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OLIVINE DETECTION AND COMPOSITION DETERMINATION AT COPERNICUS AND ERATOSTHENES CRATERS. P.C. Pinet^{1,2}, S.C. Chevrel^{1,2}, Y.H. Daydou^{1,2} and D. Dhingra³, de Toulouse; UPS-OMP; IRAP; Toulouse, France, ²CNRS/CNES; IRAP; 14, avenue Edouard Belin, F-31400 Toulouse, France, ³Dept. Earth Sciences, Indian Institute of Technology, Kanpur, India. (patrick.pinet@irap.omp.eu)

Introduction:

We build on the previous works carried out [e.g.,1,2] to document at best the compositional variation of olivine from diagnostic absorption features across the visible and near-infrared wavelengths due to electronic transitions of Fe²⁺ in the crystal structure. Based on an advanced MGM deconvolution approach, the behavior of the three primary olivine absorptions near 1 μm (referred to as M1-1, M2, M1-2) is revisited. This improved modeling is then applied to orbital observations made with Chandrayaan-1 Moon Mineralogy Mapper (M3) over Copernicus and Eratosthenes craters.

MGM implementation:

The principle of the Modified Gaussian Model is to deconvolve overlapping absorptions of mafic mineral spectra into their fundamental absorption components. Spectra are modeled in the logarithm of reflectance space as a sum of modified Gaussian distributions superimposed on a baseline continuum [e.g., 3,4]. The current procedure is described in [5,6].

Olivine Spectra Deconvolution / Methodology:

MGM inverse modeling provides with band center, band width and band depth estimates. Band centers are used to determine trend line equations for each individual absorption band, with an assessment on the regression performance (rms spectral distance between bandcenter estimate from MGM and the one from the trend line).

The olivine composition (Molar Forsterite Fo#) is then predicted based on minimizing the deviations in band centers from the established trends for the three absorptions simultaneously, using the integrated rms spectral distance to trend quantity (**sdt**).

As presented in [5,6,7], our MGM procedure has been implemented on both synthetic and natural olivine samples spanning the forsterite – fayalite solid solution series [7].

Though not discussed here, the possible influence of the presence / absence of an absorption feature in the spectral range 600-700 nm linked to electronic transitions of minor elements Cr³⁺, Ni²⁺ and/or Fe²⁺/Fe³⁺ spin-forbidden crystal field transitions is assessed.

An example is given hereafter (Fig.1) for a synthetic spectrum (Fo#20 case) from [2].

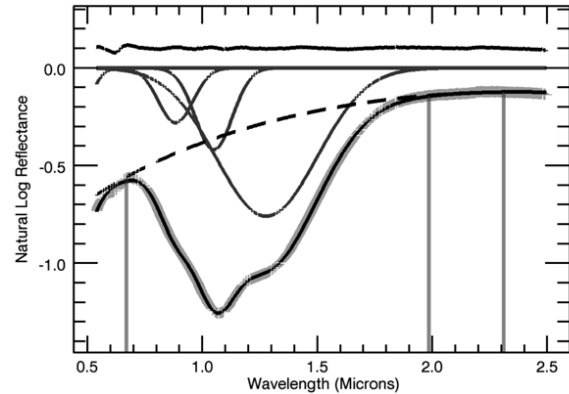


Figure 1. Case of C1DD96 (Fo#20). Measured spectrum (light grey crossed line) and MGM modeled one (thick black solid line) with the Gaussians (solid black lines) and polynomial (hatched line) and the residuals line along the spectral domain. Position of the local maxima along the spectrum used for the process of initialization (anchor points found at 670, 1985, 2310nm). For clarity, the residuals (observed – modeled quantity) are shifted by +0.1 which means that a perfect fit is displayed with a 0.1 flat line (rms : 0.005).

M3 orbital observations:

Copernicus: This procedure is then implemented on M3 spectra with the objective of documenting the petrology at Copernicus crater from spectra acquired over exposed outcrops (e.g., central peaks, inner walls and rims). The present study has been made on a subset of the M3G20090416T122951_V01_RFL hyperspectral image (140m/pixel) acquired during the OP2A optical period. Based on a previous selection of olivine-bearing spectra across Copernicus [5], we consider 5 spectra (Fig. 2) taken in the central peaks and northern wall and derive their composition (Molar Forsterite Fo#).

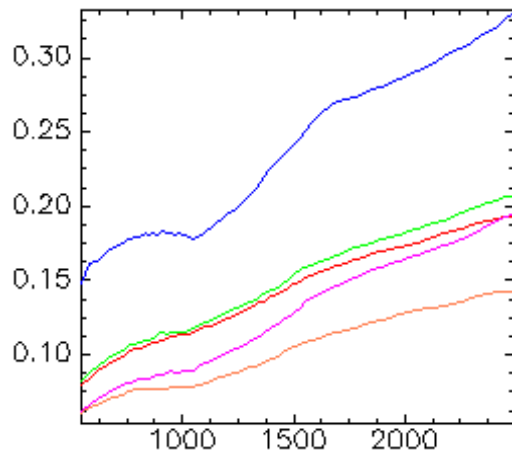


Figure 2. Selection of 5 spectra taken from the central peaks and the north wall of Copernicus crater.

As an example, the result of the MGM deconvolution for the blue spectrum (from Copernicus Pk3 peak, Fig. 2) is displayed and detailed (Fig. 3). From these deconvolutions, the olivine composition (Molar Forsterite Fo#) is derived for the 5 spectra (Fig. 4).

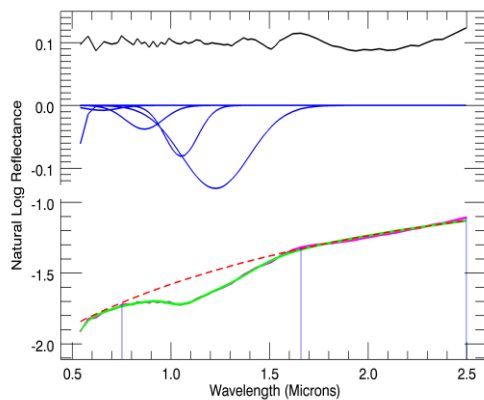


Figure 3. Copernicus Pk3 peak measured spectrum (light pink curve below the green one) and MGM modeled one (green solid line) with the Gaussians (solid blue lines) and polynomial (red hatched line) and the residuals line (black line) along the spectral domain. Position of the local maxima used for the process of initialization (anchor points found at 750, 1560, 2500nm). Residuals (see Fig.1) (rms : 0.007).

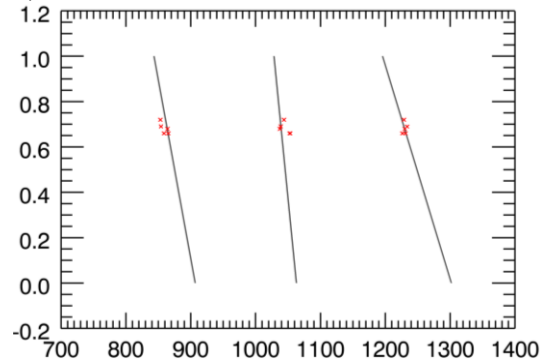


Figure 4. Olivine Composition estimates derived from our MGM for the 5 spectra shown on Fig. 2 in Molar % Forsterite vs band center (nm) graph.

A very interesting result is that for all spectra Fo# is found in the range of 0.70 \pm 0.05 consistent with the idea that there is no obvious local/regional variability in the subsurface petrology of the target.

Eratosthenes: We perform the same type of analysis (Fig. 5) on spectra acquired, during the OP1B optical period of M3-Chandrayaan mission, over Eratosthenes crater [8], in its central peak region. This crater (diameter: 65km, depth: 6.5km) formed about 3.2 Ga and is located on the southern edge of Mare Imbrium, about 250 km N-E of Copernicus. From this modeling, we produce an olivine composition estimate (Fig.6). Fo# is found in the range of 0.68 \pm 0.05.

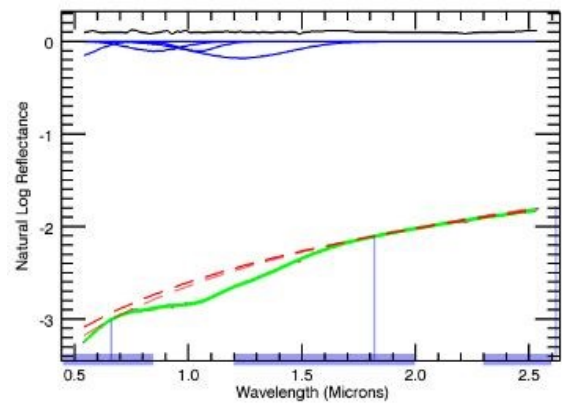


Figure 5. Eratosthenes measured spectrum (see fig. 3 caption). Position of the local maxima used for the process of initialization (anchor points found at 750, 1820, 2500nm). Residuals (see Fig.1) (rms : 0.008).

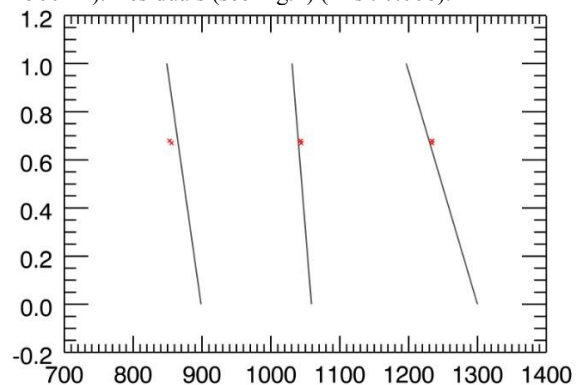


Figure 6. Olivine Composition estimates derived for the modeled spectrum shown on Fig. 5 in Molar % Forsterite vs band center (nm) graph.

Conclusions: The band center positions of the three primary olivine absorptions near 1 μ m can be used simultaneously to produce a well-constrained prediction across an extended range of olivine solid solution composition from spectra measured on synthetic, natural samples and from orbital observations. The current results obtained for both Copernicus and Eratosthenes craters indicate that the olivine composition is rather Mg-rich and homogeneous, in favor of a plutonic origin with a single mantle source. This approach is of great interest for preparing the selection of potential landing sites and in situ characterization of samples to be collected for addressing the exploration and identification of primitive mantle lunar rocks (e.g., Heracles, Chang'e-4 mission and following ones, ...).

References: [1] Sunshine J. M. and C. M. Pieters (1998) *JGR*, 103, 13,675–13,688. [2] Isaacson P.J. et al (2014) *Am. Miner.*, 99, 467-478. [3] Sunshine J.M. et al. (1990) *JGR*, 95, B5, 6955-6966. [4] Clenet, H. et al. (2011) *Icarus*, 213, 404-422. [5] Pinet et al. (2018) LPSC XLIX, #1899. [6] Pinet et al. (2019) LPSC L, #1806. [7] Pinet et al. (2019), ELS 7th Proc., #25. [8] Kumaresan, P.R. et al. (2019), pss.2019.104817.

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