CLASSIFICATION OF SOILS AT GALE ALONG THE TRAVERSE: A CHEMCAM. A. Cousin[1], P.Y Meslin[1], E. Dehouck[2], G. David[1], J. Lasue[1], O. Forni[1], S. Schröder[3], R. Wiens[4], S. Maurice[1], O. Gasnault[1], N. Lanza[4]. [1]Institut de Recherche en Astrophysique et Planétologie, Université Paul Sabatier, CNRS, CNES, Toulouse (acousin@irap.omp.eu), [2]Univ. Lyon 1, ENSL, LGL-TPE, Lyon, [3]DLR, Berlin, [4]LANL, NM, USA.

Introduction: Since its landing in 2012, the Curiosity rover has traversed more than 25 km along several geological units. Among the thousands of targets analyzed, 354 correspond to soils. Soils correspond to loose, non-consolidated material, which is the result of the physical and chemical alteration of rocks by several processes [1-3]. These soils are of great interest as they can be used to estimate the global chemical composition of the basaltic crust, but also to assess the past environmental conditions of the planet through their secondary phases. Curiosity has shown that there was up to 3 wt % H_2O in fine-grained soils [4,5], but that the hydrated phases were not in the crystalline material but rather in the amorphous component [6]. It was also shown that the fine-grained soils were more hydrated than the coarser ones [1;7-9]. Here, we use the term "soil" in a sense discussed in [3].

Objectives: This study has the first objective to list and classify all data points that have sampled a soil target along the traverse by the ChemCam instrument. Once the classification is completed, differences in composition between the different grain fractions can be investigated.

Methodology: This study uses data from the ChemCam instrument [10-11], which reports the chemical compositions of remote targets [12]. Here, we focus on soil targets only. The distinction between a soil and a rock target is first done visually from the context images (MastCam and NavCam) and the ChemCam/RMI ones. RMIs have been specifically used in order to locate each data point from ChemCam analyses. In some cases, the first point of a rock sample can have missed the target, and a soil has been sampled instead.

Each soil target has then been classified depending on their grain size, following the Wentworth scale [13]. At this stage, the grain size has been estimated visually from the RMI. Several classes have been observed: 1/fine sand (<250 µm), 2/medium sand (250-500µm), 3/coarse sand (0.5-1mm), 4/very-coarse sand (1-2mm) and 5/granules and more (>2mm).

Results: A total of 1507 data points have sampled a soil target as of sol 3007. Most of them (51 %) correspond to fine-grained soils and 29 % correspond to medium-sized soils. Soils with a coarser grain size are less sampled: coarse sand (9%), very coarse sand (8 %) and granules or larger (3%). This distribution of grain sizes in soils can be biased, as usually when a soil is sampled, the objective is to analyze a fine-grained soil.

The elemental composition of the soils varies as a function of their grain size (Fig. 1). Fine-grained soils (<250 µm) are particularly depleted in SiO_2, Al_2O_3, Na_2O and K_2O, whereas the very-coarse grained soils and granules are more enriched in these elements. One main observation is that there seems to be a threshold in composition that is set between the coarse and very coarse classes, i.e., at ~1 mm grain size. That means that there is not much difference in composition between the fine-grained, medium-grained and coarse-grained soils. Volatile elements such as S, Cl and H have been investigated, and these three elements have a higher signal in the fine-grained soils (Fig. 2).

Discussion: The distribution of grain sizes is not similar to what we observed up to sol 250 [7]. Moreover, in Fig.1 it can be seen that very-coarse grained soils and granules have a more felsic composition, which is consistent with previous studies [1,7]. In [7], it was shown that these coarser sized soils were coming from local inputs, mainly at the beginning of the traverse, where several felsic igneous rocks have been observed [14-16]. However, it can be observed that these samples present the widest compositional range, for each element. Even though most of the very-coarse grains and granules have a felsic composition, it seems that others are more mafic. We will investigate the evolution of the coarser grains composition along the traverse up to sol 3007. A more detailed analysis of these two categories of soils could bring more information concerning

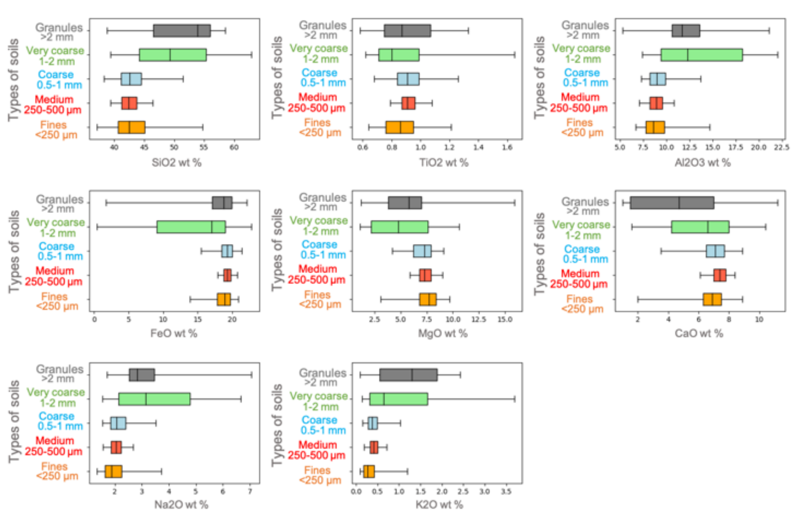

Fig. 1: Distribution of major elemental compositions for each grain size category.

the relation between these granules and local rocks along the traverse, and therefore about the processes of soil formation.

Fig. 1 also shows that soils with grain size < 1mm have overall the same composition. However, fine-grained soils (<250 µm) present the most mafic composition, but also the widest range among these samples. That could mean that possibly some buried coarser-grains have been included in this category, as the classification has been made visually. In [7] the fine-grained soils were classified visually, but also by investigating the shot-to-shot data: if there was any suspicion of a buried coarser-grain, this sample was removed. This was a very conservative way of classifying the soil samples, and very time-consuming. In this study, the classification is made only from visual inspection. However, when comparing the elemental composition of the Aeolis Palus soils up to the Bagnold Dunes [9] with those from this study, we can observe that the average composition is similar, and the dispersion obtained from this study is not higher than the dispersion of the Aeolis Palus soils, except for Al_2O_3, MgO and CaO contents (Fig. 3).

In this study the amorphous component is not investigated. It was shown that soils at Gale crater contain up to 30 wt% of this amorphous component, and that this component is the main carrier of the hydration [4-5]. A recent study also showed that this amorphous component present in fine-grained soils was enriched in hydrated Mg-sulfate [17]. In the present study we show that the finest grain-size fraction has more H, S and Cl, which is consistent with [17] regarding the H and S signals. At first glance, as fine-grained soils from this new classification have the same composition as those from Aeolis Palus, it could be suggested that the amorphous component contains the same phases all along the traverse, but this will need to be investigated more in details.

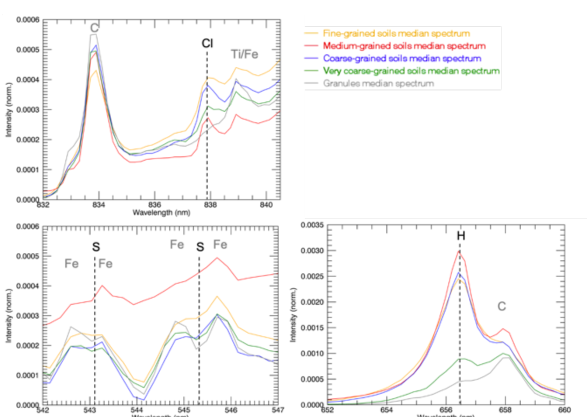

Fig. 2: Median spectrum for each of the grain size type of soils, zoomed in several minor elements regions (Cl, H, S).

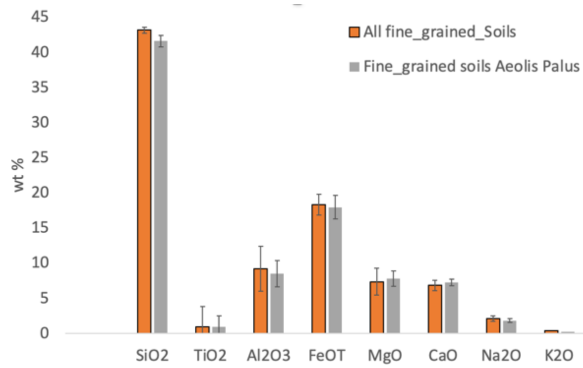

Fig. 3: Comparison of average composition obtained in fine-grained soils along the entire traverse (this study, in orange) and fine-grained soils from Aeolis Palus (in grey).

Conclusion: Up to sol 3007, ChemCam has measured 1507 data points in soil targets. This new classification of soils establishes a complete list of soil targets, along with their grain size. We have shown that the distribution of grain sizes is actually the same as what we had up to sol 250, probably as the main interest is focused on fine-grained soils. Also, we have seen that coarser-grains have overall a more felsic composition, even though some dispersion is observed and should be investigated further by looking at their distribution along the traverse. Another result is that the compositional threshold seems to be set at ~1 mm grain size. That means that the classification of soils using only the RMI seems adequate. This is reinforced by the fact that the fine-grained soils presented in this study have overall the same composition as those from Aeolis Palus, classified from shot-to-shot analysis. Finally, the amorphous component should be investigated further, but our global dataset seems to show that it has the same composition in soils along the whole traverse.

References: [1] Meslin et al., Science, 2013. [2] Taylor & McLennan, 2009; [3] Certini et al., PSS, 2020; [4] Blake et al., Science, 2013; [4] Leshin et al., Science, 2012; [6] Bish et al., Science, 2012; [7] Cousin et al., Icarus, 2015; [8] Ehlmann et al., JGR, 2017; [9] Cousin et al., JGR, 2017; [10]Maurice et al., SSR, 2012; [11]Wiens et al., SSR, 2012; [12] Clegg et al., Spect. Chem. Acta B., 2017; [13] Wentworth., The Journal of Geology, 1922; [14] Cousin et al., Icarus, 2017; [15] Sautter et al., Nat. Geos., 2015; [16] Sautter et al., Lithos, 2016; [17] David et al., submitted.

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