GEOLOGIC SETTING OF THE OLIVINE-BEARING MATERIALS IN TERRA TYRRHENA.

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Introduction: The ubiquity of olivine-bearing materials in the low-albedo surfaces of Mars as inferred from Thermal Emission Spectrometer (TES) and OMEGA data suggests that olivine occurs in a variety of geologic settings [e.g., 1, 2, 3, 4]. The distribution of olivine as a function of composition from TES data [3] suggest that olivines with similar compositions may be petrogenetically related, and olivine of different compositions may originate from different depths in the Martian mantle. The geologic settings of materials containing different compositions of olivine can provide insights into the diversity of emplacement mechanisms that may have brought olivine to the surface, as well as those processes that modified the olivine-bearing materials into the form in which they exist today.

The region of highlands north of Hellas basin in Terra Tyrrhena is a geologically complex mix of Noachian highlands, Hellas rim materials, Hesperian flows from Tyrrhena Patera, and channel systems [e.g., 5-7]. Global olivine abundance maps from [3] show that this region contains spectral evidence of individual compositions of olivine at abundances up to ~10%. In this study we use the surface expression of olivine in Terra Tyrrhena to examine the settings of different compositions of olivine, as well as its origin and evolution.

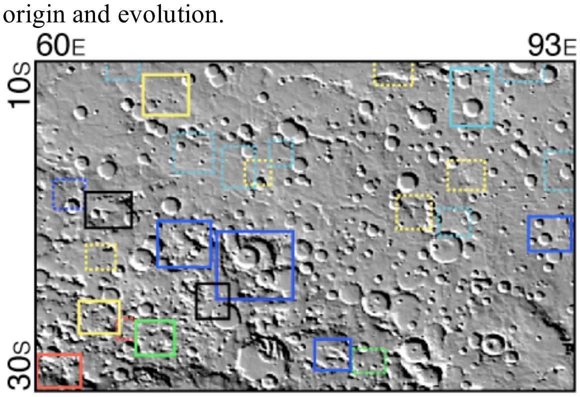

Figure 1. The study area and locations of regions of interest. Colors indicate the composition of olivine identified (black – Fo_{91}; blue – Fo_{68}; cyan – Fo_{53}; green – Fo_{39}; yellow – Fo_{18}; red – Fo_{1}). Dashed regions were identified in TES data, but could not be corroborated with a THEMIS DCS image.

Approach: Using the TES olivine index maps and 16 pixel per degree abundance maps of [3], we identified 25 locations within a study region from 60 to 93°E and 10 to 30°S (Figure 1). Each location contains spatially coherent groupings of >5 TES spectra that were modeled via deconvolution to have olivine abundances >10%. We identified at least two potential occurrences of each olivine composition in our end-member set: Fo_{91}, Fo_{68}, Fo_{53}, Fo_{39}, Fo_{18}, Fo_{1}.

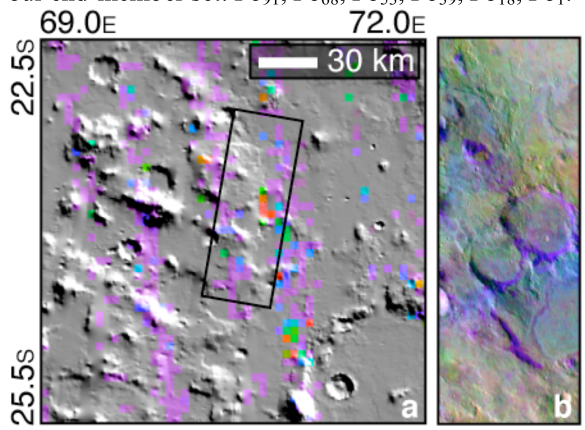

Figure 2. (a) Fo_{91} olivine abundance from 0 (purple) to 10% (red) in Terra Tyrrhena. (b) THEMIS DCS image I07975004 shows that olivine is located in small knobs and in the rims of degraded craters.

Next, we searched for Thermal Emission Imaging System (THEMIS) infrared (IR) decorrelation stretched (DCS) images over the locations (e.g., Figure 2). THEMIS IR images have lower spectral resolution (8 bands between 1500 and 650 cm^{-1}) but higher spatial resolution (100 m/pixel), which allows for detailed mapping of the surface features [8]. THEMIS DCS images (using bands 8, 7, and 5) are well suited to quickly identifying olivine-like spectral shapes, which appear as a purple color in the stretched image. Additionally, we used nighttime THEMIS IR images to make inferences about the relative thermal inertia of olivine-bearing materials to their surroundings.

We also used THEMIS Visible (VIS) and Mars Orbiter Camera (MOC) Narrow Angle (NA) images where they were available. THEMIS VIS and MOC data have spatial resolutions of 18 and ~1.5 m/pixel, respectively, and were used to examine the small-scale morphology of the olivine-bearing deposits.

Results: At least 11 of the 25 locations we examined show evidence of olivine spectral shapes in both TES spectra and THEMIS DCS images. Of these, we were able to isolate surface spectra containing each compositional shape (Figure 3). The surface spectra are not purely olivine and so do not match up at all wavenumbers, however, the emission minimum at ~900 cm^{-1} as well as minima at low-wavenumbers (500 – 250 cm^{-1}) are attributable to olivine and appear to be visible in all the spectra.

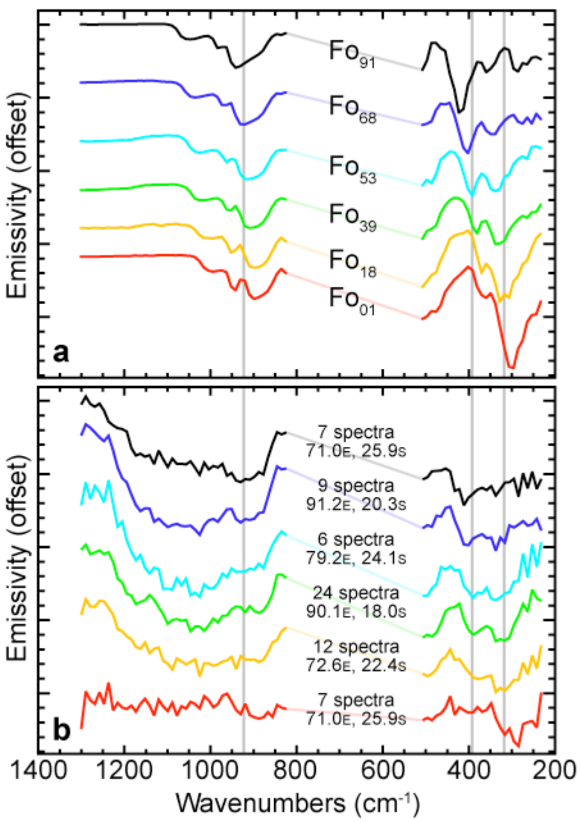

Figure 3. (a) Thermal infrared spectra of pure olivine samples at TES spectral sampling (10 cm^{-1}) with the region dominated by atmospheric CO_2 removed [9]. (b) Averages of TES atmosphere-removed (surface) spectra showing different compositions of olivine in the materials of Terra Tyrrhena.

THEMIS DCS images of the 11 corroborated locations show that olivine is found in a number of geologic settings. For example, the Fo_{91}-like olivine shown in Figure 2 is observed most readily in the rims of three abutting craters, however, it is also observed in nearby knobs and rough ridges that appear to be protruding out above smoother, channeled plains. We found Fo_{68}-like spectral shapes in four different regions, most typically as a component of knobs associated crater ejecta. We also observed Fo_{68} within some small sinuous channels, similar to Fo_{68} identifications in the channels of Chryse Planitia [1, 3, 10]. Fo_{53} and Fo_{39} are most easily identified in crater floor materials, many of which show higher nighttime temperatures (likely indicating higher thermal inertia) than their rim or exteriors. Many craters also have small ridges on the crater floors that parallel their rims. These features suggest that the crater floor materials are blockier or more coherent than the surrounding areas. Fo_{39} is also observed in global olivine maps of [3] to be a common component of the intracrater plains in Terra Tyrrhena and may not appear in THEMIS DCS images (which stretch spectral differences) as obviously as it appears in TES deconvolutions.

More Fe-rich compositions of olivine are also found in our study region; however, the TES data in which they are identified contain more noise than the other compositions. Nevertheless, both Fo_{18} and Fo_1 were identified in small groupings of TES spectra over areas corroborated by THEMIS DCS images. We observe olivine, identified as Fo_{18}, eroding out of crater rims in DCS images I18109004 and I101222002. The surface spectra identified by the Fo_1 spectral end-member are particularly noisy and petrologically unusual, but the spatial coherency of the grouping, association with small knobs of olivine-like spectral shapes in THEMIS DCS images, and strength of the ~300 cm^{-1} spectral feature of fayalite warrant its inclusion for further study.

Conclusions: A wide range of olivine compositions exist in relatively close proximity in Terra Tyrrhena north of Hellas basin. If the commonness of Fo_{39} in surface olivine is a proxy for of all of the southern highland crustal materials, it may suggest that this composition has origins in a very large-scale process, i.e. formation of the early Martian crust. Other compositions imply that they formed from a variety of depths and are being exposed in younger channels and craters. The geologic history that produced olivine must be reconciled with the associated minerals and regional geology, which includes the formation of Hellas Basin, intrusive and extrusive (explosive and flood) volcanism, and excavation by smaller impacts and channel formation.

References: [1] Hamilton et al. (2003) *JGR*. [2] McSween et al. (2005) *JGR*. [3] Koeppen W. C. and Hamilton V. E. (submitted) *JGR*. [4] Mustard, J. F. et al. (2005) *Science*, 1594-1597. [5] Greeley and Guest (1987) *Eastern Equatorial Map of Mars (I-1802-B)* [6] Craddock, R. A. and T. A. Maxwell (1990) *JGR*, 95, 14265-14278. [7] Crown, D. A., L. F. Bleamaster III, and S. C. Mest (2005) *JGR*, doi: 10.1029/ 2005JE002496. [8] Christensen et al. (2004) *Space Science Reviews*, 110:85-130. [9] Hamilton, V. E. et al. (submitted). [10] Rogers, A. D. et al. (2005) *JGR*, doi: 10.1029/ 2005JE002399.