

COMPOSITIONAL DIVERSITY OF MAFIC ROCKS IN THE VICINITY OF VALLES MARINERIS, MARS, USING MODIFIED GAUSSIAN MODEL. H. Clenet¹, J. Flahaut¹, C. Quantin¹, P. C. Pinet², Y. Daydou² and P. Allemand¹, ¹Laboratoire de Géologie de Lyon, UMR CNRS 5276, Université Claude Bernard/Ecole Normale Supérieure de Lyon, 2 rue Raphaël Dubois, 69622 Villeurbanne Cedex, France, ²UMR 5562/DTP, Observatoire Midi-Pyrénées, Université Paul Sabatier, Toulouse, France. (harold.clenet@univ-lyon1.fr)

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 $1\mu\text{m}$ wavelength domain, distinct from the pyroxenes ones. Orthopyroxene and clinopyroxene have both absorptions in the $1\mu\text{m}$ and $2\mu\text{m}$ domains [1,2].

In the present work, we chose to focus on areas which exhibit well-preserved Noachian crust. This includes both the walls of Valles Marineris, where emplaced pristine rocks outcrop [3], and large impact craters central peaks that excavate material from depths [4]. Both contexts are also studied by Flahaut *et al.* [3] and Quantin *et al.* [4], giving that way a first overview of the rocks spatial distribution and geological context.

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 Flahaut *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 coregistered in order to use all the available spectral domain.

Methodology: 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].

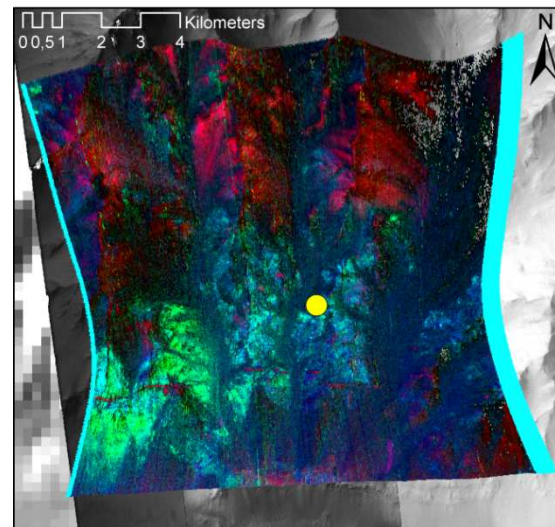


Fig 1. RGB color composite of CRISM data used on the northern wall of Coprates Chasma (Valles Marineris). Red is OLindex2, green is LCPindex and blue is HCPindex, as defined in CAT6.6 and [14] (CRISM cube FRT00009DB4). Yellow dot localize the spectrum analyzed in figure 2.

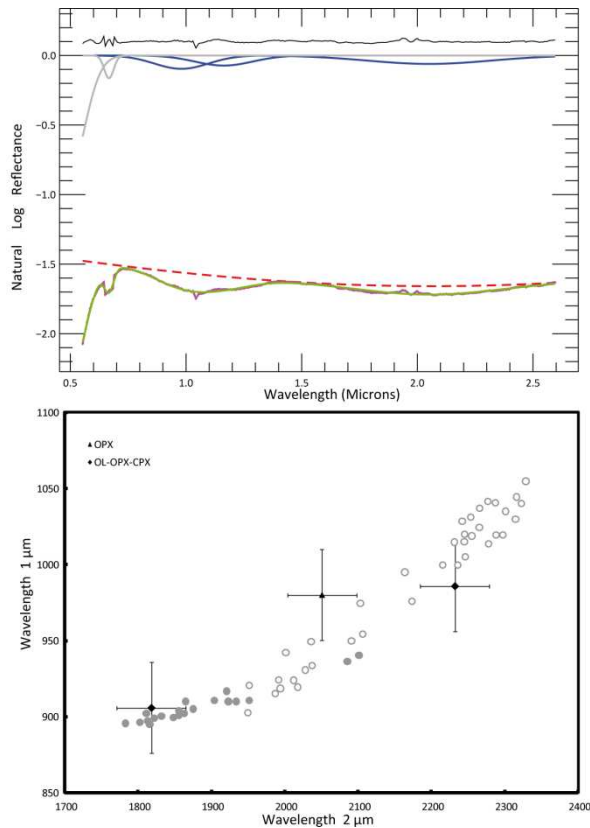


Fig 2. Top: MGM model of the spectrum defined in figure 1, in the case of an orthopyroxene composition.

Bottom: Pyroxenes absorptions centers in Adams diagram [2] with triangles for orthopyroxene only configuration and diamond for ternary mixture configuration (error bars from [15]).

Application to CRISM dataset: As mentioned earlier, we especially focus here on the Noachian crust outcrops in the region of Valles Marineris (i.e. in the walls of Coprates Chasma and in the surroundings crater central peaks). Summary parameters from [14] were first used to detect outcrops showing strong mafic signatures. Summary parameters used are the LCPindex (Low-Calcium Pyroxene), HCPindex (High-Calcium Pyroxene) and OLindex2 (Olivine). An example is shown in figure 1, in the case of the CRISM cube FRT00009DB4. Selected pixels are then analyzed using the adapted Modified Gaussian Model. In the lower part of Coprates Chasma northern wall, selected pixel shows strong absorptions both in the 1 and 2 μm domain (see top part of figure 2). The seven possible configurations, i.e. the different mineralogical combination which can involve olivine and/or orthopyroxene and/or clinopyroxene, are tested.

The simplest solution involves a pyroxene alone, considering an intermediate composition (see bottom part of figure 2). The small shift observed compared to

Adams' trend [2] could be related to the presence of olivine. However, in the case of an olivine-pyroxene mixture, mathematical solutions are rejected because the Gaussian parameters do not respect literature trends. In the case of the two pyroxenes configuration, NBSR parameters, as defined by [15], are not similar at 1 and 2 μm (respectively 0.38 and 0.49). Moreover, the Gaussian centered around 1200 nm is stronger than the pyroxenes absorptions in the 1 μm domain. These results suggest that a ternary mixture could better explain the data. Indeed, pyroxenes results are both in Adams' trend (see figure 2 bottom) and NBSR parameters are close at 1 and 2 μm (respectively 0.45 and 0.47). One should however note that olivine Gaussian centers are slightly off the trends defined by [12], this may be due to the lack of experience we have for the initialization process in the case of ternary mixture [10].

Interpretation of those results should be done with caution: further investigations are needed to determine whether dust from upper layers can affect minerals detection or not, especially when considering clinopyroxene presence in old crustal outcrops. Then, the next step is the interpretation of the Gaussian parameters in terms of chemical composition using literature (e.g. data from [12] and [16]). Calculations are ongoing to determine pyroxenes and olivine chemical compositions in different areas and to map their variations based on available CRISM dataset.

Conclusion: Our automatic procedure based on the MGM, initially developed for OMEGA/MEx data, now allow us to characterize small outcrops observed by CRISM/MRO. First results show potentially complex mineralogies in the old Noachian crust exposed in Valles Marineris. Ongoing analysis should evidence all the existing compositions and, considering the relation with crystallization conditions (e.g., [17]), highlight the petrological history in the region.

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