NEW INSIGHTS ON MARS LOW ALBEDO REGION COMPOSITION FROM JOINT ANALYSIS OF ISM AND TES SPECTRA. C. D. Cooper and J. F. Mustard, Department of Geological Sciences, Box 1846, Brown University, Providence RI 02911, Christopher_Cooper@brown.edu.

Introduction: Remotely sensed and morphologic observations have shown that the low albedo regions on Mars are volcanic rocks that are likely mafic to ultramafic in composition [1,2,3]. Visible to near-infrared spectroscopic data gathered by the ISM instrument on the Phobos 2 spacecraft found strong ferrous absorption bands at 1 and 2 \(\mu\)m in low albedo regions consistent with pyroxenes [3,4,5]. Analysis of these absorption bands showed that the principal variations in detected surface composition were due to the relative abundance of pyroxenes (high and low calcium) in these regions [3,6]. In general, the compositions are comparable to the basaltic SNC meteorites with two pyroxenes [3].

Recent observations by the TES instrument on the Mars Global Surveyor spacecraft have added much additional information to the question of the composition of low albedo regions. While the visible to near-IR region is sensitive to iron mineralogy, the mid-IR is sensitive to and diagnostic of a wide range of silicate minerals [7]. TES covers the thermal infrared in 143 bands from 1650 to 200 \(\mu\)m [8]. The TES findings show that globally the dark surfaces can be divided into two distinct units [9]. The first unit (Type I) is widespread and dominates low albedo regions in the southern hemisphere and most strongly in Syrtis Major. The second unit (Type II) has spectra that are typified by those in Acidalia Planitia and is most prevalent in the northern hemisphere. The original interpretation of these two classes of spectra was that the Type I material was probably basaltic with a composition of 50% plagioclase, 25% clinopyroxene, 15% sheet silicates, and 15% other, while the Type II material was probably andesitic with a modal mineral composition of 35% plagioclase, 10% clinopyroxene, 15% sheet silicates, 25% high-silica glass, and 15% other [9]. Additional support for andesitic compositions has come from earlier spectral work [10] and analysis of Pathfinder elemental composition data [11].

Other workers have questioned the assignment of andesite as the material corresponding to the Type II spectra. The Pathfinder data can also be explained by variations in water content of SNC parent magmas [12]. Oxidation of basaltic glass and varying crystallinities of a single melt composition can reproduce features in both Type I and Type II spectra [13]. Others have also argued that the Type II spectra could represent weathered basaltic material or glassier basalts [14].

The composition of material in the Acidalia region and the question of whether one or two pyroxenes are present in basaltic material in the Syrtis region remain as outstanding questions. Utilizing both vis-NIR data (i.e. from ISM) and mid-IR data (i.e. from TES) can promote a better understanding of the composition of low albedo materials on Mars because the wavelength regimes respond to different aspects of mineral composition (i.e. iron vs. silicate absorptions).

Data Processing: Approximately 8.5 million TES spectra were first selected for quality using factors including emission angle, temperature, spacecraft parameters, etc. [15]. The spectra were then deconvolved into atmospheric and surface components consisting of 2 dust, 2 cloud, hematite, Acidalia, Syrtis, and sulfate-cemented soil endmembers following previous works [9,15]. These endmembers along with a blackbody successfully model the low albedo regions on Mars over the 73 bands (excluding the CO\(_2\) absorption) from 233 to 1301 \(\text{cm}^{-1}\) (7.68 to 33 \(\mu\)m) [9]. Subtraction of the atmospheric components from each of the original TES spectra yielded atmosphere-removed surface spectra. These spectra were then gridded into 0.5° x 0.5° bins to create a global data set.

The 64 band ISM spectra (0.77 to 3.14 \(\mu\)m) were matched to the TES half-degree grid via a nearest-neighbors approach. The resultant data cube contains both NIR and MIR spectra of the surface in 137 bands. Because the Phobos 2 mission ended prematurely, only a limited portion of the surface was covered. The 6 best data cubes of the 9 obtained with 22 km resolution were used here (Figure 1). Although Syrtis Major is well sampled in the combined data set, the type locality (Acidalia Planitia) for Type II material is not.

![Figure 1. Coverage of Mars by 0.5° x 0.5° gridded ISM (white) and TES (grey) data. Latitude-longitude graticule is 15° x 15°.](image)

Analysis: In addition to creating the gridded hyperspectral data cube, a number of parameters were calculated from the gridded data. For the ISM spectra the strengths of the 1 \(\mu\)m and 2 \(\mu\)m bands, primarily due to pyroxene, were calculated. In general these bands are caused by ferrous iron in silicate minerals with these two bands in particular due to pyroxene. The strength of these bands is proportional to the abundance of pyroxene in the surface material. Similarly, the fractional abundances of the Type I and Type II spectra calculated from the TES data are also proportional to the exposure of these materials. Therefore, if the Type I or Type II materials are ones that contain pyroxene, the fractional abundance of those materials will be correlated with the pyroxene band strengths from ISM.
Comparisons of the remote sensing results from Mars were made with band strength data from laboratory mineral samples. Clinopyroxene powders from the RELAB database (PP-CMP-023; LS-CMP-009) have a 2 µm band strength of ~0.31. ISM band strength can thus be converted to a percent of the full clinopyroxene band strength. Additional analyses of volcanic rocks measured in both thermal and vis-NIR regimes will also be made to more directly compare results with the TES-ISM combined data.

**Results:** The relationships between 2 µm band strength and Type I and Type II fractions are shown in the scatterplots in Figure 2a&b. These plots show the results from the analysis of all ISM windows. The Type I fraction and the 2 µm pyroxene band strength are moderately correlated, however no correlation is seen between the Type II fraction and the 2 µm band.

Because each ISM window is calibrated independently, the same analysis was performed on a single set of ISM data from the Syrtis region only (Figure 2c&d). The correlation between Type I material and 2 µm band strength is much stronger here. Again, little correlation is seen between the Type II fraction and pyroxene band strength. The intercept for 100% Type I material would translate to ~20% clinopyroxene based on the 2 µm band strength, close to the 25% [9] obtained from the mid-IR.

One limitation of looking at the Type II data for either individual ISM windows or the complete global data set is that ISM did not cover the Acidalia region or other areas that are spectrally dominated by Type II material. The apparent lack of correlation between the 2 µm pyroxene band and the Type II endmember fraction is thus partly due to the high values of the 2 µm band at low Type II abundances due to the dominance of Type I material. In order to remove this bias, a re-analysis of the relationships between Type II abundances and 2 µm data was performed using only data with Type I fractional values below 0.15 (Figure 3). This analysis presents a clearer picture of the true nature of the relationship between the 2 µm band and Type II endmember abundance. Both values are low, and the lack of high values of Type II fractional abundance make any definitive conclusions about the pyroxene content of Acidalia material impossible using this approach.

**Conclusions:** The joint analysis of TES and ISM data provides more information on the composition of surface materials than an analysis of either independently. ISM 2 µm band strength measurements help constrain the abundance of pyroxene in the mafic endmembers used to fit TES data in low albedo regions.

The strong correlation between Type I endmember strength in the deconvolution of TES data and the strength of the pyroxene bands measured by ISM over some low albedo regions of Mars supports a clinopyroxene abundance of ~20%, in close agreement with the 25% found by deconvolution of the TES spectra by other workers [9].

Analysis of the Type II endmember based on ISM data unfortunately is inconclusive due to the limited spatial coverage of ISM. The 2 µm band due to pyroxene does not appear to be correlated with Type II spectral endmem-

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**References:**