Laboratory spectral measurement of particulate samples of altered olivine and related planetological studies

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Abstract. In this work we present the results of spectroscopic studies on different particulate samples of various olivines, analysed in reflectance in the range 0.2-2.5 μm. We focused on influence of grain size on the characteristics of absorption band at 0.64 μm, which is commonly present in the spectra of altered as well as unaltered olivine. The exact position of the two reflectance maxima at 0.56 μm and 0.7 μm, as well as their relative intensity, can supply important informations about the characteristics of the regolith present in the celestial object under study. For this purpose, we analysed some reflectance spectra collected by the visible-infrared imaging spectrometer OMEGA/MEx in two regions of Mars where previous works [5,6] reported the presence of olivine deposits. Our goal is to isolate such weak structures in the OMEGA spectra and to compare them with laboratory results.

Introduction. Olivine ($(Mg,Fe)_2SiO_4$) is a silicate mineral consisting of an isomorphic mixture of forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Among the materials of planetological interest, olivine is particularly important due to its ubiquity in the Solar System and to the fact that, in presence of water, it readily alters to iddingsite and various phyllosilicates [2]. For this reason, olivine plays an important role in the framework of the research on the occurrence of surface water and the geochemical evolution of celestial bodies on which it has been observed.

Laboratory research on terrestrial particulate olivine samples allows us to interpret the data coming from space missions. In the first part of present work we show and discuss the experimental results concerning reflectance measurements, made on various olivines of various grain sizes. The second part, instead, concerns comparison between laboratory results and martian spectra, in order to obtain informations about characteristics of the martian regolith.

We have produced several samples of different kinds of olivine, starting from their bulk and producing a general mixture of sand and dust. Particulate samples of olivine have been divided, using a set of sieves, in six different size classes, in order to cover the whole size range of martian regolith [3]. The volume size distribution of the average diameter D of the grains in the various ranges has been evaluated with a granulometer [7].

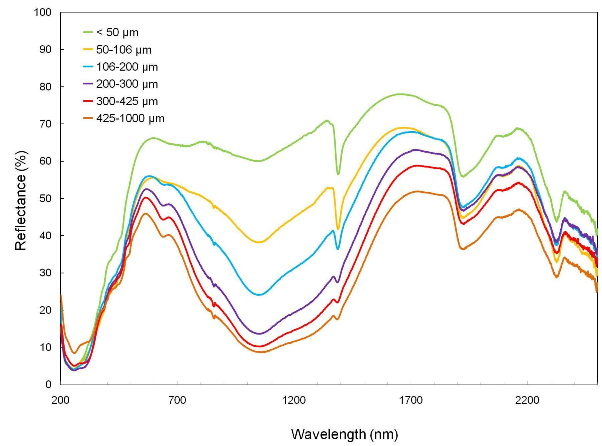

Figure 1. Reflectance spectra of a sample of olivine in the selected size ranges.

In Fig. 1 we report all the spectra relative to the six grain size fractions obtained for a sample of olivine, which seems to be the most altered among those we analyzed. The main feature present in all spectra is that at about 1 μm, ascribed to ferrous iron [1]; the early stage of aqueous alteration is clearly suggested by the bands at 1.4, 1.9 and 2.3 μm. The most likely origin of the feature at 0.64 μm is a spin-forbidden Fe^{2+} transition [4], but the altered nature of the sample allows us to state that the band could be partially due to oxidized iron present in olivine grains, as a result of their aqueous alteration. It is immediately evident that not only the continuum level increases and the spectral contrast decreases as the grain size becomes smaller, but also the two reflectance maxima around 0.64 μm undergo evident changes, both in position and in relative intensity. In details, plotting the position of the two peaks against the average effective diameter D of the grains, the maxima shift towards smaller wavelengths as D increases. A very similar trend is shown by most altered olivines. Another result is that the peak at 0.56 μm has a smaller variation then that at 0.7 μm. We also introduced a spectral parameter

$$\Delta_n(D) = \frac{[R(\lambda_1) - R(\lambda_2)]}{[R(\lambda_1) + R(\lambda_2)]}$$

where $R(\lambda_1)$ and $R(\lambda_2)$ are the measured reflectivity of the maxima at 0.56 μm and around 0.7 μm, respectively. A common general trend exists for all the olivines we analyzed: n increases as D increases, but the differences among the various types are not negligible.

OMEGA data analysis. Starting from hyperspectral images of various instrumental observations, we constructed data mosaics covering two Martian regions, where olivine has been detected: Nili Fossae, part of Isidis Basin and Syrtis Major (15-30°N, 65-80°E) and a portion of Valles Marines around Aurorae Planum and Ganges Chasma (0-15°N, 45-60°W). Each spatial pixel contains a spectrum, which varies according to the albedo of the surface; for this reason we have normalized all spectra in the visible range (0.4-0.9 μm), in order to be able to compare them properly.

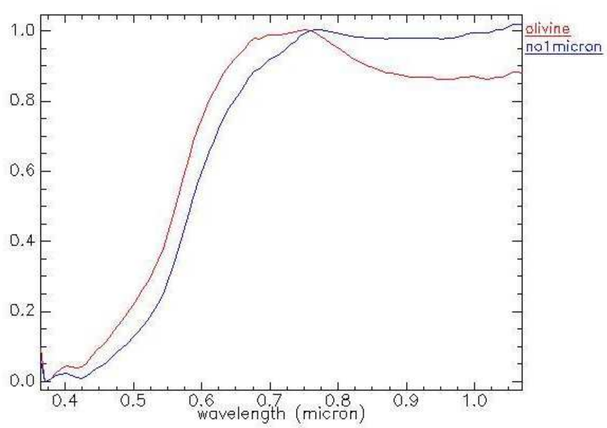

Figure 2. Average normalized spectra of the two groups discussed in the text.

Using appropriate spectral indexes, we generated two groups of spatial pixels: one containing the 1 μm olivine main feature and the other lacking it. In Figure 2 we reported the two average normalized spectra. A simple comparison between them has not allowed us to evidence the weak features at 0.56 μm and 0.7 μm, displayed in the laboratory olivine spectra. The presence of a noticeable slope between 0.4 and 0.7 μm, probably due to ferrous oxides, fairly abundant on the Martian surface, is making their identification particularly difficult. 4.

Summary and Conclusions. Comparison between laboratory results and OMEGA data can supply valuable information about the grain size and other characteristics of the Martian regolith in the analyzed regions and our attempt to obtain constraints on olivine grain size is still in progress. In the meantime, we are also testing a method, aimed to selecting spatial pixels of an hyperspectral image showing the 1 μm feature, based on the position of the spectral slope in the visible range (Figure 2). If successful, such attempt would definitely improve our ability to select olivine bearing spectra in OMEGA database.

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