Mem. S.A.It. Suppl. Vol. 16, 76

Memorie della
Supplementi

Mars mineralogy with VIS/OMEGA

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Abstract. In this paper we present preliminary results about the capability of Mars Express/OMEGA visible channel in the mineralogical study of the Mars surface. The observed spectral reflectance properties can reflect areal or intimate mixtures of different oxidation degrees of the minerals. We introduce several spectral parameters involving VIS wavelengths, which prove to be very useful in describing the mineralogical variability. We report here about the analysis of 5 Martian regions where a mineralogic diversity has already been reported: Valles Marineris, Aram Chaos, Terra Meridiani, Syrtis Major, Mawrth Vallis.

Key words. Solar System: Mars – surface – spectroscopy – mineralogy

1. Introduction

This study has been carried out by using data from the Mars Express/OMEGA imaging spectrometer. The spectral reflectance properties are a result of the complex combination among the spectra of single minerals. They can be the result of an areal or intimate mixing of different minerals or the result of one mineral with a high oxidation degree as well. The study of the band center position is the most used method to discriminate minerals. Nevertheless, in many cases this method cannot be used due to the presence of few absorptions or the impossibility to determinate the bands minimum position. For this reason it is necessary to introduce other parameters to characterize the spectra. We have mainly focused on the OMEGA visible channel (VIS). In this paper we present preliminary results about 5 regions, where a mineralogic diversity has already been reported: Valles Marineris, Aram Chaos, Terra Meridiani, Syrtis Major, Mawrth Vallis (see Fig.1).

2. The OMEGA instrument

The OMEGA/Mars Express instrument has been designed for mineralogical and atmospheric investigation of Mars. It is an imaging spectrometer covering the 0.35-5.1 μm (visible and near infrared) wavelengths range. The instrument is composed by three spectrometers: VNIR (0.35-1.05 μm), IR C channel (0.92-2.7 μm), IR L channel (2.7-5.1 μm) (Bibring et al. 2004).

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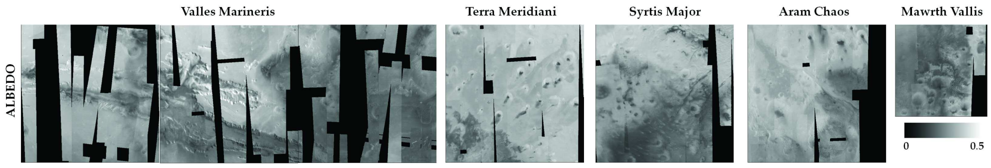

Fig. 1. Albedo maps of the 5 regions studied.

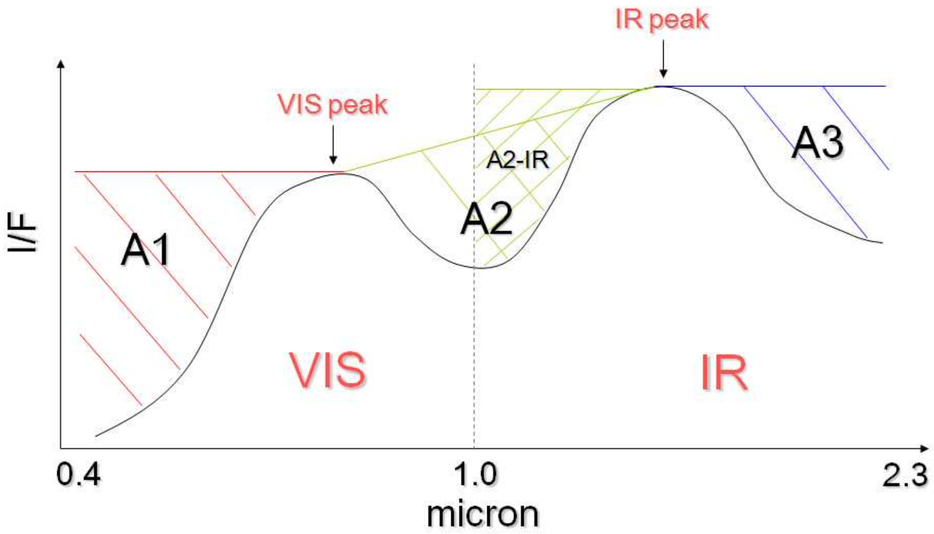

Fig. 2. Typical spectral shape of a Martian terrain. Here we show the spectral parameters used for this study.

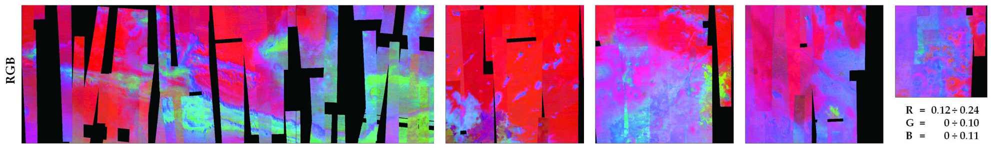

Fig. 3. RGB map of three spectral parameters over the surface regions of figure 1: Red=A1, Green,=A2, Blue=A3. The terrains with high degree of oxidation are in red colours, those with pyroxenes are in blue/cyan, while those with olivine/piroxenes are in green.

3. Method

The first step is the co-registration between the VNIR and IR C channels, because they do not observe the same areas at the same moment and therefore the two footprints of the same pixel are not geographically coincident. The co-registration between the VIS and NIR channels is needed in order to correctly reconstruct the 1 μm band and to compare our results with already published mineral maps.

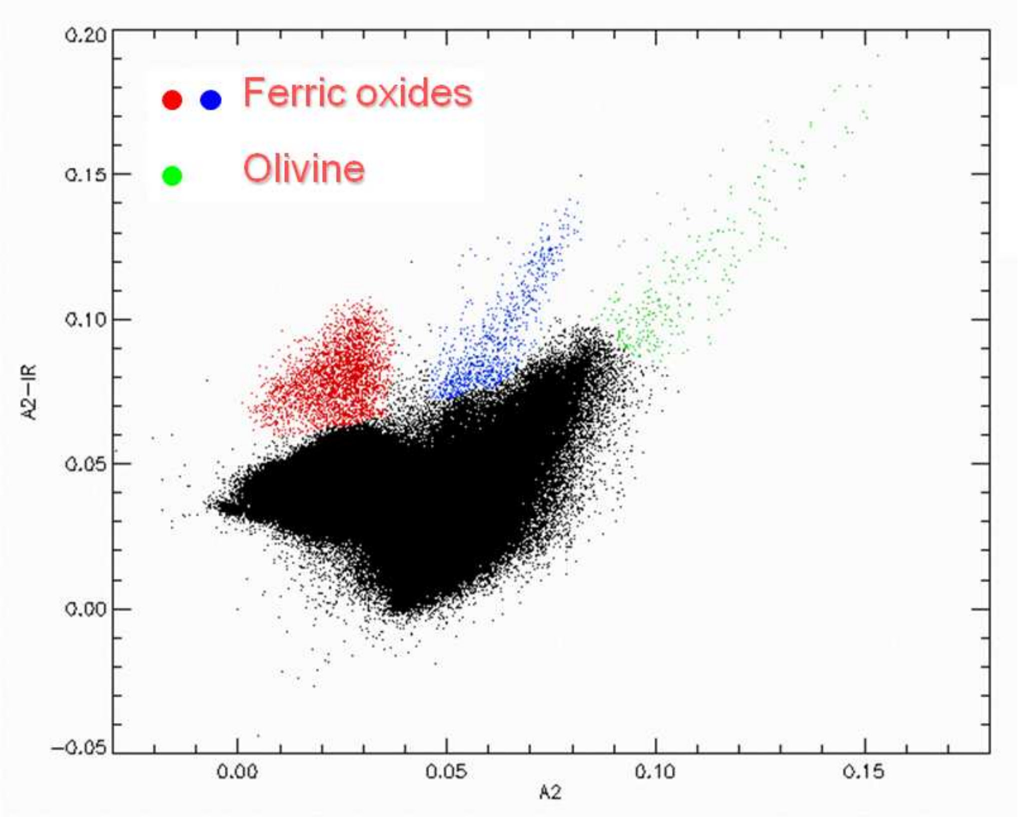

Fig. 4. Scatter plot between A2 and the A2-IR of figure 1. Ferric oxides group in two clusters (red and blu) while olivine groups in the green cluster.

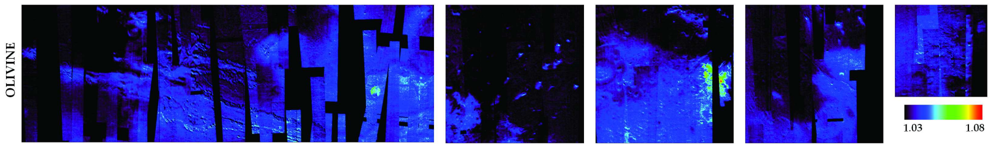

Fig. 5. Olivine maps.

4. Discussion

In general, the visible spectrum of Mars is dominated by an intense and featureless ferric absorption edge from UV (0.400 μm) to a marked peak reflectance near 0.750 μm, followed by a decrease in reflectivity towards longer wavelengths with respect to this maximum; variations of the spectral slope at 0.550 and 0.680 μm make the spectrum concave until 0.550 μm, convex from 0.550 to 0.680 μm and again slightly concave until 0.750 μm (Fig.2).

The Martian terrains exhibit variation in their degree of alteration. This diversity can indicate different environment conditions during the formation of these terrains. For this reason one of the ideas is to characterize the Martian terrains on the basis of 0.4 μm absorption (B1) that is a

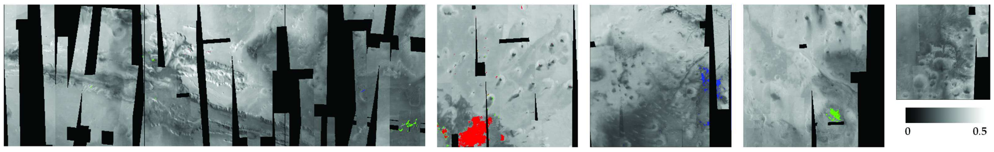

Fig. 6. The clusters identified in figure 4 are shown here overlying the albedo maps. Ferric oxides are in red and green, olivine terrains are in blue.

good estimate of the degree of oxidation and subsequently on the basis of the behaviour of two other absorptions near 1.0 μm (B2) and between 2.0 and 2.3 μm (B3).

As stated above, the use of the 1 μm band in its full width requires an accurate coregistration between OMEGA VIS and OMEGA NIR channels, since the matching of spatial and spectral information is essential in order to compare our results with the published mineral maps of Mars. For B1, we use the area (denominated A1) enclosed by the spectrum and a horizontal line tangent to the spectrum itself at the VIS reflectance peak. We use the horizontal line tangent because it is not possible to determinate the continuum. For B2 we use the area (denominated A2) enclosed by the spectrum and the linear continuum between the reflectance peaks in the VIS and near-IR. For B3 we use the area (denominated A3) enclosed by the spectrum and a horizontal line tangent to the spectrum at the near-IR reflectance peak. From the RGB map (R=A1, G,=A2, B=A3) we can point out the most important spectral classes as olivine, ferric terrains and pyroxenes (see Fig.3).

It is possible also to distinguish the ferric phase and the ferrous one from the shape and position of the Fe absorption between the VIS and IR channels (Cloutis and Gaffey 1991). However, we cannot resolve the position of the band minimum at these wavelengths because in that spectral range the VIS channel and near-IR channel have a S/N too low to achieve sufficient precision. For this reason we have introduced other spectral parameters in the visible wavelengths that exhibit variations correlated with mineralogy. Although the spectral index maps show limitations due to atmospheric effects and spatial resolution that can affect the results, some VIS spectral indexes actually reproduce minerals map of other authors with good approximation. Ferric oxides, as hematite located in Terra Meridiani and Aram Chaos, is evident if we use the ratio between the right and left shoulders of the 1 μm band. In Fig. 4, we show the scatter plot between A2 and the A2-IR (the area enclosed by the spectrum and the horizontal line tangent to the spectrum at the IR reflectance peak up to 1 μm, as shown in Figure 2). Some clusters can be defined here: red and blue points are typical of ferric oxides, red ones are typical of Terra Meridiani and blue ones of Aram Chaos and Capri Chasma. Green points are typical of olivine (Fig. 5). Finally, as shown in Fig. 6, the reflectance ratio $R_{685nm}/(R_{625nm}/2 + R_{782nm}/2)$ seems to be sensitive to the olivine (Syrtis Major).

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