

MANTLE ROCK SURFACE MINERALOGY MAPPING IN ARID ENVIRONMENT FROM IMAGING SPECTROSCOPY: THE CASE OF THE MAQSD PERIDOTITIC MASSIF IN OMAN AND IMPLICATIONS FOR THE SPECTROSCOPIC STUDY OF EXPOSED MAFIC UNITS ON MARS.

P. C. Pinet¹, H. Clenet¹, C. Rosemberg¹, G. Ceuleneer¹, F. Heuripeau, Esther Harris¹, Y. Daydou¹, D. Baratoux¹, S. C. Chevrel¹, Patrick Launeau², J.-P. Combes², S. LeMouélic², C. Sotin²

¹UMR 5562 / CNRS / GRGS, Observatoire Midi-Pyrénées, Toulouse University, France, ²UMR 6112 / CNRS, Faculté Des Sciences & Techniques, Nantes University, Nantes, France.

Introduction: The massif of Maqsd lies in a desertic region of Oman and is a large exposure of mantle rocks. It belongs to one of the largest outcrops on Earth of oceanic crust and residual mantle. The massif has been surveyed in December 2002 by means of an airborne HyMap hyperspectral sensor, with the generation of a 10x50 km coverage, produced with a 6 m/pixel spatial resolution and a spectral information consisting in 128 channels between 0.4 and 2.5 micron. A campaign of field spectrometry has also been carried out. These data have been analyzed by means of methodologies relying on multidimensional statistics and MGM deconvolution techniques. The objective is to explore quantitatively the geological surface heterogeneity at different spatial scales, ranging from the centimetric rock-scale to the integrated remote sensing scale of the observation (10 to 50m), and to provide a mean to retrieve, from the spectral characteristics, the lithologies including mixtures of pyroxenes and olivine, and to access to the petrology variations.

Methodology: It is based on a critical assessment of the mafic mineralogy identification when considering minimal a priori inputs in the MGM inverse problem [1,2,3]. MGM technique aims 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 modeled by a polynomial shape. Indeed, each Gaussian function (characterized by its band center, width and strength) or combination of Gaussians permits the identification of a mineralogical absorption band, indicative of the presence of the predominant mafic minerals (pyroxenes and/or olivine). However, it has long been recognized that the continuum removal is a difficult problem, especially when dealing with an extended spectral domain [e.g.,4,5,6,7,8,9]. Successive studies have considered a straight-line continuum, a double-linear tangential removal, a 3 component solution, consisting in a linear energy term, a linear in wavelength term, and an offset. This last solution was intended to give the continuum more flexibility to fit the characteristic spectral slope of lunar soils (« red » continuum) while keeping stability in optimizing the

continuum parameters and gaussian parameters. Reassessing the problem has prompted us to approximate the continuum by means of a slightly convex degree 2 polynomial in wavelength term, considering it as the simplest spectrum envelope to deal with variable shapes of spectra in the visible-near infrared domain, including negative slopes. Depending on the mineralogical complexity encountered, an increasing number of gaussian bands set free (no fixed parameters, either band center, width or strength) has been considered, when dealing with a ternary mixture (Opx /Cpx / Ol). As an example is shown in Fig. 1 the MGM deconvolution of a laboratory sample (courtesy of Brown / CRISM library) presenting a ternary mixture mineralogy.

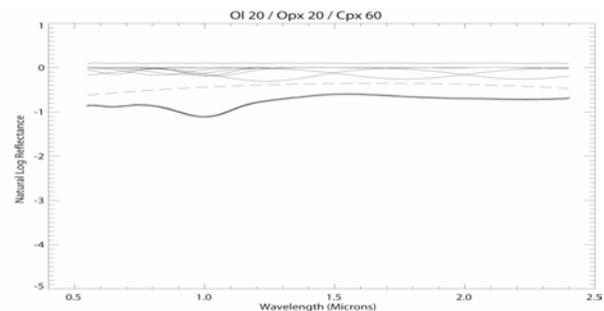


Figure 1. MGM deconvolution on sample (Ol 20% / Opx 20% / Cpx 60%)

We have then developed a procedure for a tentative mineralogical classification from MGM outputs. After MGM deconvolution, a potential identification of main components present in a given pixel is carried out through a systematic testing of all band combinations ordered by decreasing depths. Sorting of bands is performed based on the available laboratory studies addressing separately pyroxene mixtures and olivine suite [1,2,3]. The algorithm detects all possible combinations of absorption bands in the 1 and 2 micron spectral domain, in order to determine whether the pixel mineralogy is mainly controlled by the presence of orthopyroxene or / and clinopyroxene, as identified from Adams' diagram [10]. Experimental results on olivine series are also used for olivine bands identification [3].

Results and future directions: Despite the occurrence of hydration processes of the primary minerals resulting in the development of serpentinization, and of weathering processes resulting in the presence of an alteration varnish, olivine and pyroxenes can be detected. Indeed, spatially organized variations are revealed (cf. Fig. 2) that could be used to produce a new type of predictive lithology / mineralogy maps. As shown on the RGB global mosaic revealing the main units and boundaries (peridotite field in blue-green; crustal section in brownish- purple), the above MGM procedure has been applied to selected regions (colored frames) with the resulting maps displayed for 2 of them (Area 1 “cpx040M39N” and area 2 “Trocus”) as blown-ups (cf. Figs 3a & 3b). Area 1 shows the contact between the mantle and the crust, while area 2 is in the crustal section. With the support of field spectrometer and laboratory data, it gives potentially access to the synoptic mapping of subtle petrologic variations which will be checked against ground truth in a forthcoming fieldtrip peridotite

field, harzburgite and dunite are identified, while in the crustal section, rocks present lithologies consistent with troctolite, wherlite and gabbros [11, 12 (cf. Fig. 4)]. Both the implemented methodology and the produced scientific outputs are of interest for interpreting the hyperspectral data acquired for the martian surface by Omega / Mars Express or to come with CRISM/ Mars Reconnaissance. Implementation and testing of this approach on both laboratory samples from the Brown / CRISM spectral library and on OMEGA data is underway.

References: [1] Sunshine J. et al. (1990), *JGR*, 95, 6955. [2] Sunshine J. and C. Pieters (1993), *JGR*, 98, 9075 [3] Sunshine J. and C. Pieters (1998), *JGR*, 103, E6, 13675. [4] Cloutis E.A. et al. (1986), *JGR*, 91, B11, 11641. [5] Gaffey M. et al. (1993), *Icarus*, 106, 573. [6] Hiroi T. et al. (2000), *LPSC XXXI*, # 1548. [7] Noble S.K. et al. (2005), *LPSC XXXVI*, # 1255. [8] Hardersen et al. (2005), *Icarus*, 175, 141. [9] Schade U. et al. (2004), *Icarus*, 168, 80. [10] Adams, J., *JGR*, 79, 4829. [11] Amri, I (1995), *Ph.D. thesis*, Toulouse III Univ., France. [12] Combe J.P. et al. (2006), *G-cubed*, in press.

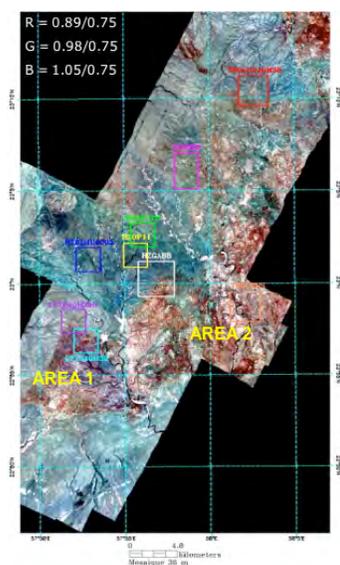


Figure 2 (Left) RGB composite (spectral ratios: R (0.89 / 0.75 micron), G (0.98 / 0.75), B (1.05 / 0.75)) evidencing the spectroscopic variability existing within the peridotite field and crustal section. See fig. 3a for AREA 1 and 3b for AREA 2.



Figure 4 (Right). Geological map of the crustal (shown in red / brown) and mantle (pale green) section of Sumail Oman ophiolite from [11].

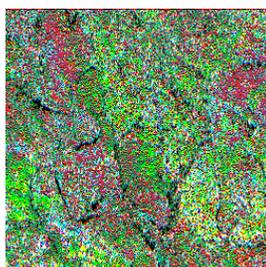


Figure 3. Tentative identification of predominant minerals from MGM results. **Fig. 3a** (Right) for AREA 1 and **Fig. 3b** (Left) for AREA 2 (square size ~ 2km x 2km). Color coding: is Red: Opx+Cpx+Ol, Brown: Opx + Cpx, Dark blue : Opx+Ol, Light blue: Opx, Dark green: Cpx, Light green: Cpx+Ol, Black: NaN.

