SYSTEMATIC MAPPING OF MAFIC MINERALS ON THE MOON: AN IMPROVED APPROACH BASED ON MODIFIED GAUSSIAN MODEL APPLIED TO M³ DATA.

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Introduction: Mafic minerals are key components when trying to understand the geological history of planetary bodies like the Moon. Indeed, their presence in igneous rocks is directly related to mantle properties and crystallization conditions. In this respect, systematic detection of olivine and pyroxenes and characterization of their compositions provide important insights into planetary thermal and chemical evolution.

Because of the Fe^{2+} electronic transition effect, hyperspectral remote sensing in the visible/near-infrared is a powerful tool to achieve this objective. Indeed, olivine and pyroxenes have characteristic absorption features in the 1 and 2 µm domains [1,2]. While several techniques aid in deconvolving absorption bands in terms of mineralogy, we employ the Modified Gaussian Model (MGM, [3]). The MGM can be used to estimate quantitatively both the modal composition of a rock and the chemical compositions of its component minerals.

An improved MGM approach dedicated to the processing of large planetary datasets has been developed recently [4]. It has been validated on Martian data, from both the OMEGA and CRISM instruments [5,6]. Here, we propose to test this approach's suitability for data collected by the Moon Mineralogy Mapper (M³) instrument.

Dataset: The Chandrayaan-1 M³ instrument is a high-resolution visible to near infrared (0.43-3.0 µm) imaging spectrometer [7]. We used data acquired at ~140 m/pixel with 85 channels. M³ data were radiometrically calibrated and photometrically corrected (PDS level 2). A mosaic composed of several M³ strips was created and processed. The mosaic is located near the crater Stevinus (~33S, 54E) where optically immature material is exposed.

Method: The MGM is designed to deconvolve absorption bands in reflectance spectra. Spectra are deconvolved into a series of Gaussian functions and a spectral continuum modelled by a polynomial shape. The optimized Gaussian functions (characterized by band center, width and strength) permit the quantification of mineralogical absorption bands diagnostic of mafic mineral abundance and composition, generally characterizing the predominant mafic minerals for each pixel (input spectrum) in the scene.

An automated procedure involving different numbers of gaussians, depending on the potential complexity of the mixture, has been implemented based on the original MGM approach [4]. The starting values for the continuum and the Gaussian strengths and widths are chosen during a spectral shape smoothing analysis, which determines the relevant local maxima of the spectrum. Relative coefficients applied to each Gaussian parameters are estimated based on [8,9]. The uncertainties are set large enough to give a large degree of freedom for the parameters. Based on laboratory spectroscopic studies addressing separately pyroxene mixtures and the olivine suite [2,3,8,9], the produced mathematical solutions are then sorted in order to keep only those that are consistent with known properties of
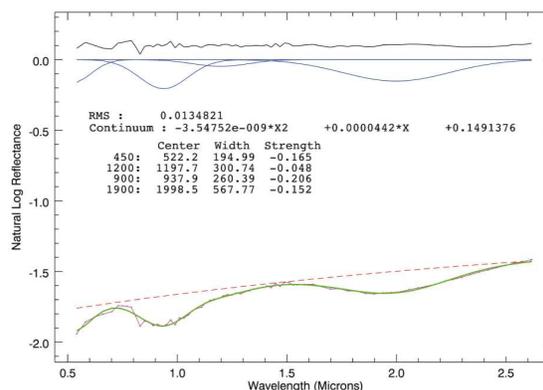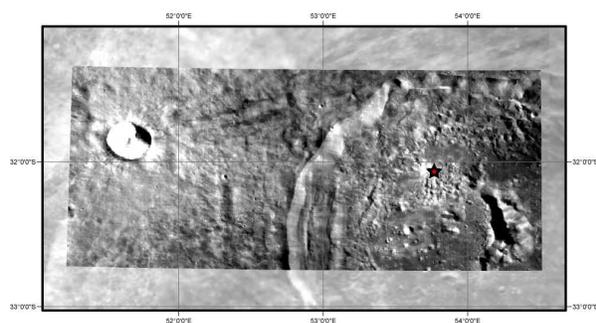

Fig. 1: Localization of a test spectrum within the Stevinus crater region (red star in the left subset) and associated MGM result considering the clinopyroxene configuration (right subset).
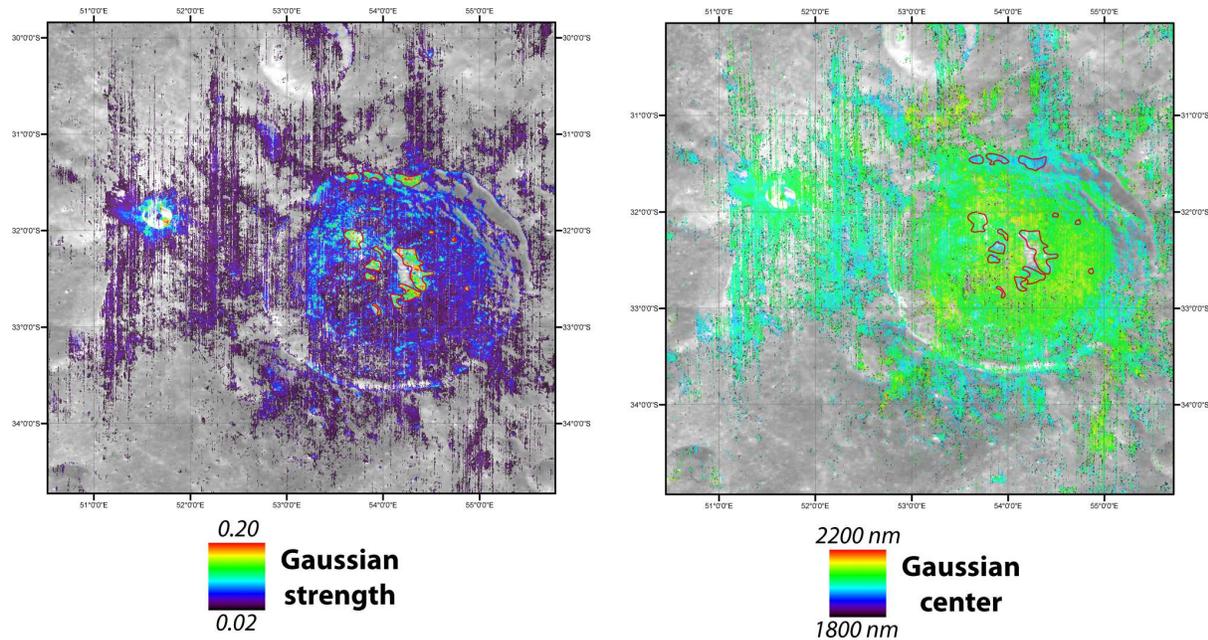
Fig. 2: Global MGM mapping over the whole Stevinus crater region. Results are obtained considering the validated clinopyroxene configuration. Left: Gaussian strength (i.e. modal abundance) associated to the 2 µm clinopyroxene absorption. Right: Position of the Gaussian center (i.e. chemical composition) considering the same absorption feature. Red lines enhance several areas where pyroxene signatures are particularly strong.

pyroxene and olivine spectra. The resulting band parameters (center, strength, width) are finally used to interpret the spectrum in terms of modal abundances and chemical compositions. Validation processes have been made on both laboratory and remote data [4].

Results on Stevinus crater region: Figures 1 and 2 show the results of our adapted MGM approach on the Stevinus mosaic. Much of the region's variability can be characterized with an initial configuration dedicated to clinopyroxene alone, although some pixels are better modeled considering rather orthopyroxene-rich rocks. This points toward local compositional variations, in agreement with results obtained on a test spectrum (Fig. 1). Calculated parameters indicate an intermediate composition, typically at the boundary between the two pyroxene types when considering the Adams 1 and 2 µm band posi-tion trend [2].

Mapping of pyroxene absorption strength show that the M^3 data are affected by instrumental artifacts (e.g., vertical stripes in Fig. 2 left). Nevertheless, the quality of M^3 level 2 calibration is good enough to map pyroxene-rich outcrops on the northern rim, in the central peak and in various spots on the crater floor. Interestingly, in those particular areas where the pyroxene signatures are very strong, we observe slightly different absorption centers (Fig. 2 right), again pointing toward local compositional variations in pyroxene composi-

tion. Additionally, these variations seem spatially distributed, indicating that a relation with the subsurface structure could exist. Analysis of high resolution imagery is now required to complete this study.

Conclusion: The adapted MGM approach used in this study shows promising results when applied to M^3 data. Pyroxene-rich outcrops are correctly detected in the observed regions, and variations in mineral composition are also observed. This is of particular interest to better constrain lunar petrology using impact craters central peaks that excavate material from depth. To test further our processing pipeline, additional mosaics have been prepared for validation. These mosaics include more mineralogical diversity, including greater diversity in pyroxene composition and the presence of olivine.

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