

Martian Eolian Dust Analyzed by ChemCam. J. Lasue¹, A. Cousin¹, P.-Y. Meslin¹, N. Mangold², R.C. Wiens³, G. Berger¹, E. Dehouck⁴, O. Forni¹, W. Goetz⁵, O. Gasnault¹, W. Rapin⁶, S. Schröder⁷, A. Ollila³, J. Johnson⁸, S. Le Mouélic², S. Maurice¹, R. Anderson⁹, D. Blaney¹⁰, B. Clark¹¹, S.M. Clegg¹², C. d'Uston¹, C. Fabre¹³, N. Lanza³, M. B. Madsen¹⁴, J. Martin-Torres^{15,16}, N. Melikechi¹⁷, H. Newsom¹⁸, V. Sautter¹⁹, and M. P. Zorzano^{15,20}

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Introduction: ChemCam is a Laser-Induced Breakdown Spectroscopy (LIBS) instrument on-board the NASA Mars Science Laboratory rover, which is currently exploring Gale Crater, Mars. A pulsed infrared laser ablates the target of interest generating a plasma, the light from which is collected and analyzed by spectrometry [1, 2]. Each shot on target removes just a few nanograms of material.

The composition of the first few shots is characteristic of the global martian fine dust, which covers the entire planet [3] and contributes to the local geology analyzed by MSL [4, 5]. This work compiles the ChemCam first shots taken on calibration targets and martian targets over four years to refine the composition of the Aeolian fine dust detected by ChemCam.

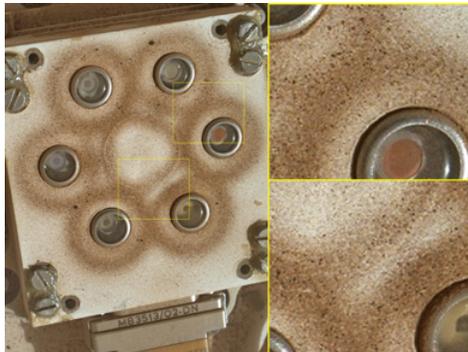


Figure 1: Sol 323 MAHLI image of the REMS UVS, taken after the passage of the regional dust storm. Dust grains sticking to the magnetic rings with different albedos and colours are seen.

Martian fine dust deposition: A global component of fine dust aerosol can be mobilized by aeolian processes on the surface of Mars and deposits constantly on the Mars rovers, while being sometimes removed by the action of wind. As shown in Figure 1, very small dust particles deposit on the rover and affect the detection of REMS UV sensors. In analyzing the first ChemCam shot, we analyze dust mostly from airborne origin and recent deposition which should consist of a typical grain size distribution around 1-2 μm [e.g. 6].

ChemCam passive spectroscopy [7] has also been used to assess the variations in dust cover from the rover paint target located amongst the ChemCam calibration targets (CCCT). The passive spectroscopy presents reddening of the rover paint CCCT with time that indicates deposition or removal of the dust particles on its surface.

Martian fine dust composition: Since the beginning of the mission, every first shot analyzed by ChemCam has presented a significant compositional contribution, always identical, that is representative of a global martian component. This contribution, appearing in the first five shots, is routinely removed from the analysis of the targets of ChemCam to get the composition of the underlying rock [8]. The consistency of this first spectrum gave the opportunity for the ChemCam team to improve the distance correction for the ChemCam data [9, 10]. For compositional quantification, the dust deposited on martian targets typically presents little variation. We can therefore make use of about 8500 spectra available over 1500 sols to determine the composition of this material.

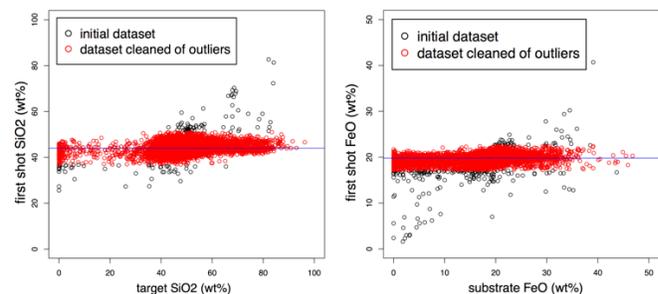


Figure 2: Comparison in SiO_2 (left) and FeO (right) content of the first shot versus the content of the underlying rock. This shows that the majority of the data points do not present correlation with the underlying target composition after cleaning out the outliers (usually fresh targets with no dust coverage).

Figure 2 compares the first shot composition with the composition of the underlying rock target, indicating that the two values are not correlated. In this way, all the major and some minor elements of the eolian dust are detected. The line ratios are consistent with a basaltic composition similar to the one detected glob-

ally on the planet [3-6]. Every ChemCam first shot presents a strong H line, indicating that this fine dust is a contributor to the H content of the martian samples also detected by the SAM instrument at the level of 1.5-3 wt.% [4, 12, 13]. This in turns means that this fine dust also contains part of the hydrated amorphous phase of the soil. This is illustrated in Figure 3 which shows the distribution of the hydration index in ChemCam data as compared to soils and dunes.

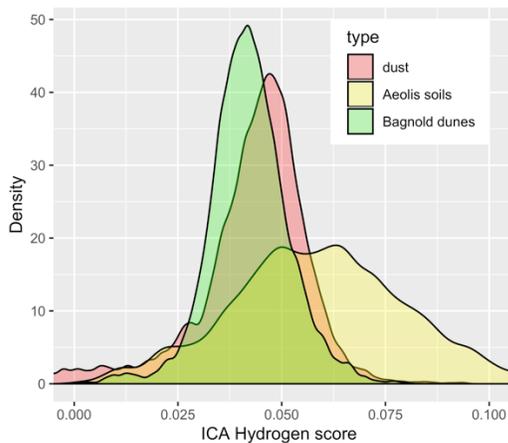


Figure 3: Comparison of the hydrogen signal distribution for eolian dust (red), the Aeolis Palus soils (yellow), and the Bagnold dunes (green) at Gale. ICA = independent component analysis. [14]

As shown in Figure 4, comparison between the fine dust component and typical fine soils, indicates a similar content in major elements with soils analyses from ChemCam and dust deposits from APXS (normalized with H₂O=2wt.%) [17]. Alkalis are variable while the minor elements Ba, Sr, Rb, Li are detected in quantities similar to previous soil analyses. Mn and Cr appear to have larger peak areas than typical ChemCam soils. S and Cl peaks are detected in agreement with APXS enrichment of S and Cl in dust [17].

Conclusion: The chemical composition of the martian fine dust component can be analyzed with the ChemCam instrument and compared to other measurements. The compositional homogeneity of the dust at the 350-micron scale of the ChemCam LIBS spot probably indicates an efficient mixing of the dust grains at this scale and/or the widespread presence of their lithic source.

The dust composition shows similar trends to the APXS dust measurements on the observation tray of MSL. There are significant differences with the Aeolis Palus soils and Bagnold dunes, as the dust is lower in CaO, and higher in SiO₂. The dust content in FeO and TiO₂ is larger than the soils and probably associated with nanophase oxides components, such as titanomagnetite. The dust spectra show the presence of

volatile elements (S and Cl), and the hydrogen content is similar to Bagnold sands, but lower than Aeolis Palus soils. The dust may be a contributor to the amorphous component of soils, but differences in composition indicate that the two materials are not equivalent.

This may be linked to the presence in the eolian dust of a mixture of altered and unaltered materials in the eolian dust mixed over the planet in a global cycle. Therefore, dust may not constitute the most chemically altered soil component, and the physical weathering of unaltered phases of rocks and pebbles during their transport may have played an important role in its formation.

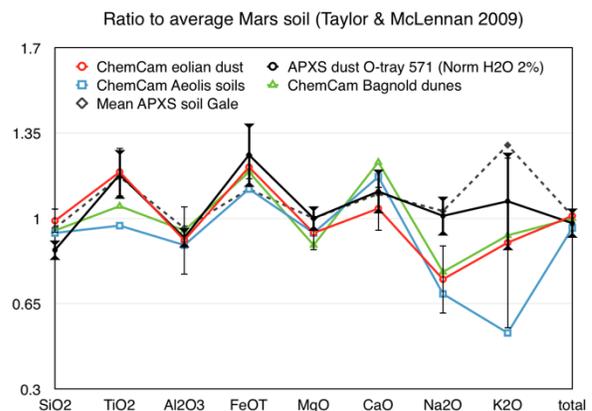


Figure 4: Mean 1st shot with standard deviation ratio to average Mars soil [15] and comparison with ChemCam fine soils [5, 16] and APXS dust measurements [17].

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References: [1] Maurice *et al.* (2012) SSR, DOI 10.1007/s11214-012-9902-4 [2] Wiens *et al.* (2012) SSR, DOI 10.1007/s11214-012-9912-2 [3] Yen *et al.* (2005) Nature, DOI: 10.1038/nature03637 [4] Leshin *et al.* (2013) Science, DOI: 10.1126/science.1238937 [5] Meslin *et al.* (2013) Science, DOI: 10.1126/science.1238670 [6] Clancy *et al.* (2003), JGR, DOI: 10.1029/2003JE002058 [7] Johnson *et al.* (2014) Icarus, DOI: 10.1016/j.icarus.2014.02.028 [8] Wiens *et al.* (2013) Spectrochim. Acta, Part B, DOI: 10.1016/j.sab.2013.02.003 [9] Melikechi *et al.*, (2013) Spectrochim. Acta, Part B [10] Mezzacappa *et al.* (2016), Spectrochim. Acta, Part B [11] Lasue *et al.* (2014) LPSC, [12] Blake *et al.* (2013) Science DOI: 10.1126/science.1239505 [13] Schröder *et al.* (2014) Icarus doi: 10.1016/j.icarus.2014.08.029 [14] Lasue *et al.* GRL doi: 10.1029/2018GL079210 [15] Taylor & McLennan (2009) Cambridge Univ. Press [16] Cousin *et al.* (2014) Icarus doi: 10.1016/j.icarus.2014.04.052 [17] Berger *et al.* (2016) GRL doi: 10.1002/2015GL066675