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# Classification/Quantification of non-homogeneous basalts using Multivariate Analysis for MSL/ChemCam data

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## Introduction

ChemCam is part of the Mars Science Laboratory (MSL) – Curiosity – rover payload, which is scheduled for launch at the end of November 2011. This instrument is the first one using Laser-Induced Breakdown Spectroscopy (LIBS) for planetary exploration. Chemcam will investigate the geochemistry of the Martian surface [1, 2] at remote distances (1 to 7 m). It is composed of two physical parts: the Body Unit, located in the core of the rover, which includes three spectrometers and their electronics, and the Mast Unit, on top of the mast, which includes the laser, the telescope, the Remote Micro Imaging (RMI) and their electronics. ChemCam performs a small-footprint measurement (0,2 to 0,6 mm in diameter) : the LIBS technique creates a plasma of ablated material in electronically excited states, and then analyses the light with its spectrometers to obtain emission spectra and therefore analyze the composition of the sample. The Flight Model underwent several calibrations before delivery, with a wide range of samples and conditions [3]. Several tools are developed to analyze the data, like the peak identification tool with its ChemCam specific table, and statistical tools to determine the elemental composition of analyzed sample using "Partial Least Square" method (PLS) [4], and also to classify rocks using the Independent Component Analysis (ICA) [5, 6, 7]. The objective of this work is to show the capability of ChemCam to classify phyric textured basalts with porphyrocrysts of variable compositions set in fine-grained mesostasis.

## Dataset

This study focus on several basalts having compositions ranging from 42% to 54% $SiO_2$ (figure 1): the maximum standard deviation in composition is observed for the SiO2 content and is equal to 3.31 %. All have the same common features: phenocrysts of olivine, plagioclases or pyroxenes. The TAS diagram (figure 2) shows that these basalts are classified from picro basalt to basaltic andesite, via basanite and trachy basalt.

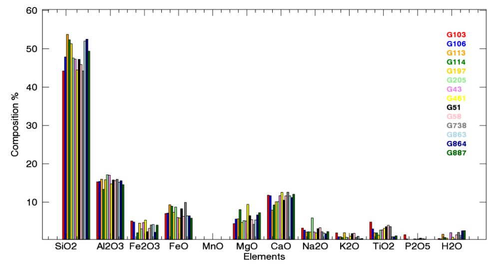


Figure 1: Composition of each basalt to classify.

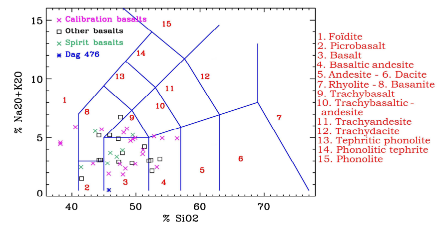


Figure 2: TAS Diagram showing the repartition of the basalts used for the model (pink crosses), and those used to be classified (black squares).

The experimental setup used to analyze these basalts is the EQM (Engineering and Qualification Model), which is the same than the flight model. The basalts were placed in a chamber where the Martian environment is simulated (6 mbar, 95.7% $CO_2$, 1.6 % Ar, 2.7% $N_2$) [8 for more details]. There were placed at 3 m from the instrument. For all of them, a set of 4 bursts of 10 shots were fired, each on different locations on the target, without considering where the rock is ablated (in a phenocryst or in the matrix). As the 10 shots of each burst are integrated, only 1 spectrum is acquired by burst. The mean of the 4 spectra acquired per rock is then used to be the "unknown spectrum" to classify. Looking at each spectrum, the non-homogeneous characteristic is well visible (figure 3). This figure shows two of the five spectra acquired in a picrite (basalt with olivines phenocrysts in a fine-grained matrix). They are normalized by the standard deviation spectrum. The black one corresponds to the matrix spectrum, whereas the red one presents only magnesium and silicon lines, which come from a magnesium-rich olivine. Neither the black spectrum obtained on the matrix nor the red spectrum of olivine phenocrysts represents the whole-rock composition of the analyzed basalt. Thus we use the mean spectrum of each rock for their classification.

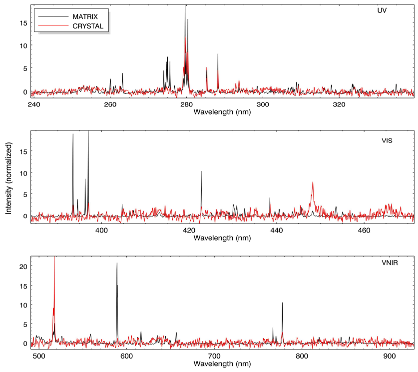


Figure 3: Plot of the Picrite spectra. In black : spectrum acquired on the matrix, in red : spectrum acquired in an olivine phenocryst.

## Calibration data for the Model ICA/PLS

To create a model for the ICA method, we select spectra from all the basalts that have been used for calibration of the Flight Model, taken when the instrument was in ambient conditions, and the samples under Martian environment, at 3 m [3]. All of these targets are all homogeneous and correspond to pellets of compacted powder. We included as well data from single crystals such as olivines (fayalite, forsterite and natural 83%), feldspars (albite, andesine, labrador and anorthite), pyroxenes (enstatite, diopside, augite), obtained with the EQM, under the same conditions. To be sure to understand the effects of the crystallization on the LIBS spectra, we added homogeneous pellets of the basalts to classify: they were crushed and then homogenized, as the calibration targets [9]. Figure 3 shows the TAS diagram for all the basalts from the calibration sets (pink crosses), and for the basalts to classify (black squares). For the PLS model, only data from the basalts acquired with the EQM are used : the spectra and also their oxides composition.

## Discussion/conclusion

The work concerning the ICA is still in progress but it is obvious that the crystallization stage will play an important role to determine the rock type/composition as shown by Spirit and Opportunity data. Moreover, the landing sites proposed for MSL will probably display quite altered fields, with important variation in composition at the millimeter scale, commonly found for clay deposits. PLS study was performed using the data acquired by the EQM: spectra from basalts with porphyrocrysts. Table 1 shows the results for the PLS study concerning a basalt with feldspar phenocrysts. Variations between the composition obtained from the 4 spectra are low (RSD<8%) and the composition from the mean spectrum is consistent with the reference data. This attests that LIBS spots were done only on the matrix.

| | sp. 1 | sp. 2 | sp. 3 | sp. 4 | mean spectrum | Reference composition |
|---|---|---|---|---|---|---|
| $SiO_2$ | 47,3 | 47,4 | 47,3 | 47,4 | 47,3 | 47,58 |
| $Al_2O_3$ | 17,0 | 17,0 | 17,0 | 17,1 | 17,0 | 17,12 |
| $Fe_2O_3$ | 10,7 | 10,7 | 10,6 | 10,7 | 10,7 | 11,76 |
| MnO | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,14 |
| MgO | 5,0 | 5,2 | 5,1 | 5,1 | 5,1 | 5,18 |
| CaO | 11,6 | 11,7 | 11,7 | 11,7 | 11,7 | 10,12 |
| $Na_2O$ | 2,3 | 2,2 | 2,3 | 2,2 | 2,2 | 3,89 |
| $K_2O$ | 0,7 | 0,8 | 0,7 | 0,8 | 0,7 | 0,86 |
| $TiO_2$ | 2,8 | 2,7 | 2,8 | 2,7 | 2,8 | 2,72 |
| $P_2O_5$ | 0,4 | 0,3 | 0,3 | 0,3 | 0,3 | 0,41 |
| $H_2O$ | 2,1 | 2,0 | 2,0 | 2,0 | 2,0 | 0,19 |

Table 1: Results of the PLS concerning a basalt : the 4 spectra, the mean spectrum and the reference data.

## References


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