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Global distribution of mafic minerals abundances and associated chemical composition at Mars: a legacy of OMEGA

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Abstract

One of the major goals of the OMEGA/Mars Express instrument was to constrain the igneous terrains of Mars. The entire NIR OMEGA dataset, acquired over 3.6 Martian years, was used and formatted for such an analysis. To derive the modal composition and grain sizes at a planetary scale, a radiative transfer model was used to reproduce these millions of spectra representative of igneous terrains of Mars. The lithology can be summarized in five mineral maps at km-scale (Figure 1): plagioclase, pyroxenes, olivine and Martian dust analogue. The corresponding oxide composition translates into a Martian crust of basaltic composition. These data products are a part of the OMEGA/MarsExpress legacy and will be distributed throughout the PSUP portal and PSA archive.

1. Introduction

The knowledge of the igneous composition of Mars surface allows a better understanding of the volcanic and magmatic history of the planet. Previous past global orbital analyses focusing on the igneous mineralogy on Mars have shown that its crust consists in tholeiitic basalt [1], and that the dark albedo regions are dominated by plagioclase, pyroxene, and at a more local scale olivine ([2],[3],[4]). The mineral abundances of regolith-like surfaces can be derived from the spectral modelling of NIR reflectance spectra with a radiative transfer model ([5], [6]). We present here the analysis of all NIR hyperspectral data to derive abundances of the mafic minerals on Mars at the global scale with a spatial sampling of ~1.85 km/px at the equator.

2. Dataset

We used the complete near-infrared dataset of OMEGA from 1 to 2.5 µm. All raw OMEGA image-cubes were processed and compiled into a global hyperspectral cube of the Martian surface from 60°S to 60°N that covers more than 85% of the surface. The methodology to obtain the global cube, its validation and first applications are detailed in [7]. The work presented here aims at characterizing the surface mineralogy in terms of igneous assemblages, as a result only terrains exhibiting strong pyroxene signature were selected for the modelling. The high latitudes were also excluded for modelling purpose [9] reducing the sample to be modelled to 10.3 million of spectra from 30°N to 60°N.

3. Modal mineralogy

We applied Shkuratov radiative transfer model [6] to all selected OMEGA spectra. We simulated a mixture of 5 different minerals referred to as end-members: plagioclase, two poles of pyroxenes (both low- and high- calcium), olivine and palagonite as a Martian dust analogue for the low albedo terrains selected here. The corresponding abundance maps are represented on Figure 1.

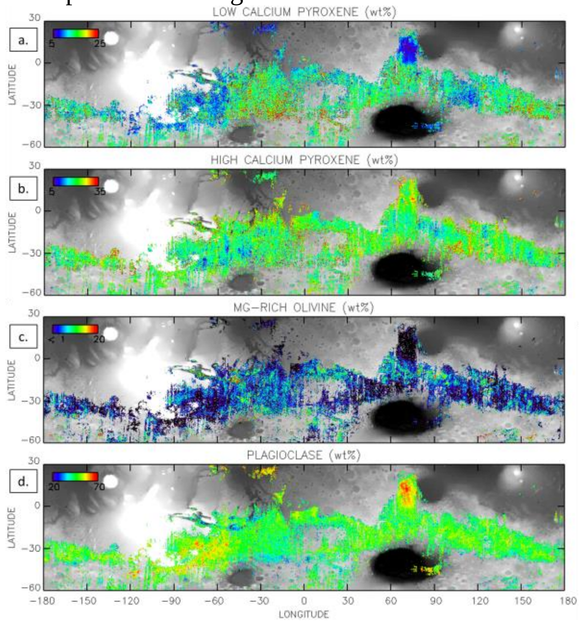

Figure 1: Abundance maps (wt%) of (a) LCP, (b) HCP, (c) Olivine, (d) Plagioclase.

We found that those terrains are dominated by plagioclase (~50 wt% on average) and pyroxenes (~40 wt%). An evolution of the LCP/(HCP+LCP) ratio is observed with time at the global scale. This suggests a decrease of the degree of partial melting of the magma with throughout the geological eras.

4. Oxide composition

The abundances maps of mafic minerals were used to predict the chemical composition according to the minerals found on the surface. We used individual oxide composition and density of each end-member. The OMEGA-based global chemistries corresponds to the basaltic rock class (tholeiitic basalt) with a few pixels associated to more mafic rocks (picritic type mainly enriched in olivine)This distribution is in good agreement with previous orbital and *in situ* analysis of chemical composition [1]. Spatial variations are observed and well correlated with some geological units [9]. Conversely, the mineralogical/chemical diversity observed from *in situ* invesigations (e.g. [10],[11]) is not highlighted.

Additionnally, we found that the OMEGA-derived iron content (Figure 2) predicts a surface depleted in iron compared to other orbital based data from GRS and *in situ* measurements [12]. The discrepancies between GRS and OMEGA may be explained by the fact that both instruments sample different depth of the surface (few cm compared to few µm) and are thus no sensitive to surface alteration in the same way.

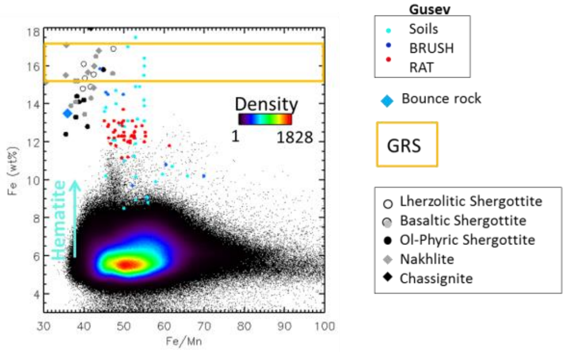

Figure 2: Fe with respect to Fe/Mn ratio. OMEGA data are represented in density. The vertical blue line indicates the trend when hematite is used instead of palagonite as the dust analogue.

This may also be confirmed with *in situ* measurements suggesting that olivine is primarily affected by the weathering on Mars ([13],[14]). The olivine alteration translates into alteration rinds that can mask olivine detection which may partly explains the decrease in iron content observed, if this phenomenon occurs at the global scale.

5. Conclusion

At the global scale we observe on average a rather homogeneous surface in terms of chemistry and mineralogy, however the mineral abundance maps reveal strong localized variations. Such variations have to be put in a geological context to better understand their origin. The next step will be to use a more local approach based on the global maps presented here (Figure 1). These additional analyses at a smaller scale should be very promising to provide constraints on the compositional heterogeneity of any mafic region/volcanic edifice and on mantle compositional models.

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