SPECTRAL UNMIXING FOR SULFATE IDENTIFICATION IN PANCAM IMAGES. M. Parente[1], J. L. Bishop[2] and J. F. Bell III[3]. [1]Stanford University, Packard Engineering Building, 350 Serra Mall, Stanford CA, 94305, cyberey@stanford.edu, [2]SETI Institute / NASA-Ames Research Center, Mountain View, CA 94043. [3]Cornell University, Ithaca, NY 14853.

Introduction: The Mars Exploration Rover (MER) in Gusev Crater has exposed in its tracks an unusual occurrence of a soil high in sulfur and high in phosphorus [1-3] at a site called Paso Robles. Mossbauer (MB) measurements also suggested the presence of a ferric sulfate minerals [4]. Ferric sulfates account for about 25–29% of the Paso Robles composition [1]. The sulfate-rich soil seems to be concentrated in the parts exposed by the MER tracks and is typically bright. It has been found in other locations such as Arad and Tyrone. The focus of this work is the interpretation of Panoramic Camera (Pancam) [5] images in the attempt to identify sulfate spectral signatures in Paso Robles and Arad soils using automated statistical algorithms as an alternative and/or an aid to expert assessment.

Discussion: It has been observed that scatterplots of multispectral data tend to be tear-drop shaped or deltoid, radiating away from the so called dark point, the scanner response to a target of zero reflectance in all bands [6] which is close in concept to a virtual endmember as described by [7]. We observed a similar trend in analyses of the data from Pancam scenes.

Spectral Mixture Analysis assumes that each mixed pixel on the surface is a linear combination of the spectra of the endmembers. The linear mixing assumption can be retained for intimate mixtures if the reflectance values are converted into single scattering albedo [8]. We observed Pancam scenes of Paso Robles and Arad soils and concluded that linear mixing is a sufficient first order approximation for exploratory analysis of the mineralogy of the sites.

Spectral unmixing is the inversion of the mixing model into endmemember spectra and surface abundances [9]. We devised an unmxing algorithm that jointly performs endmember selection and abundance calculation and can operate regardless of ground truth data. When ground truth data on the endmebers is available the algorithm optimizes the calculations by automatically constraining the estimates of the endmembers to vary within certain tolerances.

A more detailed explanation of the algorithm and an application to remote sensing data can be found in [10]. In this particular application we took into account that the dark point must be present as an endmember and that one endmember must be the ubiquitous martian dust.

To enable comparison with our results we created a library of mineral spectra that were convolved with Pancam filter bandpasses. Selected sulfate mineral spectra are plotted in fig 1.

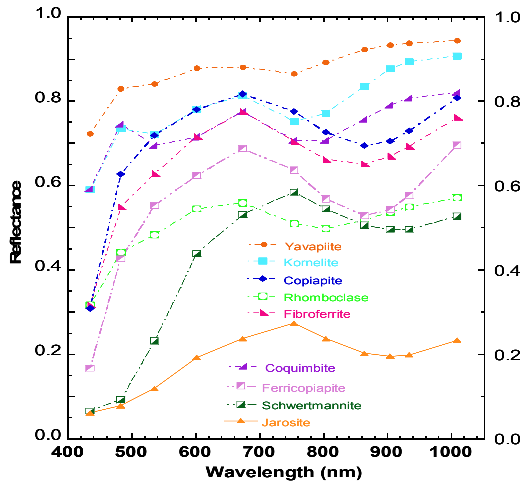

Fig 1: Pancam convolved spectra of sulfate minerals.

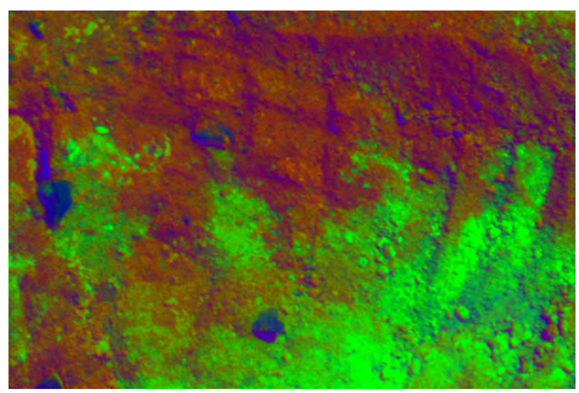

Fig 2: Endmember map from spectral unmixing of Paso Robles scene, sol 426; sulfate (green), dust (red), shade (blue).

Paso Robles (Sol426): Sulfate rich soils were exposed in the rover trenches as shown in fig. 2 (in green). As we can see in fig. 3, this endmember exhibits diagnostic spectral characteristics (e.g., a convex upward feature near 480 nm, a reflectance maximum at ~670 nm and a minimum near 800-850 nm) that are consistent with a few ferric sulfate minerals, and best fit by kornelite and coquimbite. However, these two minerals are not identified by MB analyses so we are investigating other possibilities [11]. The estimated abundance for the sulfate endmember is 37%. We also detected a ferric phase which accounted for about 10% in abundance. We detected typical martian dust at ~ 34% abundance and the shade endmember (~18% abundance).

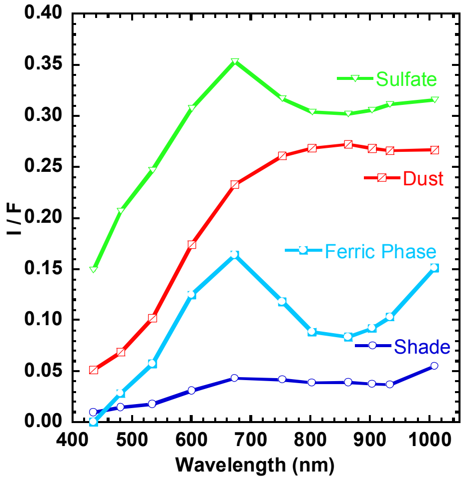

Fig 3: Endmember spectra for sol 426.

Paso Robles (Sol400): The endmember spectra show close similarity with the ones for sol 426, (as expected). We show the abundance map for this sol (fig. 4) to remark that the algorithm correctly identifies shade in between the rover marks, dust in the compressed soil and the sulfate in the exposed subsurface soil. The abundance of the sulfate phase was estimated at ~42% in this scene, the dust at ~31%, the shade at ~16% and the ferric phase at ~11%.

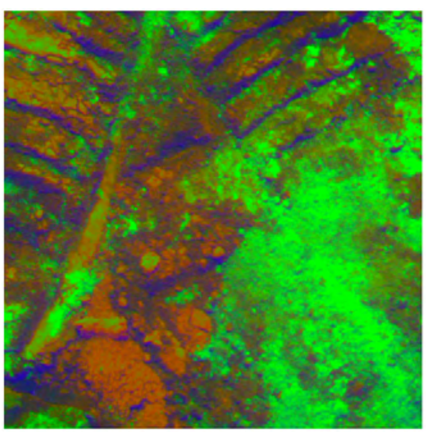

Fig 4: Endmember map from spectral unmixing of Paso Robles scene, sol 400; sulfate (green), dust (red), shade (blue).

Arad (sol 721): Endmember analysis confirmed the expectation that the salty soils exposed by the rover tracks presented sulfate-like signatures. Similar to the features already identified for the sulfate in sol 426, the sulfate endmember at the Arad site showed a reflectance maximum at ~670 nm and a minimum near 800-850 nm. The abundance of the sulfate phase turned out to be ~38% while we detected ~40% of dust content and ~22% was ascribed to the shade endmemember. We did not detect a ferric phase in Arad soil.

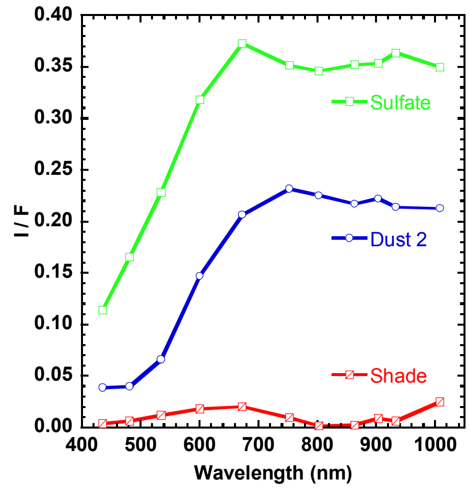

Fig 6: Endmember spectra for sol 721.

Conclusions: Spectral unmixing has enabled us to map components due to sulfate, dust, a ferric phase, and shade in several unusual bright region soils uncovered by the rover tracks in Gusev crater. Coquimbite and kornelite best match the Pancam spectral signature for the sulfate endmember for the Paso Robles sites, while fibroferrite best matches the sulfate endmember spectrum for Arad.

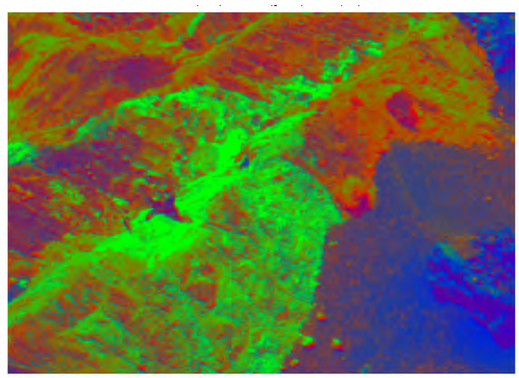

Fig 7: Endmember map from spectral unmixing of Arad scene, sol 400; sulfate (green), dust (red), shade (blue).

References:
[1] Ming, D. W. et al. (2006) *JGR, 111,* E02S12. [2] Arvidson, R. E. et al. (2006) *JGR, 111,* E02S01. [3] Gellert, R. et al. (2006) *JGR, 111,* E02S05. [4] Morris, R. V., et al. (2006) *JGR*, doi: 10.1029/2005JE002584, in press. [5] Bell, J. F. et al. (2006) *JGR,*