Identification of Spectral Endmembers in CRISM Data Using Factor Analysis and Target Transformation

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Introduction

Spectral datasets contain large volumes of data with variable mixtures of individual spectral endmembers. It is often difficult to identify and isolate these spectral endmembers from the data since they are not often separated from other components. Factor analysis and target transformation is a methodology that addresses this problem and can be used to both identify the number of individual components and test for the presence of and isolate individual endmembers using a set of mixed spectra [1].

This methodology has been applied to laboratory and spacecraft thermal infrared (TIR) spectral data [2-5]. Here, we have adapted and applied these techniques to visible/near-infrared (VNIR) spectral data collected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) on board the Mars Reconnaissance Orbiter [6].

Methodology

Factor Analysis

- Factor analysis uses a set of mixed spectra to derive a set of orthogonal eigenvectors and associated eigenvalues to estimate the number of individual components in a system
- The first 10 eigenvectors derived typically contain all the spectral variations present
- We applied factor analysis to a spectral range of 120 spectral bands from 1.8 – 2.6 µm

Target Transformation

- Target transformation reconstructs endmember spectra using linear combinations of the set of eigenvectors
- The algorithm generates a least squares fit of the significant eigenvectors to laboratory spectra
- A good spectral match indicates the mineral endmember may be present in the set of mixed spectra

Automation

- Factor analysis can be applied to the entire CRISM data set
- Eigenvectors are generated from a sample of every 5 pixels in a CRISM FRT
- Target transformation is applied to a standard set of 12 spectral endmembers

Basic Steps of Target Transformation

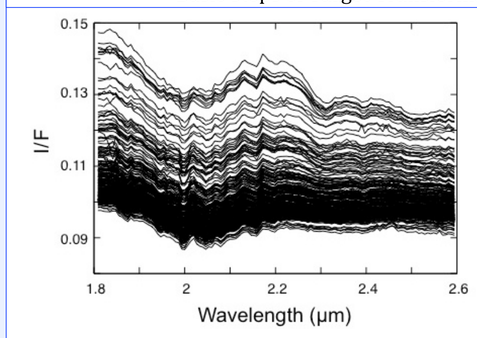


Figure 1: 225 mixed spectra from CRISM FRT000093BE. Perform factor analysis on the mixed spectra.

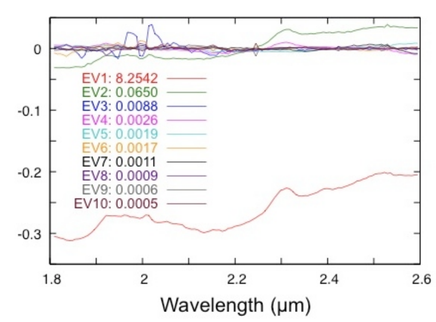


Figure 2: Eigenvectors (plotted) and eigenvalues (listed) from factor analysis on spectra from **Fig. 1**.

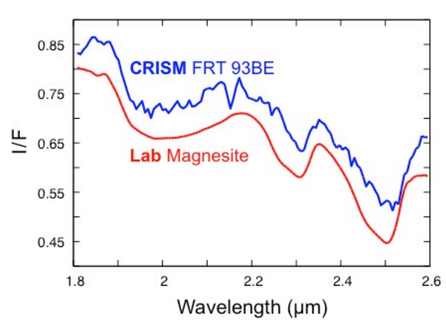


Figure 3: Apply target transformation to eigenvectors to generate a least squares fit to endmember. Spectra are offset for clarity.

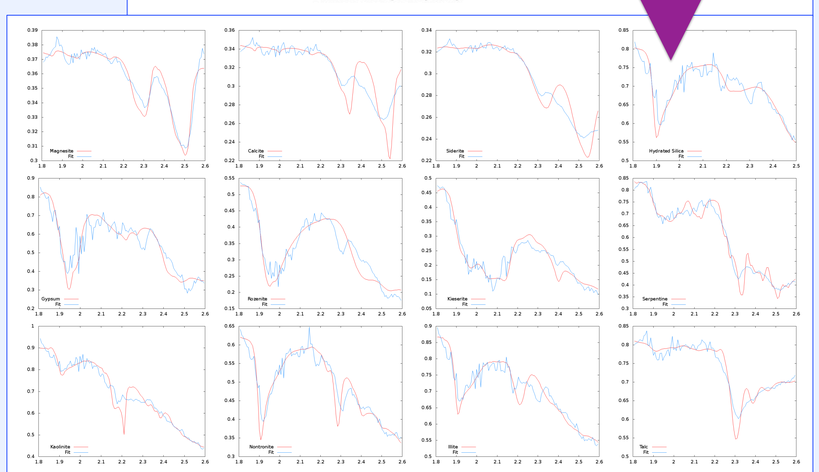


Figure 4: Sample 12-plot generated using automated program.

Future Work

Future Work

- Target other wavelength regions to identify more characteristic endmember absorption features
- Apply the automated technique to the global CRISM data set
- Quantitatively isolate endmembers using Root Mean Square (RMS) values
- Refine methodology for CRISM Multi-spectral products (MSPs)

References:

[1] Malinowski E. R. (1991) *Factor Analysis in Chemistry*, 2nd ed., John Wiley & Sons, New York.
[2] Bandfield J. L. et al. (2000) *JGR*, 105, 9573-9587.
[3] Bandfield et al. (2002) *JGR-Planets*, 107, 5092.
[4] Glotch T. D. and Bandfield (2006), *JGR*, 111, E12S06.
[5] Hamilton V. E. and Ruff S. W. (2012) *Icarus*, 218, 917-949.
[6] Murchie S. L. et al. (2007) *JGR*, 112, E05S03.
[7] Ehlmann B. L. et al. (2008) *Science*, 322, 1828-1832.
[8] Michalski J. R. and Niles P. B. (2010) *Nat. Geosci.*, 3, 751-755.
[9] Wray J. J. et al. (2011) *LPS XLII*, Abstract #2635.

Results

Carbonates

- We tested our methodology on CRISM data containing evidence for carbonates [7-9].
- Target transformation confirms the presence of Mg-rich carbonates in Nili Fossae as previously detected by *Ehlmann et al.* [7] (**Fig. 6**).
- **Figure 2** shows where we have detected additional CRISM FRTs containing Mg-carbonate in Nili Fossae.
- Target transformation also confirmed the presence of siderite in Leighton Crater [8].
- Previously identified carbonates [9] on the Huygens rim crest showed no clear match to any carbonate in the spectral library (**Fig. 7**).

Carbonates identified in Nili Fossae

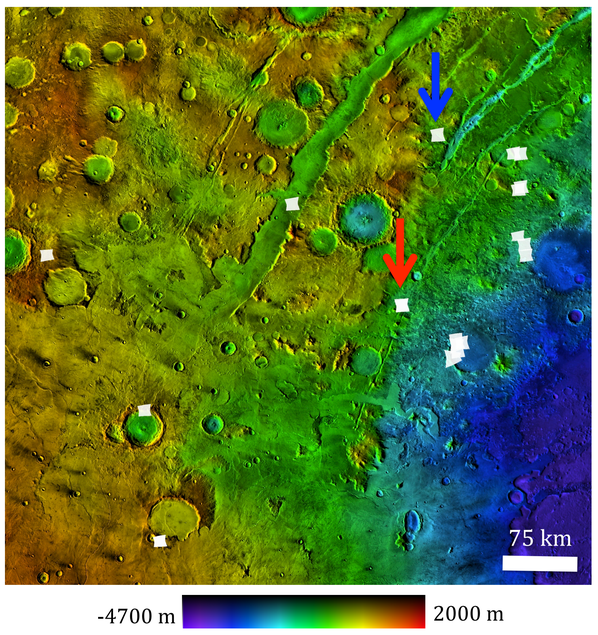


Figure 5: Mg-carbonate deposits are shown as white boxes. The **red** arrow points to **FRT 93BE** and the **blue** arrow points to **FRT 3E12**. The background image is MOLA elevation (color) over the THEMIS daytime global infrared mosaic.

Recovered magnesite endmembers

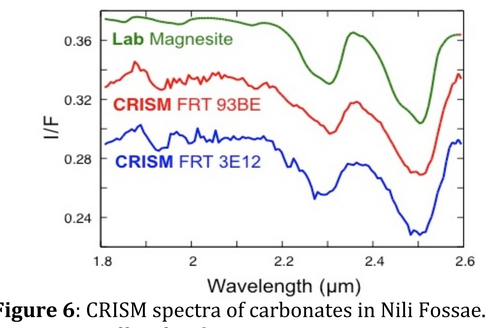


Figure 6: CRISM spectra of carbonates in Nili Fossae. Spectra are offset for clarity.

Poor fit example

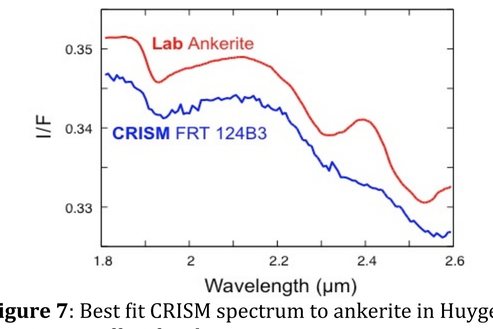
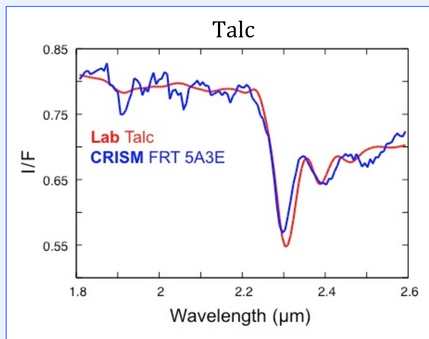


Figure 7: Best fit CRISM spectrum to ankerite in Huygens. Spectra are offset for clarity.

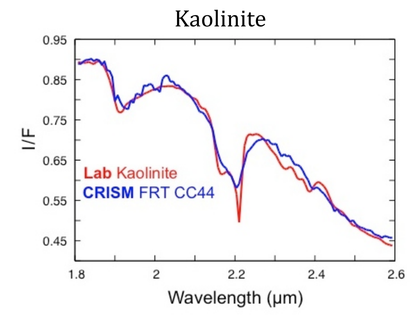
Recovered Endmembers

Talc



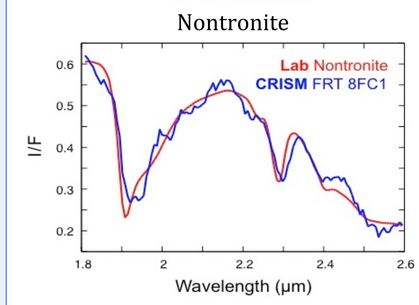
Nili Fossae talc endmember

Kaolinite



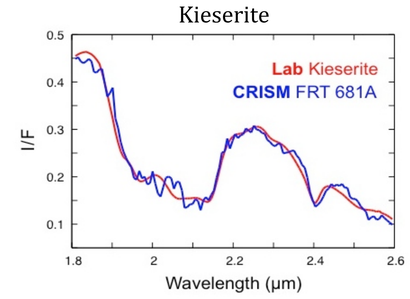
Cross Crater kaolinite endmember

Nontronite



Nili Fossae nontronite endmember

Kieserite



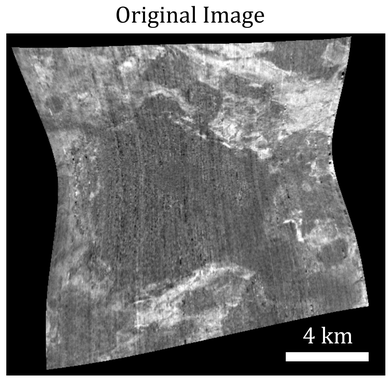
Valles Marineris kieserite endmember

Figure 8: We identified spectral features resembling talc, kaolinite, nontronite, kieserite, gypsum, rozenite, and illite using target transformation.

Noise Removal

- Reconstruction of the original CRISM data using only the first significant eigenvectors (in this case 10) showed significant reductions of noise in the spectral data.
- Noise removal techniques more clearly identified regions containing high carbonate index values while lowering the noise typically present in CRISM index maps (**Fig. 9**).

Original Image



Cleaned Image

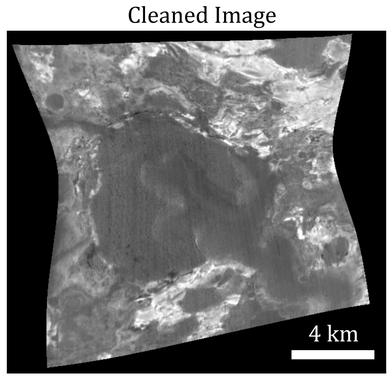


Figure 9: Noise removal process applied to CRISM FRT00003E12 carbonate index.