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Clustering of ChemCam targets at Gale

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Abstract

Compositions measured by ChemCam reveal multimodal distributions, suggesting the existence of several uniform groups of distinct composition. It is confirmed by a clustering analysis.

1. Introduction

The Chemistry Camera (ChemCam) onboard the Curiosity rover includes a Laser-Induced Breakdown Spectroscopy (LIBS) instrument and a Remote Micro-Imager (RMI) [1; 2]. ChemCam spectra are rich in compositional information, with numerous atomic emission lines per element [3]. The spectra are processed using multivariate analyses [4; 5; 6] and by studying individual lines [7, 8, 9]. This technique gives access to the chemical composition of the samples, without preparation, up to 7 m from the rover; A good analysis requires a few tens of laser shots per point and several points per target.

During the first 6 months of operations in Gale crater more than 100 targets were probed with ChemCam, addressing the need for a survey of the landing site composition along the traverse [10]. Here we propose to extend the clustering analysis of ChemCam LIBS spectra already conducted on the first 3 months of the mission [11], which offers a synthetic summary of this large dataset.

1.1 Pre-processing

The data are pre-processed into clean spectra [12] that are treated through an Independent Component Analysis (ICA) [4]. The ICA components are monotonic and positive function of elemental abundances, but the relationship is not necessarily linear. They serve as input to a clustering algorithm.

Note that given the sub-millimeter size of the laser interaction with the target, the classification does not directly apply to the rocks and the soils but rather to grains and cements making them.

1.2 Clustering analysis

A divisive algorithm [13] is applied to the average spectra of each point probed by ChemCam. It constructs a tree-like hierarchy by a series of successive splits into smaller and smaller clusters. At each step, a new child cluster is started with the sample for which the average dissimilarity to all other samples is largest.

This approach is appropriate to search for the main data structures, to reveal relations between the samples, and to find the optimal number of clusters.

2. Preliminary results

During the first three months, Curiosity traversed through a smooth hummocky unit, which has been subdivided into several geomorphic units [14]. The clustering analysis of ChemCam data also suggested the existences of compositional groups (Figure 1). Two clusters have samples enriched in sodium with a mixture of rocks, pebbles, and soils that are certainly closely related to each other. Another group, which can possibly be subdivided into four clusters, is made of mafic rocks. The soils appear in a well separated cluster, suggesting a weaker contribution from the surrounding rocks, and are characterized by their enrichment in hydrogen [15].

In the following three months of the mission, Curiosity entered a unit lower in elevation and consisted of fractured bedrock. Basaltic units were found as well as cross-stratified and conglomeratic sedimentary rocks in some sections [16].

The composition changed too along the traverse [10] with a slight decrease of potassium after about 50 Sols, and again around Sol 150. Similarly, Na, Si, and Al abundances are generally lower after Sol 50, with a few exceptions. While Ca global trend follows the same behavior, several targets showed high-Ca after Sol 130; In particular small features, such as veins, were revealed with high-Ca and high-S in YellowKnife Bay [17]. On the contrary, there is a slight increase of iron after Sol 50.

As expected more compositional groups appear now in the clustering analysis. The most obvious two new groups that were revealed after the first three months are respectively enriched in calcium and in magnesium (Figure 1).

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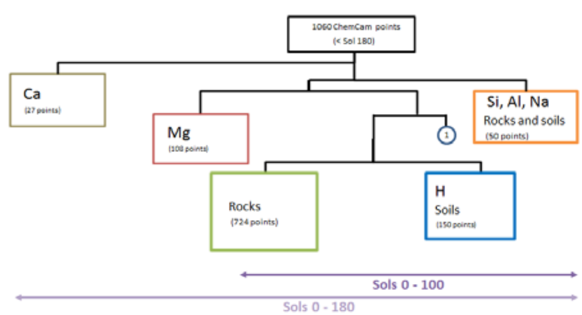

Figure 1: Simplified dendrogram of the hierarchical clustering of ChemCam data