THEMIS DETECTOINS OF FORSTERITE-FAYALITE COMPOSITIONS WITHIN TERRA TYRRHENA.

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Introduction: The primary objective of this work is to determine whether the Thermal Emission Imaging System (THEMIS) can distinguish Mg-Fe variations in olivines on the Martian surface [1]. We do this by studying a range of olivine-bearing materials identified by the Thermal Emission Spectrometer (TES) within Terra Tyrrhena [2-4]. The geologic province of Terra Tyrrhena lies within the ancient southern highlands of Mars, north of the Hellas Basin and is composed primarily of dissected Noachian highlands (Npld), Hesperian ridged plains (Hr), and Hellas rim materials [5, 6]. This study builds on previous work that concentrated on the geomorphology and stratigraphy of Terra Tyrrhena [5,7,8] by incorporating thermal infrared compositional information to the geologic interpretation of the area.

Background: The presence and composition of olivine can be used to place constraints on the origin, evolution, and erosion of a host rock, and it is thus an important rock forming mineral. Previous studies indicated olivine is a relatively common component of the Martian surface at abundances of ~10-20% [e.g. 2]. In addition, [2] found that more Mg-rich and Fe-rich compositions are present than previously inferred from Martian meteorites and remote sensing, and they used their observations to help constrain the relative timing of igneous events, evolution of the Martian mantle, and climatic conditions since emplacement.

It is apparent that six compositions in the Mg-Fe olivine series are distinguishable at the TES 10 cm^{-1} sampling [2]. We hypothesize that the higher spatial resolution of the THEMIS instrument (~100 m per pixel) will aid in investigating small-scale variations in olivine composition that may not be distinguishable at the lower spatial resolution of the TES instrument (~24 km^2). Here, we seek to determine if these six TES-derived olivine compositions can be reliably differentiated at THEMIS resolution and thus identified in THEMIS data.

Approach: Upon investigation of the global distribution and abundance maps of [2], we identified four localities within Terra Tyrrhena composed of materials containing olivine with differing compositions (Fo_{91}, Fo_{68}, Fo_{53}, Fo_{39}). We use these sites to investigate the geologic diversity of olivine-enriched materials and our ability to discriminate the olivines' Mg-Fe composition at THEMIS resolution. These locations contain spatially coherent groupings of pixels with >0.10% total olivine abundance (from TES) and covering an area >150 km^2. Attempts were made to choose localities that were geographically close to one another, however this was not possible with the Fo_{53} composition, which is primarily located in the northern Terra Tyrrhena province. Distinct occurrences of the Fo_{18} and Fo_{01} compositions were also surveyed, but because they occur in low abundances and in conjunction with other olivine compositions [2], we do not investigate them further.

We used decorrelation stretched (DCS) images to investigate the olivine-bearing deposits identified by [2]. A decorrelation stretch is a color enhancement technique that exaggerates differences in uncorrelated multispectral information [9]. Olivine is easily discernible in DCS images because of it's strong and relatively narrow emission feature at ~10.65 - 11.25 μm [10], which corresponds to the 11.0 μm band of the THEMIS instrument. Previous studies have used DCS images to investigate possible olivine-bearing terrains and have concluded that olivine appears to be the most common agent of spectral variability at this wavelength [e.g. 11].

Here, we develop a mask using THEMIS emissivity data processed as false color DCS images to investigate variability in the olivine-bearing terrains. For each area, we choose 1-2 images that have olivine-bearing terrains corroborated by TES detections and process the image using a DCS algorithm on bands 5, 7, and 8 (9.3, 11, 11.8 μm). We then convert the color image to hue, saturation, and value space (HSV) and using the values for the red and green channels, as well as the saturation channel, create a mask that highlights the most olivine-bearing pixels. A unique mask is created for each different area and then applied to the three other olivine-bearing terrains.

Initial results: Olivine laboratory spectra convolved to THEMIS spectral resolution shows that there are slight but distinct variations observable in the spectra (Fig 1). In the shorter wavelength region of the Christiansen feature, the Mg-rich compositions exhibiting a sharp decrease in emissivity at 8.5 μm (band 4, line A) relative to the mid-range and Fe-rich compositions which begin a more gradual decrease in emissivity around 9.3 μm (band 5, line B). There is also a slight inflection in most of the spectra around 10.2 μm

(band 6, line C), where the Fo_{91} spectrum has a slight concave shape, Fo_{68} is flat, and the remainder have a convex shape. There is a second inflection in the longer wavelength region centered at ~11.8 μm (band 8, line D) where the spectra begin to increase in emissivity. The $Fo_{91}$and Fo_{68} spectra have convex shapes, the Fo_{53} and Fo_{39} spectra are relatively flat, and the Fo_{18} and Fo_{01} spectra are concave. Although these differences may appear to be slight, they provide a basis for which to investigate the detectability of different olivine compositions in the THEMIS data.

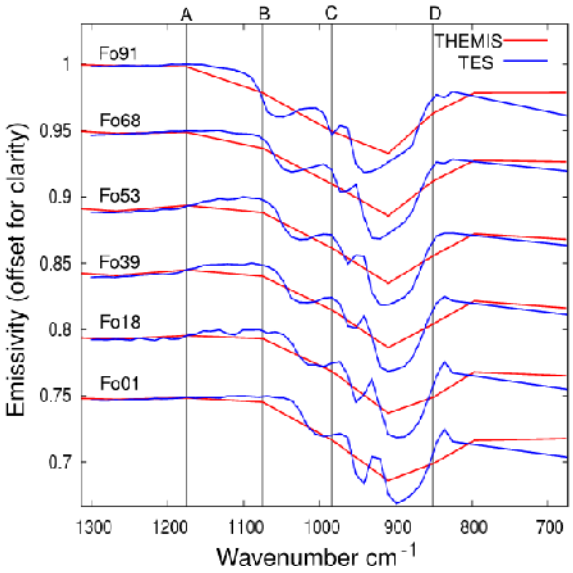

Fig.1 Shown in blue are laboratory data resampled to TES resolution and normalized to Fo_{18} over the THEMIS wavelength range to reduce contrast variations. Shown in red are the spectra convolved to THEMIS resolution. Vertical lines denote key spectral features in the THEMIS data.

Fo91 DCS mask. Initial results using the Fo_{91} mask (Fig. 2) show that there are no significant detections of other TES confirmed olivine compositions (Fo_{68}, Fo_{53}, Fo_{39}) (not shown). However, the mask does detect small olivine-bearing deposits that appear to be similar to the Fo_{91} terrains in the other olivine-bearing areas (also not shown). This interesting first result will be explored further and may add to the geologic interpretation of the region.

These results are promising, and substantiate our initial qualitative analysis of the images from the four olivine-bearing areas: specifically we noted that the different olivine-bearing terrains appeared to have slight variations in their coloration based on the DCS images and that variation was most likely due to differences in the olivine composition.

However, there are two caveats to our method that must be addressed: 1) the DCS is accurately representing the stretched coloration of the olivine-bearing material and is not a function of variation between a different regional terrain composition and that of the olivine-bearing material and 2) the mask may not be accurately detecting variations in composition but instead detecting variations in abundance. The first caveat can be addressed using deconvolution results from [2] which indicate that the regional terrain does not vary significantly between the four areas and thus we do not expect color variations to be dominated by differences between the olivine-bearing deposits and the regional terrain. The second caveat can again be addressed using deconvolution results from [2] which indicate that the Fo_{91} area has the highest abundance based on TES at 25%, Fo_{68} follows with 20%, Fo_{53} at 20%, and Fo_{39} at10%. By constructing the remainder of the masks and testing them on the other sites, we will be able to determine if the masks are identifying pixels based on composition or abundance (e.g. Fo_{68} would work on Fo_{91}, but not on Fo_{53} and Fo_{39}, whereas Fo_{39} should work on all the areas if the masks are correlated with abundance).

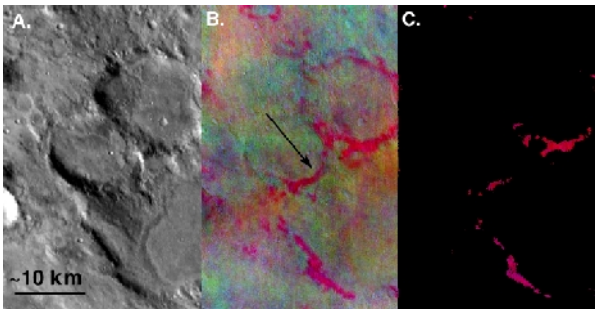

Fig. 2 Section of THEMIS image I07975004. A) Band 9 brightness temperature image. B) Radiance corrected emissivity displayed as 5/7/8 DCS (Fo_{91}-bearing materials appear red/magenta). C) Mask showing only those pixels that match color and saturation criteria in Fo_{91} area.

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