Radiative Transfer Models for Reflectance Spectra

A Model of Spectral Albedo of Particulate Surfaces: Implications for Optical Properties of the Moon

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[Icarus, 1999]

**FIG. 1.** A scheme of light propagation: (a) through a particulate medium and (b) through plates in a pile.
Quantitative compositional analysis of martian mafic regions using the
MEx/OMEGA reflectance data
1. Methodology, uncertainties and examples of application

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### Spectral Endmembers

Reflectance spectra are obtained from existing libraries and inverted to estimate values of k.

This requires knowledge of particle size!
The derived optical constants can then be used to forward-calculate what the reflectance spectra should look like for different grain sizes.

[Poulet et al., 2009]
Fig. 2. Effects of the admixtures. (A) Synthetic spectra of intimate mixtures of HCP mixed with varying concentrations of plagioclase (from 0 to 80% by step of 20%). A spectrum extracted from the mafic-rich DCT terrains is shown in red for comparison. (B) Same as (A) but with LCP instead of HCP. (C) Same as (A) but with olivine (Fo90) instead of HCP. (D) Synthetic spectra of three mixings of olivine (Fo90) with HCP in different proportions (0, 20, 40). The grain size is 50 µm for each mineral.
3.2. Sensitivity to the grain size

Clase and dust) can be assessed using major end-members of different phases (LCP, HCP, plagio-

from the remote measurements of OMEGA, the modal composition of DCT terrains. The two simulations differ in the HCP end-members (diamond: Fig. 4. Poulet and Erard, 2004)

Fig. 5. Sensitivity to the grain size. (A) The OMEGA spectrum (black line) is compared to three models. The best fit (red line) is obtained by assuming all the parameters free (see Table 2 for final results) and was already shown in Fig. 3. If the grain size is forced to be 100 (blue spectrum) or 200 µm (green spectrum), the fits are slightly degraded. (B) The abundances of three major minerals correspond to the simulations shown in (A).

Fig. 3. Modeling of a spectrum extracted from the DCT unit of Terra Meridiani. (A) Spectra of the major end-members used in the fit procedures. (B) OMEGA spectrum (black line) compared to two best fit models (red and blue lines) and a model-derived spectrum (green line) for which the LCP component was excluded. The best fits in red and blue include diopside and augite respectively as the HCP end-member. The values of the RMS are indicated.
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Fig. 9. (A) Spectra of end-members used for the fits shown in (B). The olivine is forsterite with grain size forced to be 10 µm. (B) Spectrum and best fits without olivine (red), with an olivine abundance forced to be 10% (green) and 15% (blue). Grain size and abundance are indicated for each end-member. Values in parenthesis correspond to the best fit (red spectrum) and are compared to the simulation with 10% of olivine. The arrow indicates the location where the spectrum is the most affected by the presence of olivine. (C) Same as (A) but the grain size is here forced to be 100 µm. (D) Spectrum and best fits without olivine (red) and with olivine at 5% (blue).

Fig. 10. Two OMEGA observations of a dark terrain (354.7° E, 2.63° S) close to the Opportunity landing site (solid lines) with similar photometric angles (nadir pointing, solar incidence angle of ∼50°) but different amounts of dust in the atmosphere (dustier conditions in black). Aerosol optical depths $\tau$, interpolated at 0.926 µm from Pancam measurements, are indicated (Lemmon et al., 2004; Lemmon, 2006). The surface spectra retrieved from these observations (dashed lines) are similar, which further validates our approach.

Therefore applied to the OMEGA data cubes over Terra Meridiani because of the proximity of the MER-B that measures the aerosol optical depth thanks to Pancam observations. A test was done in using two overlapping observations of Terra Meridiani obtained with different amounts of dust in the atmosphere (Fig. 10). After removing the aerosol contribution, the derived surface spectra of the same region are similar, making us confident in the accuracy of our aerosol correction method. Aerosols are characterized by a decreasing continuum slope between 1 and 2.5 µm. The removal of their contribution increases the spectral signatures and modifies the general slope of the spectra (Fig. 11).

We now aim to estimate the uncertainties on the modal mineralogy resulting from the aerosols contribution. For this investigation, we model several thousands of aerosol-cleaned OMEGA spectra, whom the inferred mineralogy was previously derived from uncorrected spectra (see simulation 1 of Fig. 7). Small differences between the abundances and the grain size distributions exist, but they are all within the derived uncertainty of the method (Fig. 12):

\[29 \pm 4\% \text{ in comparison to } 28 \pm 3\% \text{ for the HCP component, } 11 \pm 4\% \text{ versus } 10 \pm 4\% \text{ for LCP and } 50 \pm 6\% \text{ versus } 52 \pm 4\% \text{ for plagioclase}\]

This sensitivity test indicates that the application of our spectral model to OMEGA spectra uncorrected for the aerosol contribution produces reliable values.

4. Application of the method to the DCT unit of Terra Meridiani

4.1. Derived mineralogy

We use the spectral model on OMEGA reflectance spectra extracted from a part of the mafic-rich regions observed in Terra Meridiani, also referred as DCT unit (Arvidson et al., 2003). Detailed mapping of the Terra Meridiani region shows that different...
Fig. 6. Spectra extracted from different low albedo regions compared to their best fit model in red. Each spectrum corresponds to one OMEGA pixel. Left, from top to bottom: Syrtis Major Lavas (SML), Hesperia Planum (HP), Nili Fossae olivine-rich terrain (NFO), Echus Chasma (EC), Terra Tyrrhena (TT). Right, from top to bottom: Hesperia Planum (HP), LCP-rich outcrop (LCP1), olivine-rich dunes in Nili Patera (SMN2), Solis Planum (SL), Terra Tyrrhena (TT). For TT and HP, two spectra are shown to emphasize the spectral diversity of these regions. The RMS values are in the 0.11–0.28% range depending on the spectrum.