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Introduction: The ChemCam (CCAM) instrument provides the first insight on martian soil and dust chemical variability at the submillimeter scale as it is capable of isolating various soil components that bulk measurements would average out. Because each individual soil analysis (or LIBS point) is typically obtained from a series of 30 to 50 laser shots, and each shot produces a spectrum of a deeper portion of the soil, it is possible to retrieve a depth profile of chemical composition to depths of a few mms in soils (compared to a few 10's of μm in rocks). Finally, the instrument is sensitive to the presence of hydrogen, which has been observed since the very first spectrum obtained by CCAM on Mars.

During the 100 first sols of the mission, 126 LIBS points have been acquired on soil targets. Here, a soil target is defined as a loose, unconsolidated material, with grain sizes typically < 3 mm.

Chemical diversity of soil targets: The chemical diversity of soil targets has been analyzed by Partial Least Square (PLS) and Independent and Principal Component Analysis (ICA, PCA) [1, 2, 3]. The large dataset is also well-suited to clustering analysis [4]. These analyses reveal a compositional trend between at least two major end-members: a mafic component (Type 1) and an alkaline-, aluminum- and silica-rich component (Type 2). Most of Type 1 soil targets, such as Portage and Crestaurum, were located at or in the vicinity of an aeolian ripple called Rocknest dune (in scooping trenches, rover wheel tracks, or on its crest), but the Type 1 component was also found at various places along the rover traverse (e.g., Beaulieu_1). Their composition is similar to the composition of the average martian soil, and to the composition of the dust measured by ChemCam on rock surfaces (Table 1). However, they clearly differ from the rocks found in the Rocknest area: they have more Mg, and less Fe+Ti than the latter (Fig. 1) (see also [4]). Type 2 soil targets were mostly found in the vicinity of the landing site, and their felsic composition is more representative of some local rocks, such as Stark, or some high Si minerals in Mara and Jake Matijevec. A few LIBS points are also high in Ca and low SiO_2 , suggesting that Ca is associated with some anions that are not

easily measured by ChemCam (S, P, Cl, F), or with some carbonates [5, 6]. There is also some variability within Rocknest ripple [5,6], and between the top and the interior of this aeolian bedform.

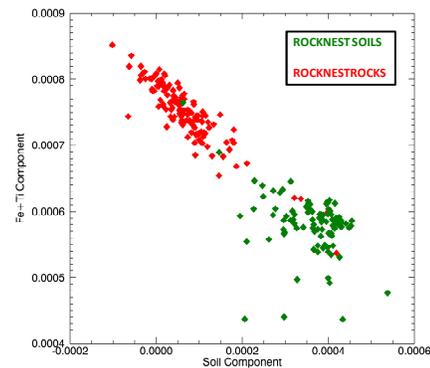


Figure 1. ICA classification of soils and rocks measured at Rocknest site showing a clear distinction between them along the (Fe+Ti) and (Soil) components. The Soil component contains Mg, Cr and Mn (see [2]).

Relationship between composition and grain-size distribution: A qualitative analysis of CCAM data, based on RMI images and some spectral features (variations in peaks' width, and variations in composition with depth), suggests that Type 1 corresponds mostly to soils that are fine-grained at the LIBS scale, while Type 2 corresponds to coarser, mm-sized grains that could originate from rocks in this location. The observed compositional trend is best explained by mechanical mixing between Type 1&2 components. The abundance of coarse grains and pebbles with high Si, Na+K, Al contents suggest that the associated mineral phase is very common near the landing site, even though their relative concentration has probably been enhanced by the removal of finer grains caused by the sky crane thrusters's blasts. The mm-sized grains covering the Rocknest ripple, or possibly the cement responsible for their induration, are slightly enriched in Si, Al and alkaline elements compared to the interior of the aeolian bedform, suggesting a more local origin.

Relationship between soil type and hydration: ICA analysis [2] reveals a hydration trend that closely follows the trend in composition/grain-size (Fig. 2). The fine-grained, mafic soil component (Type 1) is

significantly enriched in H with respect to Type 2 soils and to local rocks. This trend is consistent with the hypothesis that soils are a mechanical mixture of a locally derived component and a component found globally; the latter, fine-grained component controls soil hydration. DAN bulk measurement of hydrogen [8] and CCAM analyses imply that the dust, coarse silt/fine sand particles found globally contain more than 1.5 wt% of water, which is consistent with SAM analysis [9]. This hydrogen could be from adsorbed water – and the larger specific surface area of the fine-grained, Type 1 component could account for its greater H content – or could be present in hydrated alteration products, or both. However, Chemin has not found firm evidence of the presence of crystallized hydrated phases yet [10]. This suggests that the hydrogen may be associated with the significant fraction of amorphous phase(s) detected in the soil. Indeed, amorphous (or short range ordered) silica phases like allophane and ferrihydrite are mostly responsible for water adsorption in terrestrial andisols because of their large specific surface area [11, 12] and the presence of surface hydroxyl functional groups [13]. These phases are thus expected to be characterized both by their hydration and ability for adsorption; both should go hand-in-hand.

Comparison between day and pre-dawn measurements of H by CCAM on Crestaurum soil does not show any significant difference in H content [14], but diurnal exchanges are not expected to involve more than a few μm of water, which translates to variations of concentration of ~ 100 ppm to ~ 1000 ppm depending on the thickness over which this water is adsorbed (1 cm to 1 mm, respectively). This difference may be below the detection limit of CCAM.

Implications and Perspectives: The martian surface is known from orbital measurements to hold between 2 and 10 wt% of water-equivalent hydrogen at equatorial and mid-latitudes [15,16], but the carrier of this hydrogen has not been firmly nor uniquely identified. The MSL instruments suite shows that the dust and fine-grained particles, whose chemical composition is similar to the average Martian soil, could account for at least a few wt% of this budget. This has important implications for the understanding of the hydration of the martian soil at a global scale, and if H is present as adsorbed water, for the understanding of regolith-atmosphere exchanges. Further laboratory work and calibrations are needed to use CCAM for quantification of hydrogen in soils and rocks.

Acquisition of soil and rock targets along the rover traverse, coupled with cluster analysis of the large anticipated CCAM dataset [4], should also give some

clues to the origin and relationship between soil and dust, and to the respective contributions from global, regional and local sources.

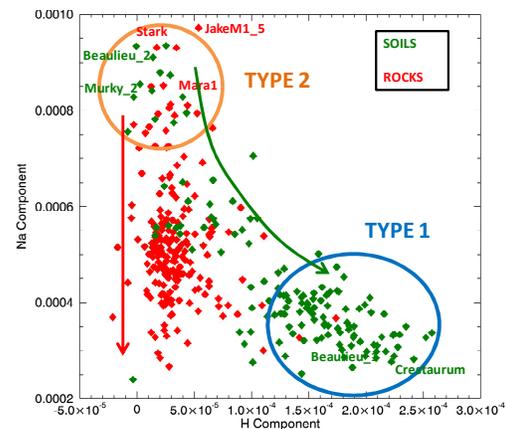


Figure 2. ICA classification of soils and rocks along Na and H components, showing a clear hydration trend between Type 1 & 2.

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃ T	MgO	CaO	Na ₂ O	K ₂ O
Average martian soil	45.4	0.9	9.7	18.4	8.4	6.4	2.7	0.4
Beaulieu_1	41.2	0.8	9.5	15.7	9.5	9.1	2.0	0.5
Portage (CCAM)	44.8	0.6	11.3	15.2	7.4	7.4	2.4	0.7
Dust (CCAM)	41.5	0.7	10.6	14.8	6.5	7.6	2.3	0.8
PLS RMSEP	7.3	0.7	3.1	6.2	3.9	4	0.9	0.9

Table 1. Composition of a few soil targets and dust (from 1st shot of all rock targets) obtained by PLS. RMSEP = RMS Error of Prediction. See [1] for a detailed discussion of the performance of the PLS method, including a comparison with APXS data on Portage. The average martian soil composition is taken from [7].

References: [1] Lasue J. et al. (2013), this meeting. [2] Forni O. et al. (2013), this meeting. [3] Anderson R. et al. (2013), this meeting [4] Gasnault O. et al. (2013), this meeting. [5] Fisk M. et al. (2013), this meeting. [6] Clegg S. (2013), this meeting. [7] Taylor and McLennan (2009), Planetary Crusts: Their Composition, Origin, and Evolution. Cambridge University Press (Cambridge). [8] Litvak M.L (2013), this issue. [9] Archer Jr. et al. (2013), this meeting. [10] Bish, D.L. (2013), this meeting. [11] Bartoli F. et al. (2007), Eur. J. Soil Sci., 58(2). [12] Moldrup P. et al. (2003), Soil Sci. Soc. Am. J., 67 [13] Jänchen J. et al. (2009), Icarus, 200(2) [14] Schröder S. (2013), this meeting. [15] Maurice S. et al. (2011), JGR. [16] Milliken R. et al. (2007), JGR.