HIGH-MAGNESIAN OLIVINE IN THE ARGYRE RIM: DERIVED FROM A PRIMITIVE MAGMA?

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Introduction: The thermal emissivity spectra (2000-200 cm^{-1}; 5-50 μm) of a suite of synthetic olivines ranging in composition from forsterite (Mg_2SiO_4) to fayalite (Fe_2SiO_4) were previously acquired [1,2]. A spectral index was determined for each of these compositions and applied to Mars Global Surveyor Thermal Emission Spectrometer (TES) data to map olivine on the surface of Mars. Many interesting olivine-bearing deposits were identified as a result of this mapping strategy; however, here we focus on multiple high-Mg olivine deposits that are circumpositioned within the ~1800-km-diameter Argyre crater in the southern highlands [3,4] as part of an eroded annulus that may be the uplifted basin rim. Spectral unmixing has allowed the lithologies to be determined.

Dozens of recovered Martian meteorites are dominatly crustal igneous rocks that can provide valuable information about their mantle source regions. Because the majority of these meteorites are highly fractionated rock types, they do not yield this information by direct means. One possible exception is the olivine phyric shergottite Yamato 980459, which has a very primitive character and may be a primary melt of an olivine + low-Ca pyroxene Martian mantle [1]. The upper mantle of Earth is dominated by olivine, as is likely for Mars. The geologic setting and the derived lithologic composition of the Mg-rich olivine-bearing materials found in the Argyre rim suggest that these regions on Mars are representative of primitive mantle-derived material, possibly similar to Y-980459.

Mapping of Olivine on Mars: Laboratory olivine spectra used for this study were the same as those presented in [2,4]; samples were synthesized [2] by Donald Lindsley (Stony Brook Univ.). The samples vary in composition from forsterite (Fo_{100}) to fayalite (Fo_0) and include 12 intermediate compositions. Sample Fo_{60} was too small to retrieve a good-quality spectrum.

The spectra that were acquired in the lab (Figure 1) were applied to the study of TES data to map the presence of various-composition olivines on the Martian surface. We used a spectral index (different from that of [3]) to map the long-wavelength inflection (defined by the blue, red, and green dots) that appears in all olivine spectra and migrates to longer wavelengths with increase Fe content of the olivines.

Once the olivine index for each composition was mapped to TES data, many interesting olivine deposits were identified globally, but in particular, many high-Mg olivine pixels were mapped in the circum-Argyre region (Figure 2), similar to those found by [3]. Most olivine deposits occur in the northern half of the rim, especially in the NE part.

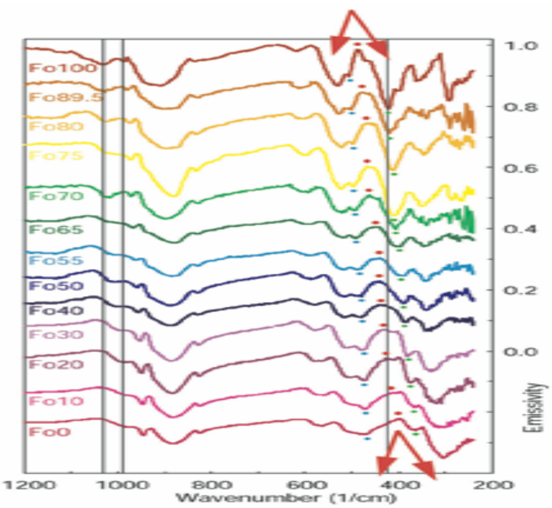


Figure 1. Thermal emissivity spectra of the synthetic Mg-Fe olivine solid-solution series. Vertical lines are included to facilitate comparisons of band positions. The migrating long-wave inflection shown by the red arrows is the one used for index mapping.

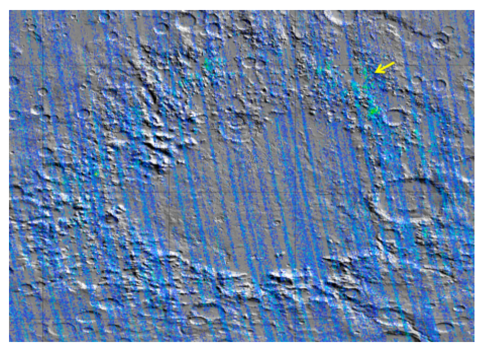
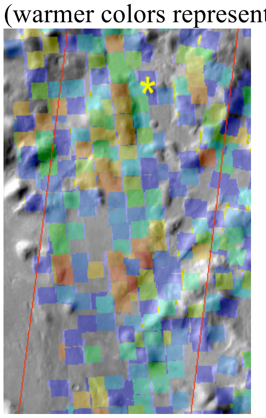


Figure 2. Index mapping of high-Mg olivine (greenish) circumlocated around Argyre basin (32 ppd) in an eroded annulus. Arrow shows area seen in Figure 3.

Results: Figure 3 shows the TES index and THEMIS decorrelation stretch (DCS) of one region of high-Mg olivine. In order to study the composition of the olivine-bearing rock, corresponding TES data were analyzed. TES data were also analyzed for what was thought to be "non-olivine"-bearing (on the basis of the DCS color) near-by basalt strata. Once the TES data were retrieved, they were spectrally unmixed using atmospheric endmembers (derived by [5,6]) and a suite of common rock-forming minerals (e.g., olivines, feldspars, pyroxenes, oxides, micas, other clay minerals, sulfates, and glasses). Figure 4 shows the atmospherically corrected TES spectra and the model fits to these spectra. The RMS(%) value for the olivine-bearing terrain was 0.289; the “non-olivine” bearing basaltic terrain was 0.252. The results showed that the “non-olivine” terrain actually contained a significant 24% olivine, and the olivine-bearing terrain contained ~34% olivine. These spectra are both different from the Surface Type 1 or Surface Type 2 basalts determined by [7]. The lithologies of the 2 circled areas (Fig. 3) are listed in Table 1. The olivine-rich terrain contains a large amount of plagioclase (~30%) and a significant amount (16%) of Opx, some of which could be pigeonite (due to a similar spectral shape). Deconvolution values of less than ~6% are likely not actually to be present (Table 1).



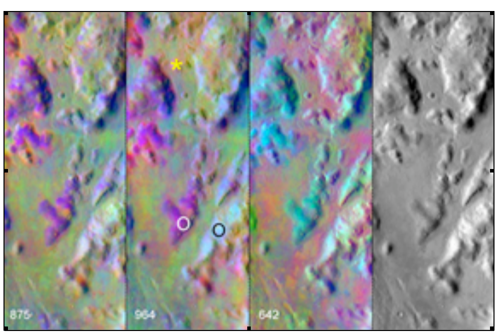


Figure 3. (Top) TES pixels showing olivine index (warmer colors represent higher olivine; red lines show THEMIS image boundaries); (Bottom) THEMIS DCS scene I08016003. Olivine appears as purple (in 875/964) or cyan (in 642). Yellow asterisk in same location (top and bottom). Compositions were derived from units within circles (white = olivine-dominated; black = near-by basalt).

Table 1. Deconvolution results.

Constituent Minerals	Olivine-bearing Terrain (~vol%)	Near-by Basalt (~vol%)
Olivine	34	24
Plagioclase	30	16
Opx	16	16
Cpx	3	0
Alteration material	10	11
Glass	0	17
Sulfate	6	0
Carbonate	2	4

The position of the spectral inflection (Fig. 1) is a good identifier of Fe-Mg olivine composition [4]. Comparison of data in Figs. 1 and 4 (as well as the spectral deconvolution results) shows the olivine composition in the olivine-rich terrain to be in the range of Fo_{80} to $Fo_{89.5}$. This strategy for determining olivine composition worked very well for determining the olivine composition (Fo_{65-70}) in Yamato 984028 [8].

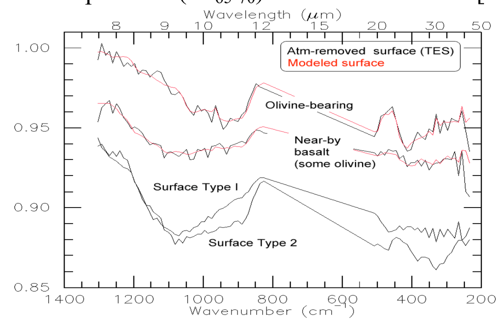


Figure 4. TES surface spectra (black) and model results (red). Spectra are offset for clarity. Linear segments centered at 667 cm^{-1} cuts out the deep atmospheric CO_2 band.

Discussion: The composition of these circum-Argyre olivine units is unusually Mg-rich for Martian materials. Most olivine-bearing Martian meteorites are Mg-poor [9]. The Mg-rich compositions are found in the olivine phyric shergottites, with the most Mg-rich olivine being in meteorite Y-980459 (Fo_{86}) [1,10]. The Argyre high-Mg olivine lithologies are found to be associated with a circular basin rim (~550 km radius from crater center) in this multi-ringed, ancient crater [11]. The olivine locales map across ~200 km of the rugged terrain of an eroded annulus (Nereidum formation [12]). We suggest that this olivine-bearing rock that forms the Argyre basin rim existed as an ancient, crustal basement layer that was impacted during Argyre-basin formation and was uplifted into its current rim position. The derived composition of the olivine ($Fo_{80-89.5}$) as well as the other constituent minerals suggest an origin as a primitive, mantle-derived basalt, possibly an ancient analogue to Y-980459. The possibility that most of the pyroxene is Opx, rather than pigeonite, may reflect a significant difference between ancient and more recent Martian magmas.

References: [1] Musselwhite, D. S. et al. (2003) *MaPS, 41,* 1271-1290. [2] Dyar, M. D. et al. (2009) *Amer. Mineral., 94,* 883-898. [3] Koeppen, W. C. and V. E. Hamilton (2008) *JGR, 113,* E05001. [4] Lane, M. D. et al. (in prep.) [5] Smith, M. D. et al. (2000) *J. Geophys. Res., 105,* 9589-9608. [6] Bandfield, J. L. and M. D. Smith (2003) *Icarus, 161,* 47-65. [7] Bandfield, J. L. et al. (2000) *Science, 287,* 1626-1630. [8] Dyar, M. D. et al. (2010) *this volume.* [9] McSween, H. and A. H. Treiman (1998) In Planetary Marterials, RIM, 36. [10] Greshake, A. et al. (2004) *GCA, 68,* 2359. [11] Andrews-Hanna et al. (2008) *Nature, 453,* 1212-1216. [12] Thomas, P. G. and Ph. Masson (1984) *Earth, Moon, Pl., 31,* 25-42.

Acknowledgements: This work is supported by NASA’s Mars Odyssey Participating Scientist and Mars Fundamental Research programs.