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Compositional diversity of mafic rocks in the vicinity of Valles Marineris, Mars, using Modified Gaussian Model

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Abstract

We present our results on mafic minerals detection and characterization using an adapted version of the Modified Gaussian Model. We look at large crater central peaks with MRO/CRISM data to probe subsurface composition. Here are the first results concerning chemical composition of pyroxenes.

1. Introduction

Mineralogical composition is essential to further comprehend planetary evolution. As it is linked to mantle properties and crystallization conditions, the chemical composition of each mineral in the primitive crust is related to the igneous processes which have affected the planet. In this respect, detection of mafic minerals, such as olivine and pyroxenes, and characterization of their respective composition is used to evidence petrological history.

Because of the Fe^{2+} electronic transition effect, hyperspectral remote sensing in visible/near-infrared delivers very useful information for characterizing the petrology of igneous rocks. Olivine has three characteristic absorptions in the 1µm wavelength domain, distinct from the pyroxenes ones. Orthopyroxene and clinopyroxene have both absorptions in the 1µm and 2µm domains [1,2].

In the present work, we chose to focus on large impact craters central peaks that excavate material from depths [4].

2. Methodology

1.1 Dataset

Data used in this study were acquired by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard the Mars Reconnaissance Orbiter (MRO) spacecraft. CRISM observations provide visible and near-infrared (VNIR) spectral coverage (0.32–3.92) with maximum spatial resolution of ~18 m/pixel [5]. CRISM observations were processed as described in *Ehlmann et al.* [6] to account for atmospheric and photometric contributions. Noise was removed using the despiking and destriping algorithms available under CAT 6.6 for TRR2 datasets [7]. Visible and near-infrared channels were also coregistred in order to use the entire available spectral domain.

1.2 Adapted Modified Gaussian Model

To deconvolve hyperspectral data, we use the Modified Gaussian Model (MGM) originally developed by *Sunshine et al.* [8] and adapted by *Clenet et al.* [9,10]. MGM methods aim at deconvolving the absorption bands in reflectance spectra. It is achieved considering a sum of Gaussian functions and assuming that the spectral continuum can be modelled by a polynomial shape. Each Gaussian function (characterized by its band center, width and strength) or combination of Gaussians permits the identification of a mineralogical absorption band, generally characterizing the predominant mafic minerals.

An automatic procedure involving different numbers of gaussians, depending on the potential complexity of the mixture, has been implemented on the original MGM approach [10]. The starting values for the continuum and the Gaussian strengths and widths are derived on the basis of a spectral shape smoothing analysis, determining the relevant local maxima along the spectrum. Relative coefficients applied to each gaussian parameters are estimated based on [11,12]. The uncertainties are set large enough to set a large degree of freedom on the parameters. Based on laboratory spectroscopic studies addressing separately pyroxene mixtures and olivine suite [2,8,11,12], the produced mathematical solutions are then sorted in order to keep only those which verify

the mineralogical constraints. The resulting band parameters (center, strength, width) are then used to interpret the spectrum in terms of modal abundances and chemical compositions [9,10]. Validation processes have been made on both laboratory and natural data [9,10,13].

3. Results on crater central peaks

The seven possible configurations, i.e. the different mineralogical combination which can involve olivine and/or orthopyroxene and/or clinopyroxene, are systematically tested on each pixel of the CRISM image. Based on the validated configuration(s), the dominant mineralogy is found and the different units can be mapped (e.g., [9]).

Calculated Gaussians parameters are then studied to extract specific information on the minerals. Here we focus on pyroxenes chemical composition. We use the position of the absorption center, directly related to Ca and Fe content [14], to map variability into each central peak. Small variations can be found (e.g., figure 1 on Alga crater), showing no obvious link with morphology. This may be related to impact process or to different units in subsurface, as impact crater may have sampled rocks over several kilometers in depth. Other crater central peaks show similar trends (figure 2) with even a larger range of composition. One should note on Ritchey central peaks a small shift above Adams trend, probably related to small abundance of olivine.

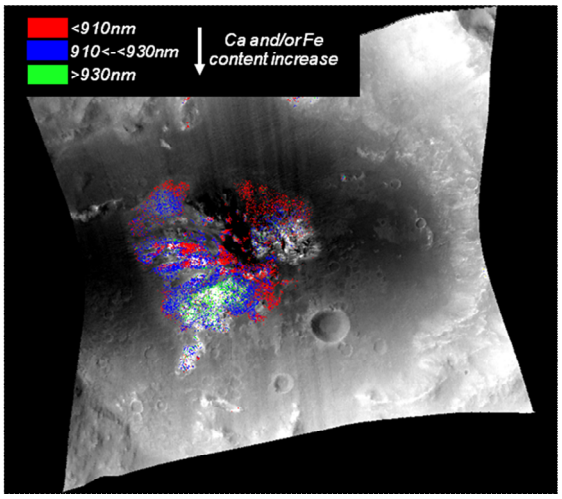

Figure 1: Pyroxene 1µm absorption centers as an indicator of orthopyroxene chemical composition.

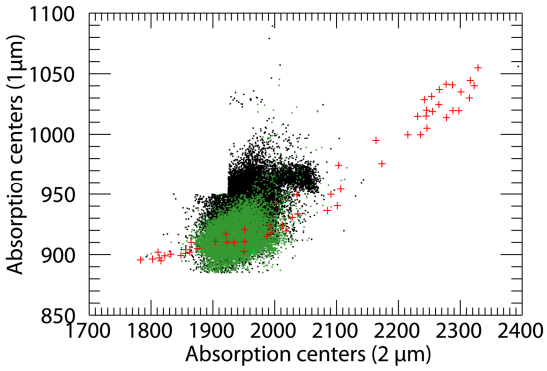

Figure 2: Comparison between Alga and Ritchey central peak pyroxenes (respectively green and black dots) and Adams reference trend (red cross)

Calculations are ongoing to determine pyroxenes (and olivine) chemical compositions for additionnal central peaks, as weel as rock exposures in the walls of Valles Marineris, and to map their composition variations based on available CRISM dataset.

6. Conclusions

Our automatic procedure based on the MGM now allows us to characterize small outcrops observed by CRISM. First results in crater central peaks show orthopyroxene dominant mineralogies associated to the old Noachian crust. Small variations in pyroxene composition can be observed without obvious link to specific morphology. Ongoing analysis should evidence all the existing compositions and, considering the relation with crystallization conditions (e.g., [15]), highlight the petrological history in the region.

References

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