAP, Toulouse, France (acousin@irap.omp.eu), [2]IMPMC, Paris, [3]LANL, Los Alamos, NM, USA; [4]Dept. of Geoscience, UNLV, NV, USA, France, [5]Cornell University, Ithaca, NY, [6]IAS, Orsay, France, [7]Université de Lyon, France;[8]DLR, Berlin, Germany, [9]Purdue University, Lafayette, USA.

Introduction: Soils are loose, unconsolidated materials resulting from the physical and chemical alteration of rocks by several processes [eg., 1-3]. The study of soils can allow us to estimate the global composition of the crust by examining their primary constituents [2], as well as to better understand the past and present environmental conditions on Mars. Orbital data have shown that dust and soils are hydrated (4 ±1 wt%) and relatively homogeneous across the planet [4]. Soil analyses performed by the Viking, Pathfinder and MER rovers have confirmed this [5]. The Mars Science Laboratory (MSL) mission with the Curiosity rover showed that fine-grained soils in Gale Crater contain up to 3 wt% H_2O [1,6,7], and that this hydration is primarily carried by the X-ray amorphous component [8]. ChemCam observations have shown that fine-grained soils are more hydrated than coarser soils [1, 9], likely due to the amorphous component [10,11], which appears to contain hydrated Mg sulfates [11]. The Perseverance rover explored the crater floor of Jezero for 414 sols, as well as the delta front for another 235 sols. The soils analyzed during this period allow us to investigate the relationship between the grain size and soil mineralogy, evaluate local vs more global contributions[12], and make comparisons with other in situ data elsewhere on Mars.

Objectives: The SuperCam instrument [13,14] on Perseverance uses the LIBS technique, as does ChemCam on MSL. This technique uses a laser with a spot size of only 150-500 microns [13], allowing analysis of pure phases when the grains are larger than the spot size, or of a mixture finer grains. In general, between 30 and 50 shots are performed on each analysis point (and at least 5 points per target). The shock wave generated by the laser for each shot causes some excavation, so allows new grains to be analyzed with each shot. Thanks to this technique we can analyze the soils in detail, at the sub-millimeter scale. Similarity of techniques between MSL and Mars2020 allows comparisons between Gale and Jezero craters.

The objectives of this study are: (1) classify analyzed soils by grain size; (2) analyze relationships between grain size and composition; (3) evaluate potential local vs. global components present; and (4) compare the compositions of finer grains between Gale and Jezero, to investigate homogeneity of fine-grained soils across Mars, as suggested by previous work [5, 6, 15, 16].

Methodology: This study uses all SuperCam analysis points of regolith material, whatever the type: indurated soil, ripple, disturbed (by the rover wheel for example) and undisturbed soil. Soils on top of a flat rock have been included, but only if the soil was thick enough to avoid sampling the rock below. As the laser beam is small, the grain size analysis was done on each LIBS point and not on the whole image as the objective here is about the size and composition of the grains that were analyzed by LIBS and therefore the methodology used is different from [12]. Only the RMI images were used, except where WATSON images were also available (a few targets only). We use the Wentworth scale for the grain size classification [17]. The ChemCam soil targets come from [18], where targets were classified up to sol 3007, using the same methodology. For chemical compositions, the major element oxide data are used from for both instruments [19,20], using the shot-to-shot data, as each laser shot acquires data on a new set of grains due to excavation caused by the shock wave. The first 5 shots are however removed as they can contain more dust [21]. The identified buried coarser grains by [22] have also been removed in the SuperCam dataset. To compare ChemCam and SuperCam data, we have used an Independent Component Analysis (ICA) technique, using a JADE algorithm [23-25].

Results: *Classification* As of sol 645, 48 different SuperCam targets were soil, with a total of 362 points analyzed. Most of the LIBS points have sampled a fine-grained regolith or a very-coarse grained one (59% and 20%, respectively). The other categories (medium sand, coarse sand and granules or bigger) are less represented with only 7, 6 and 9 % of the population, respectively. Therefore, this study will focus mainly on the fine and very-coarse grained types of regolith. Most of the regolith targets analyzed with SuperCam are either in the Máaz formation, or along the delta front (specifically at Observation Mountain, the regolith sampling site). The number of observations performed is biased by the time spent in each area, and what was the main mission objective. We did not spend so much time at Observation Mountain (23 sols) but the objective being the regolith sampling, more analyses were performed to help the decision of sampling.

Chemistry/mineralogy vs grain size Very coarse regolith shows more dispersion compared to the fine-grained soils. Both types of soil show a bimodal distribution for the MgO content, but there are more coarser grains enriched in MgO. From the ternary diagram (Fig. 1) the finest grains globally occur in the triangle composed by plagioclase and the two pyroxenes, with a large majority of them located in the middle of it. This is consistent with VISIR data showing homogeneous spectral properties along with a pyroxene signatures in these fine-grained regolith [26]. The coarsest grains (left plot) plot in the olivine-pyroxene-feldspar domain; however, the majority of them are located near the olivine composition.

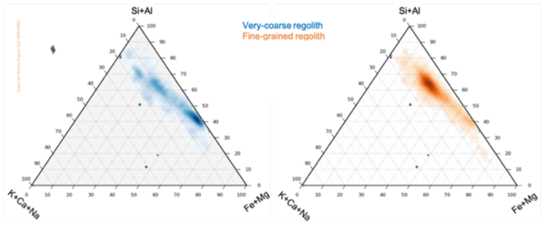

Figure 1: Ternary diagram representing the very coarse grains (left, in blue) and the fine-grained regolith (right, in orange) observed by SuperCam, shot-to-shot. Individual points correspond to the Calib. Targets.

This can also be observed in a Al/Si vs (Fe+Mg)/Si diagram (Fig.2), where coarsest regolith is overall more enriched in MgO and depleted in Al_2O_3 compared to Máaz rocks, and finest regolith being mainly in the middle of the mafic-felsic trend, as seen in Gale. Coarse-grained regolith shows more variability in Mg#, and this is discussed more in detail in [27].

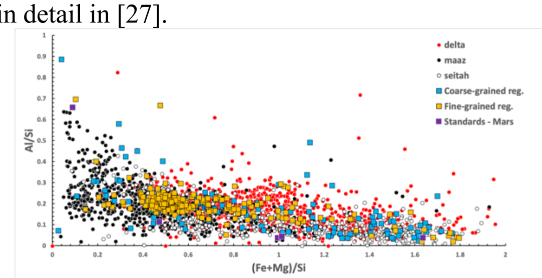

Figure 2: Al/Si vs (Fe+Mg)/Si for fine and coarse-grained soil compared to the Seítah, delta and Máaz rocks.

Chemistry/mineralogy along the traverse The same type of ternary diagram, shows that fine-grained soils are homogeneous all along the traverse, whereas coarser grains show some variability. Coarse grains analyzed in the Máaz formation show the highest dispersion, with at least 1 point sampling a feldspar-like grain – even though the vast majority correspond to olivines or olivine-low Ca pyroxenes mixtures. At Seítah there is very little dispersion, most of the coarse grains correspond to olivines with a few other points that are more similar to fine-grained soils (e.g. more felsic). At Observation Mountain, only a single very coarse grain was sampled and showed a diverse composition, more altered.

Comparison to Gale crater ICA technique is useful for comparing Gale and Jezero spectral datasets. ICA showed that Jezero fine-grained soils are overall more enriched in MgO compared to those analyzed at Gale crater, whereas the latter are more enriched in K_2O. CaO does not seem to differ between the two locations. Data from Jezero seem to show less S whereas the Cl signal seems to be slightly more elevated. This will be investigated more in detail.

Discussion: Fine-grained soils of Jezero have a general composition matching well that of pyroxene. However, the laser beam samples several grains for each shot, and this composition reflects a mixture of several phases. A few shots have sampled some buried coarser grains and this is reflected by the bimodality of the MgO content. Finest grains are more enriched in Cl, H, and S which are related to secondary phases. At Gale crater, this was attributed to the amorphous component [1,7], which contained some hydrated Mg sulfates [11]. Fine-grained regolith seems to contain some local inputs, as S seems to be lower at Jezero, probably due to less sulfate veins in that region, whereas Cl is more present, probably related to the presence of perchlorates [28]. In contrast to Gale crater, very coarse regolith corresponds mainly to olivine. The likely source (Seítah formation) and transport of these grains is discussed in [27]. The only very coarse grains analyzed at Observation Mountain shows a different composition, and might correspond to a more local input, such as from the delta top, or from altered rocks containing some carbonates as seen in the vicinity. These very coarse grains are directly related to local rocks. At Gale crater an important fraction of very coarse grains were felsic, reflecting the dominance of felsic igneous rocks [29,30].

Conclusion: Mainly fine-grained and very coarse-grained regolith has been analyzed by SuperCam during the first 634 sols of the Mars2020 mission. Very coarse grains show more dispersion in their compositions due to their size, and they are more locally sourced compared to fine-grained soils, as seen in previous studies. Comparison of the regolith observed at Gale and Jezero showed that even grains <150 microns contain some local component.

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