

**Analysis of Mars Thermal Emission Spectrometer Data Using Large Mineral Reference Libraries.** M. I. Staid, J. R. Johnson, and L. R. Gaddis. U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001

**Introduction:** A method is presented for the analysis of Mars Thermal Emission Spectrometer and Mini-TES data that allows mineralogical analysis relative to spectral reference libraries of unlimited size. The algorithm has been applied to the Mars type I and II surface spectra of Bandfield et al. [1] using spectral libraries of various composition and size. Our goals are to determine the influence that reference library size and composition have on the interpretation of Mars TES and Mini-TES data and to demonstrate a method of analysis relative to very large spectral libraries where the number of reference materials exceeds the number of wavelength measurements.

**Background:** Extensive laboratory and field measurements support the identification of a wide range of minerals using thermal infrared spectral data [summaries in 2,3,4]. Because the thermal infrared spectra of mixed surfaces may be closely modeled using a linear combination of endmember spectra [e.g. 5,6], linear deconvolution has been used as the principal approach for mapping the mineralogy of Mars with TES data [e.g. 7,1,8]. These deconvolution approaches have been extensively validated using field observations and laboratory measurements [e.g 6,9, 10,11].

In typical linear deconvolution approaches, the upper limit to the number of reference spectra or end-members that can be used to model a scene must be less than or equal to the number of unique spectral bands within the image (plus the unity constraint if imposed). In practice, the best solution uses the minimum number of variables required to model the spectral information [12]. This limitation requires spectral libraries to be tailored down from larger numbers of available spectra based on compositional assumptions about the surface being observed.

To allow the simultaneous consideration of all available spectra in an objective manner, we have developed an analytical technique for the analysis of TES data based on multiple endmember spectral mixture analysis or MESMA [13,14,15]. The advantage of the MESMA approach is that it allows deconvolution relative to spectral libraries of unlimited size, while forcing the solution to use a physically reasonable subset of minerals from the larger reference library. The application of a MESMA approach to Mars data has been previously validated using reference libraries of limited size on TES data and laboratory thermal emissivity measurements [e.g. 14, 15] and through direct comparisons to the ASU iterative ejection method using the same reference libraries [17]. In the current study

we have expanded our analysis to include larger reference libraries than have been previously applied to the deconvolution of TES data.

**Approach:** The MESMA algorithm for TES data uses a spectral library composed of six atmospheric spectra [1] and a blackbody spectrum combined with laboratory measurements of up to 186 available minerals, glasses and palagonitic soils. These spectra are derived primarily from the ASU thermal emission spectral library as well as through collaborations with other scientists [e.g. 18,11,16,19].

Our implementation of the MESMA algorithm initially compares all possible combinations of a preset number of mineral spectra from the larger reference library (currently set to three minerals) along with six atmospheric endmembers and a blackbody spectrum. The blackbody is used to compensate for grain size variations between the library spectra and the TES data. The best model containing positive endmember abundances for each spectrum is identified on the basis of the rms error computed for each combination. Then each unused library endmember is alternately added to the existing endmember set and a new rms error is computed for each combination. The spectrum that provides the best improvement (and is selected with a positive abundance for all endmember components) is then kept as an additional endmember. This procedure is then repeated until a pre-set maximum number of reference minerals are selected (currently set to twelve minerals). The algorithm produces fractions for each endmember chosen from the spectral library and the black body component along with rms and residual spectrum error images. The algorithm is currently run over the spectral range of 233-509 cm<sup>-1</sup> and 827-1304 cm<sup>-1</sup>.

For this study, we compared MESMA deconvolutions of the Mars type I and II surface spectra of Bandfield et al. [1] using a range of different reference libraries containing from 32 to 172 mineral reference spectra. The six atmospheric endmembers (atmospheric dust, water-ice, and synthetic water vapor and CO<sub>2</sub>) were also included in our deconvolutions of the surface spectral types after determining that fits were improved when using these components due to small amounts of residual atmospheric contributions to the data.

**Results:** Lowest-error solutions from the smallest and largest reference libraries used to deconvolve Surface Type I and II spectra are presented in Table I as normalized abundances for several major mineral classes.

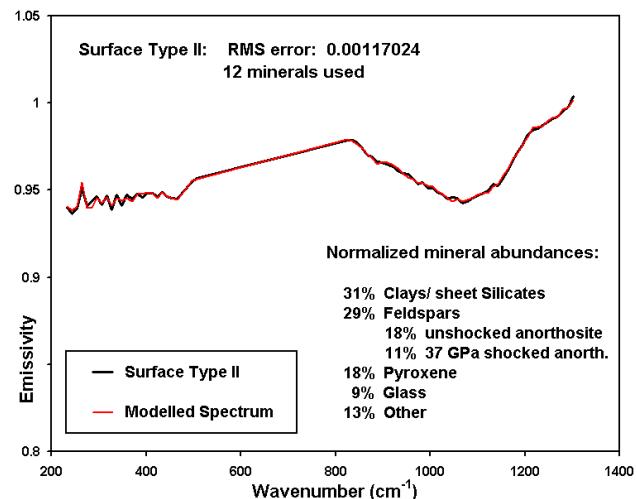
Table I.	Surface 1		Surface 2	
# endmemb.	lib 32	lib 172	lib 32	lib 172
<b>Feldspar</b>	37	27	25	29
<b>Pyroxene</b>	43	50	18	18
<b>Clays/Sheet</b>	5	0	16	31
<b>Glass</b>	0	0	23	9
<b>oxides</b>	9	13	4	0
<b>F/PX</b>	0.86	0.54	1.39	1.61

Implementation of the deconvolution algorithm using a 32 endmember mineral reference library based on Bandfield, 2002 (lib 32 in Table I) produces results for surface types I and II that are generally consistent with previous basalt and basaltic-andesite interpretations [1]. The primary difference between our results and those of Bandfield et al. [1] is a higher level of pyroxene relative to feldspar in both surface types which are closer to results obtained by Wyatt and McSween [20]. Such differences may result from the larger wavelength range of our analysis, small differences in the reference library and inclusion of atmospheric components in the deconvolution.

Increasing the reference library to include additional emission spectra from the ASU library as well as the Si- and K-glass spectra [11], fine and nano-phase Hematite [19], shocked plagioclase spectra [16] and a surface dust spectrum [21] results in different lowest error solutions. Most notably, the abundance of clays/sheet silicates for surface type II increases at the expense of the glass components (e.g. lib 172, Table I and Figure 1). These results are more consistent with the weathered basalt interpretation of Wyatt et al. [11]. Another interesting outcome of runs using larger reference libraries is the identification of shocked feldspars [16] within the lowest error solution of surface type II (e.g. Figure 1).

Our preliminary results indicate that the composition and size of the reference library can produce significant changes in feldspar-to-pyroxene (F/PX) ratios obtained from TES deconvolutions. The MESMA deconvolution of surface I using 172 endmembers (Table I) results in a very low error fit of 0.0016 emissivity and F/PX ratios of 0.54. These ratio values are significantly lower than those obtained by other analyses of basaltic TES spectra which have ratios between 1.3 and 2.8 [e.g. 7]. The F/PX ratio is of particular interest because lower ratio values are more consistent with the mineralogy of the SNC basaltic shergottites which have feldspar-to-pyroxene ratios ranging from 0.38-0.88 [22,23]. However, the implications of these preliminary results for the presence of SNC-like surface compositions are not clear. Removing the single

augite spectra selected in the 172 endmember run from the reference library results in a 171 endmember run with a new F/PX ratio of 1.0 (and an associated rms error increase of ~13% to 0.00186 emissivity). Also, extensive analyses of TES data [24] have not identified the presence of large exposures of SNC-like compositions on the surface of Mars. Nevertheless, our results do indicate that interpretation of the TES spectra can be highly influenced by the composition of the reference library and this issue will continue to be an important focus of future work analyzing spectra relative to large reference libraries.



**Figure 1.** MESMA deconvolution of surface type 2 (Bandfield et al., 2000) based on a 172 mineral reference library.

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