MARTIAN GLOBAL SURFACE MINERALOGY FROM THE THERMAL EMISSION SPECTROMETER: SURFACE EMISSIVITY, MINERAL MAP, AND SPECTRAL ENDMEMBER DATA PRODUCTS.

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Introduction: One of the primary goals of the Thermal Emission Spectrometer experiment on the Mars Global Surveyor is to determine the mineralogy of the Martian surface. This information has been used to place constraints on the range of igneous processes present [1,2]. The extent of water related processes on Mars has been significantly constrained by the TES experiment [3-5]. The mineralogy of the Martian dust has also been refined using TES data [6-8]. These mineralogical results have made a significant contribution towards determining the development of Mars, complimenting other datasets and existing information.

Mineralogical determination requires the isolation of surface emissivity from the measured radiance and a variety of techniques have been developed for this purpose. Additionally, deconvolution techniques have been developed and extensively tested to separate the individual mineral contributions to the surface emissivity [9-14]. These methods and techniques have produced a variety of data products that are currently available through http://tes.asu.edu/

Multiple Emission Angle Observations: Multiple emission observation data have been used to separate surface and atmosphere radiative contributions using a correlated-K [15] gas absorption determination and a plane-parallel radiative transfer atmospheric model [6]. Bandfield and Smith produced surface emissivity and dust aerosol opacity spectral shapes as well as refined surface temperatures and dust opacities.

Spectral shapes are displayed in Figure 1. The dust opacity shape has been used for refined opacity determinations from both the TES and THEMIS instruments [16]. Low albedo region surface emissivities were recovered with increased wavelength coverage over previous retrievals. Moderate to high albedo surface spectra were also recovered for the first time.

Moderate to high albedo surface spectra provide sensitivities unique from other chemical and spectroscopic measurements and are able to provide useful new constraints on the mineralogy of the dust and soil. These spectra are diagnostic of fine-particulates with plagioclase and/or zeolites and minor amounts of bound or adsorbed water [6,8]. Small amounts (~2-3%) of carbonates appear to be present as well, serving as a sink for atmospheric CO_2.

Nadir Observations: *Atmospheric Correction.* Bandfield et al. noted that TES equivalent emissivity data can be closely approximated by a linear combination of surface and atmosphere aerosol components (Figure 2). This property was utilized to develop an atmospheric correction algorithm that determined atmospheric contributions from a linear least-squares fit of surface and atmosphere components [17]. A second surface-atmosphere separation method was developed which utilizes the non-correlation of the derivative of the atmosphere and surface components to determine the amplitude of their contributions to the spectra [17]. There is close agreement between these two methods under a variety of atmospheric conditions and surfaces as well as with the multiple emission method mentioned above. These results are also consistent with ratioed data [8].

Spectral Units. Most TES spectra can be closely approximated using 8 spectral shapes; 2 atmospheric dust, 2 atmospheric water-ice, and four surface emissivity spectra [1]. The four surface spectral types match those of basaltic, andesitic, and hematite mineralogies as well as fine-particulates (approximated by a blackbody spectrum in the wavelength regions used). Mars does not display massive amounts of compositional diversity and >99% of the surface can be characterized by the basaltic, andesitic, and surface dust shapes.

Basalt and "Andesite". Mars displays a global dichotomy in surface mineralogy [1]. Basaltic surfaces are almost entirely restricted to older, heavily cratered terrain with several local exposures in the northern lowlands [18]. A second surface composition is indicative of a basaltic andesite to andesite mineralogy. This surface is present in significant quantities throughout most low-albedo regions and the highest concentrations are located in the northern lowlands, particularly the circum-polar sand seas.

The formation mechanism behind the silica component present is subject to debate between researchers who find large quantities of basaltic andesite/andesite difficult to produce [19] and researchers who find difficulties with the occurrence and distribution of an altered basaltic surface [5,20]. For simplicity, this surface will be referred to as "andesitic" and, as the references may indicate, I do not pretend to have no preferred formation mechanism.

Other Spectral Units. Spectral diversity is present at local scales at least to the 3 km sampling of the TES instrument and a number of discoveries are the subject of ongoing studies. Grey hematite has been located in several regions within layered deposits within Sinus Meridiani, Aram Chaos, and Valles Marineris [4].

Many of the possible formation mechanisms for these materials require liquid water in some amount, though a volcanic origin is also possible. Surface exposures of olivine have been located in Nili Fossae, Ganges Chasma, and other locations [2,21]. The geologic context of the exposures is currently being examined. TES data is continuing to provide evidence of additional local exposures of unique mineralogies, including orthopyroxenite [2], a possible ash deposit [22], and other spectrally unique (though the associated mineralogy remains unidentified) surfaces.

Data Products: A purpose of this abstract is to make many of the data products produced by [1,5,6,23] publicly available. These products include the following:

- Surface emissivity cubes at 1, 2, and 4 pixels per degree (ppd) in ISIS and ENVI file types
- Mineral maps at 1, 2, and 4 ppd in ISIS and ENVI file types
- Labeled and unlabeled mineral concentration images draped over shaded MOLA topography at 4 ppd (Figure 3)
- An ascii file containing the 7 canonical TES endmembers, including atmospheric, basaltic, hematite, and andesitic emissivity spectral shapes
- An ascii file containing high and low albedo surface emissivities and dust opacity spectra derived from TES multiple emission angle observations

A link to these files is currently located at http://tes.asu.edu as well as more specific ancillary information.

Conclusions: The TES investigation has fundamentally changed and enhanced our understanding of the development of the Martian surface and conditions present throughout its history, though perhaps more questions have been raised than answered. The higher spatial resolution of the Mars Odyssey Thermal Emission Imaging System and the combined spatial resolution and unique wavelength coverage of the Compact Reconnaissance Spectrometer for Mars on the Mars Reconnaissance Orbiter will help provide a geologic context for these mineralogies as well as complimentary spectral information. The global scale spectral remote sensing of Mars will continue to reveal the unique development of Mars.

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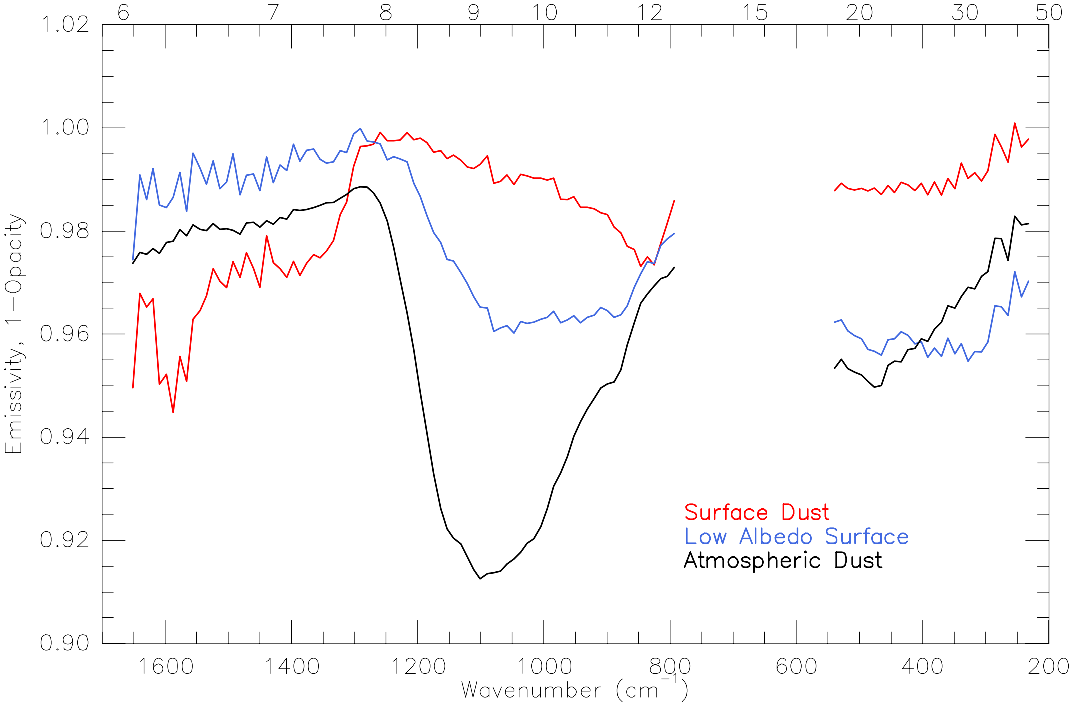

Figure 1. Spectral shapes recovered from multiple emission angle observations. The surface dust spectrum is characteristic of mid- to high albedo surfaces. The low albedo surface is representative of low latitude dark surfaces. The atmospheric dust opacity shape is constant over most Martian conditions.

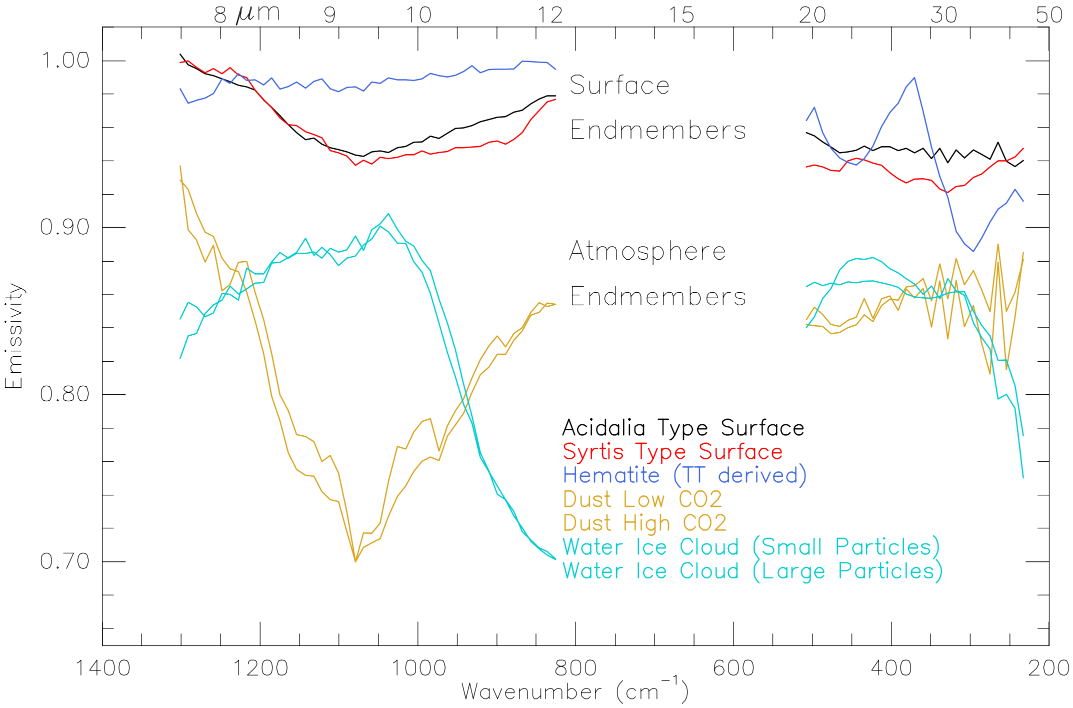

Figure 2. Surface and atmosphere TES spectral endmembers. Most TES spectra of warm surfaces can be well modeled using a linear combination of these 7 spectral shapes plus blackbody to approximate the surface dust and to account for variations in spectral contrast.

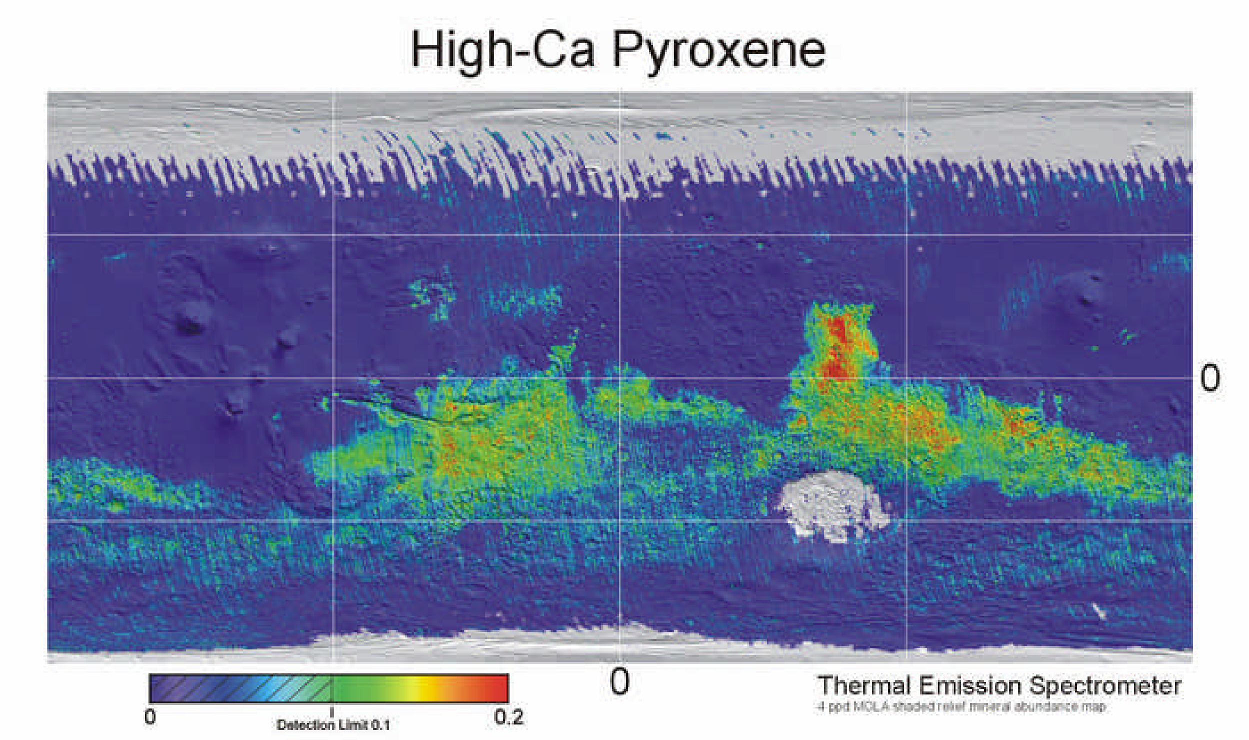

Figure 3. Concentration map of high-calcium pyroxene at 4 pixels per degree. High concentrations correspond to basaltic surfaces. Mineral concentration maps are available in digital and image formats at 1, 2 and 4 ppd.