EPSC Abstracts
Vol. 6, EPSC-DPS2011-1009, 2011
EPSC-DPS Joint Meeting 2011

GLOBAL DISTRIBUTION OF OLIVINE-BEARING DEPOSITS ON MARS FROM NEAR INFRARED HYPERSPECTRAL MEASUREMENTS.

A. Ody, F. Poulet, Y. Langevin, J.-P. Bibring, B. Gondet, J. Carter, M. Vincendon. Institut d'Astrophysique Spatiale,Université Paris-Sud, 91405 Orsay cedex, France

1. Introduction

Olivine is an important mineral of basaltic rocks and its presence and composition can be used to place constraints on the petrogenesis of the crust and the mantle of Mars. Previous investigations by remote sensing observations and in situ measurements indicate that olivine-bearing rocks and soils are widespread on the martian surface [1,2,3] . OMEGA/MEx has returned visible and near-infrared reflectance data since 2004 and provided consistent identification and spatial distribution of several classes of mafic minerals including olivine. This work focuses on the global distribution of the olivine mineral as revealed by the OMEGA instrument after more than three martian years of observations. Regional studies of specific olivine-bearing deposits are studied in order to better constrain the origin of these deposits.

2. Method and Mapping

This analysis focuses on the near infrared reflectance OMEGA measurements using the C channel spectral range (1.0–2.5 µm), where the 1 µm absorption band of olivine mineral is present. The shape and the depth of the 1 µm absorption band depend on the iron content of the olivine but also on its grain size and on its abundance. The identification and mapping of the different type of olivine derived from three spectral parameters developed in [3] and [4]. The first spectral parameter preferentially detects Mg-rich olivine and the second and third spectral parameter detects olivine with an higher iron content, with a larger grain size and/or a larger abundance. Surface frost, atmospheric effects (clouds, aerosols) and instrumental artefacts interfere with OMEGA observations, leading us to implement a filtering process based on parameters that gauge the presence of H_2O, CO_2 ice and dust opacity [5]. Final map with a grid of 40 pixel/° are obtained by merging the three parameters and by selecting the highest value of the criteria for each pixel. Quantitative compositions (volumetric abundance) of a few olivine-bearing deposits are also obtained using a radiative transfer model adapted for basaltic surfaces [6].

3. Distribution of olivine

Global map of olivine is shown in Fig. 1a. The color range from blue to red is an indicator of the nature of olivine. Spectra representative of the olivine end-members are illustrated in Fig.1b. In contrast to the TES-based olivine distribution, the OMEGA-based olivine distribution is uneven, while olivine is still mostly localized in the southern highlands associated with pyroxene. All previously olivine regions

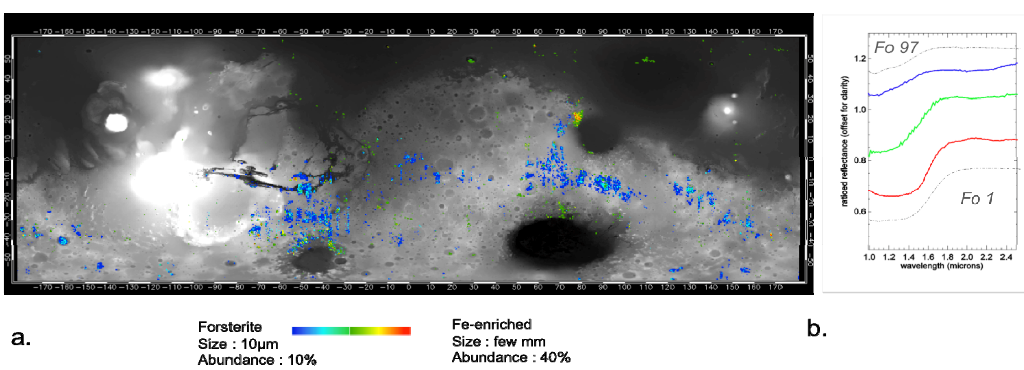

Figure 1. (a) Global map of olivine. The detection limit is 10-15% for small grain size (~10 µm). (b) Examples of typical olivine spectra extracted from the map. Blue spectrum (extracted from Terra Tyrrhena volcanic province) is well representative of the deposits mapped in blue, the green spectrum comes from the terrace of Argyre and the red spectrum from Nili Fossae, where the strongest signatures of olivine on Mars are found.

identified by [1] and TES including Nili Fossae, Terra Tyrrhena, Syrtis Major and Ganges Chasma are detected. Numerous additional small deposits, especially around the Argyre and Hellas basins and in the northern plains are here reported. It is also important to note that Mg- rich olivine is mostly found in regional enhancements, whereas the Fe-enriched or larger grain size olivine is more commonly found in discrete occurrences and in groups of discontinuous patches around the 3 main basins. In order to better understand the global distribution of the different types of olivine, we have studied the olivine distribution with altitude, latitude and age. To do so, olivine detections are divided into two groups, Mg-rich olivine (blue deposits in Fig. 1a), and Fe-enriched and/or larger grain size and/or larger abundance olivine (red and green deposits in Fig. 1a). The locations of the olivine-bearing deposits are plotted over USGS geologic map of Mars [7] to roughly estimate the age of the materials in which they reside. Mg-rich olivine deposits are found in both Hesperian and Noachian terrains, whereas Fe-enriched or/and larger grain size and/or larger abundance olivine detections are predominantly associated with the Noachian terrains.

Fig. 2 shows that olivine detections are distributed according to four ranges of altitude. Mg-rich olivine detections are common in all altitudes, but most of the detections are nevertheless localized in the southern highlands (namely between 0 and +5 km in altitude). Fe-enriched and/or larger grain size and/or larger abundance olivine detections are mainly found in terrains of altitude between -2.5 and 0 km, which corresponds to the terrace of major basins (Hellas, Isidis and Argyre), and between -4 and -2.5 km, which correspond to olivine presents in the northern plains.

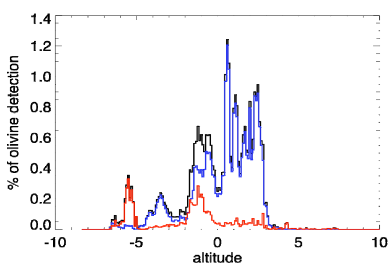

Figure 2. Histogram of olivine detections versus altitude, normalized by MOLA altitude histogram, Fe-rich olivine detections are in red, Mg-rich olivine detections are in blue, total number is represented in black.

4. Origin of olivine deposits

Three groups of olivine-bearing deposits have been identified according to their spectral characteristics and their spatial distribution. (1) The widespread olivine deposits in the southern Highlands (blue deposits in Fig. 1a) are associated with low albedo and pyroxene-bearing regions, and are present in both Noachian and Hesperian terrains. They are characterized by a forsteritic composition and their abundance has been calculated by the radiative transfer model to be lower than 15%. We interpreted these widespread Mg-Rich olivine deposits as evolved basaltic terrains mainly associated with volcanic provinces. (2) The discontinuous patches of olivine on the terraces of the three main basins (Argyre, Isidis and Hellas) are localized in Noachian terrains and are characterized by an higher iron content and/or a larger grain size composition and/or larger abundance. Spectral modeling indicate that their composition still close to that of forterite one, with abundances in the range of [15, 40%]. This olivine distribution strongly suggests that its formation is related to the large basin formation events. The impacts that formed the Argyre, Hellas, and Isidis basins may have excavated deeply enough to expose mantle materials as suggested by recent simulations [8]. We thus interpret these olivine deposits as olivine-bearing material excavated from the upper mantle during the impact. (3) Several localized exposures of strong Fe-enriched and/or large grain size olivine signature and/or with larger abundance are found in the southern highlands and in the northern plains. There are no obvious volcanic edifices nearer to these deposits, so we cannot specify their source of these flows. These olivine-bearing materials could be basaltic magma that was mantle-derived and arrived at the surface without significant fractionation.

References

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