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ChemCam Analysis of Soil Diversity along Bradbury-Glenelg Traverse

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The ChemCam (CCAM) instrument onboard the NASA Mars Science Laboratory rover, which combines a Laser-Induced Breakdown (LIBS) Spectrometer and a Remote Micro-Imager (RMI), provides the first insight on martian soil and dust chemical variability at the submillimeter scale. It is capable of isolating various soil components that bulk measurements would average out, and it can provide a depth profile of chemical composition to depths of a few mms in soils. It is also sensitive to the presence of hydrogen. CCAM is used for remote sensing at typical distances of 2 to 7 m. It has been used intensively since its first active use on Sol 13. A large fraction of the data has been obtained on soil targets (126 LIBS points during the 100 first sols of the mission), which are defined here as a loose, unconsolidated material, with grain sizes typically < 3 mm.

Both Partial Least Square (PLS), Independent and Principal Component Analysis (PCA, ICA) and clustering analysis have been used to analyze the chemical diversity of these targets. They reveal a compositional trend between at least two major end-members: a mafic component (Type 1), similar to the composition of the average martian soil and to the composition of the dust measured by CCAM on rock surfaces, and an alkaline-, aluminum- and silica-rich component (Type 2), more representative of some local rocks found in the vicinity of the landing site. Some variability in Ca and SiO_2 contents is also observed within the Rocknest ripple, an aeolian bedform extensively analyzed by CCAM and other MSL instruments, suggesting the presence of a high-Ca phase likely associated with either S, P, Cl or F, as also observed in neighboring rock targets. These soil targets, however, clearly differ from the rocks found in the Rocknest area, having more Mg and less Fe+Ti than the latter.

A qualitative analysis of CCAM data also 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.

ICA analysis reveals a hydration trend that closely follows the trend in composition/grain-size. 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 and CCAM analyses imply that the dust, coarse silt/fine sand particles found globally contain more than 1.5 wt% of water. This hydrogen could be from adsorbed water or could be present in hydrated alteration products, or both. However, the Chemin instrument has not found firm evidence of the presence of cristallized hydrated phases yet. 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 andisoils because of their large specific surface area and the presence of surface hydroxyl functional groups.

The martian surface is known from orbital measurements to hold between 2 and 10 wt% of water-equivalent hydrogen at equatorial and mid-latitudes, 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.