SEARCH FOR ANALOGUE SITES OF NEW MARTIAN SHERGOTTITE SPECTRA USING NIR DATA.

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Introduction: Martian meteorites are the only Martian samples we have, and among them shergottites are the most numerous. These meteorites are mainly composed of olivine, pyroxene and plagioclase with compositions ranging from basaltic to ultramafic [1]. Their exact source region at the Martian surface is still unknown and their crystallization age is largely debated, with some reports of ~4 Ga [2] and others at only hundreds of millions of years [3]. These uncertainties prevent us from fully exploiting information that shergottites give us about the composition and evolution of the surface and mantle of Mars. Previously, [4,5] tried to identify possible source regions of some well-known Martian meteorites including some shergottites (basaltic shergottites Los Angeles, Shergotty, QUE94201 and the lherzolitic shergottite ALHA77005) by comparing their spectral properties with those of the Martian surface in the near-infrared using OMEGA data. Recently, we acquired new spectra of Martian shergottites in the visible and near infrared at the RELAB laboratory, increasing the diversity and representativeness of shergottite spectra. Here, we extend the study of [4,5] to this new collection of Martian shergottite spectra to better constrain the possible geological settings and ages of the different shergottites.

Sample and spectra acquisition method: This study is based on spectra from six new samples of Martian shergottites measured for the first time: the basaltic shergottite (or gabbroic shergottite [6]) NWA6963, the olivine-phyric shergottites Tissint, NWA1068, NWA2626 and NWA6234, and the lherzolitic shergottite NWA7397. These new samples include exciting recent finds and falls [e.g., 7,8] that are revealing important information about Mars's history and its magmatic processes. Moreover, they include four spectra of olivine-phyric shergottites (Figure 1) which were not well represented in previous attempts to link meteorite spectra to the surface. Spectra of whole-rock bulk shergottites were measured from powders at the Keck-NASA Reflectance Experiment Laboratory (RELAB) at Brown University. Measurements were made from 0.3 to 2.5 µm with a bidirectional spectrometer using incidence and emission angles of 30° and 0°, respectively and calibrated with a halon standard.

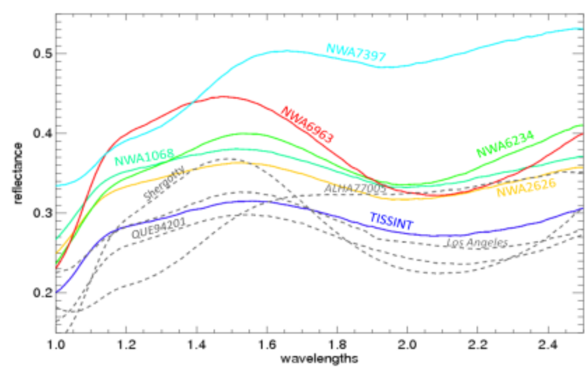

Figure 1. *Spectra of the six studied new shergottites meteorite (color solid lines) in the NIR. Spectra of some other shergottites (grey dashed lines) extracted from [9,10] are also represented for comparison.*

OMEGA observations and fitting method: The OMEGA dataset provides global coverage of the Martian surface at km-scale resolution allowing identification and mapping at a global scale of regions with spectral properties similar to shergottites. We restricted our study to the first 3000 orbits of the C channel data (1.0–2.5 µm), what is sufficient to derive global maps and first results. OMEGA observations disturbed by surface icy frosts and atmospheric effects (clouds, aerosols) are removed from the dataset with a filtering process [11]. The fitting method is the same as that previously described in [4]. In order to take into account spectral effects of aerosols, dust coverage, spatial mixtures and photometry, every OMEGA spectrum is fitted by the meteorite spectrum (SNC_spectrum hereafter) with the following free parameters: a continuum offset (**O**), a slope parameter (**Sl**) and a scale parameter (**Sc**). The fitting function is:

F = **Sc***SNC_spectrum + **O** + **Sl*** wavelengths

In order to be consistent with aerosol effects, the slope parameter is restricted to negative values. The quality of the fit is evaluated with the χ^2 value calculated between 1 and 2.5 µm for each OMEGA pixel.

χ^2 global maps with a grid of 40 ppd are derived for each meteorite (by selecting the lowest value of χ^2 for each pixel in the case of overlap). Given the SNR of OMEGA spectra, only fits for χ^2 values lower than 0.002 can be considered as satisfactory and are mapped. However, because χ^2 values are affected by many factors, an additional visual inspection was performed for each meteorite to validate and select best fits which are mainly characterized by $\chi^2 < \sim 0.0013$ and by small slopes and large scale parameters.

Results: Figure 2 shows the distribution of best fits for all six new shergottite spectra, color coded as a function of shergottite type. For comparison, best fits for other well-known shergottites from [4,5] are also plotted in corresponding light colors. The distribution of best fits for the new six shergottites are in global agreement with best fits of previous shergottite spectra and are mainly found in ancient and low dusty terrains of the southern hemisphere. The basaltic shergottite NWA6963 shows good fits in the early Hesperian volcanic provinces of Hesperia and Thaumasia Planum what is in agreement with previous studies [4,5]. However, contrary to Los Angeles, Shergotty and QUE94201, NWA6963 does not show good fits in the region of Syrtis Major. The olivine-phyric shergottites also show several good fits in the volcanic provinces of Thaumasia and Hesperia Planum, but these are mostly restricted to the Tissint meteorite with χ^2 values mainly larger than 0.00125. Most of the good olivine-phyric shergottite fits are found in regions where olivine is commonly detected, mainly in Terra Tyrrhena, and to a lesser extent in Terra Cimmeria, the north-west of Argyre as well as the northern Argyre rim [12]. In the region of Terra Tyrrhena good fits of olivine-phyric shergottites are mainly associated with an olivine-enriched unit (early Hesperian plains and crater floors [12]), and principally to the edge of the unit where the olivine signature is weaker. Basaltic shergottites NWA6963 (and Los Angeles, Shergotty and QUE94201) show also good fits in this region but these fits seem to be more associated with the adjacent olivine-poor Noachian terrains than to the olivine-enriched unit. The lherzolitic shergottite NWA7397 is also fit well in this region associated with stronger olivine signatures, as well as in other olivine-enriched terrains like Nili Fossae, some craters' dunes or ejecta in the northern plains, and in the Argyre and Hellas rims. Except for the Terra Tyrrhena region, these results are in agreement with best fit locations of the other lherzolitic shergottite ALHA77005.

Conclusion: Given these results, and those of previous studies [4,5], it seems that the early Hesperian volcanic provinces, and the ancient highlands terrains including olivine-poor Noachian terrains and olivine-enriched early Hesperian units [12], are good potential source regions for the martian shergottites. Although we cannot exclude for the moment that good fits of olivine-phyric shergottites and basaltic shergottites at the edge and around the olivine-enriched units could be partially due to mixing between the Noachian olivine-poor and Hesperian olivine-enriched units, the ancient highlands terrains are a particularly interesting potential source region because of their widespread presence at the martian surface (they form the larger part of the southern hemisphere) and because they show spectral signatures similar to the three types of shergottites. While the ages of basaltic shergottites being currently debated, this study and the previous one [4,5] are more consistent with an old age of these shergottites based on spectroscopy.

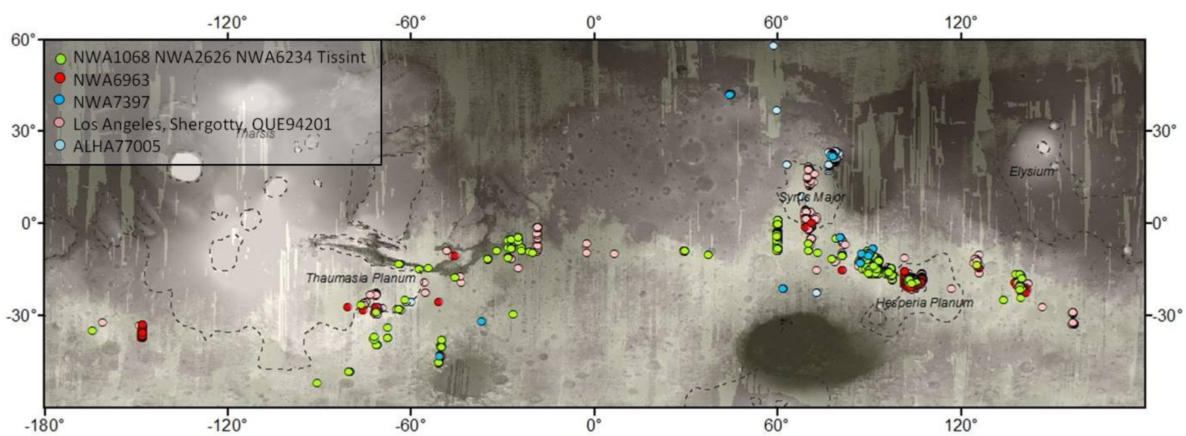

Figure 2. *Global map showing best fits obtained with all six new shergottite spectra, with best fits for basaltic shergottites mapped in red, olivine-phyric shergottite mapped in green,and lherzolitic shergottite mapped in blue. For comparison, best fits for other well-known shergottites are also plotted in corresponding light colors [4,5]. In background: the MOLA elevation global map and the OMEGA dust global map (brown color).*

References: [1] McSween and Treiman (1998), in *Planetary Material*, vol36, pp6-53.[2] Bouvier et al., (2009), *Earth and Planet. Sc. Lett.*, 280, 285-295. [3] Nyquist et al., (2001), *Chronology and Evolution of Mars*, Kluwer, Dordrecht, pp. 105–164. [4] Ody et al., (2013), *LPSC 44*. [5] Ody et al., (2014), in preparation. [6] Filiberto et al., (2014), *American Mineralogist*, in press. [7] Chennaoui Aoudjehane H. et al. (2012), *Science,338*, 785. [8] Filiberto J. et al. (2012)*MAPS,47(8)*, 1256. [9] McFadden and Cline, (2005), *Meteor. & Planet. Sc.*, 40,151.[10] RELAB spectrum DD-MDD-024/C1DD24, QUE94201, 44, Dyar M. [11] Ody et al., (2012), *JGR*, 117, E00J14. [12] Ody et al., (2013), *JGR*, vol 118, 234–262.

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