MAPPING OF MARTIAN SURFACE UNITS USING HRSC COLOR DATA L. Wendt[1], J.-P. Combe[2], T. B. McCord[2], G. Neukum[1]. [1]Institute of Geosciences, Freie Universtät Berlin, 12249 Berlin, Germany, Lorenz.wendt@fu-berlin.de [2]Bear Fight Center, 22 Fiddler's Road, Winthrop, WA 98862, USA.

Introduction: To outline Martian surface units, one approach is to use morphologic and textural features identified in panchromatic imagery. These datasets provide high spatial resolution and coverage, but convey only indirect information about the mineral composition of the surface materials. On the other hand, imaging spectrometers like the Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité (OMEGA) or the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) are very well suited instruments to determine the surface mineral composition, but have only a limited spatial resolution (350 m to 4 km for OMEGA) or coverage (1% of the surface of Mars for CRISM targeted observations. In this study, we investigate the potential of the color dataset of the High Resolution Stereo Camera (HRSC) onboard Mars Express to bridge this gap.

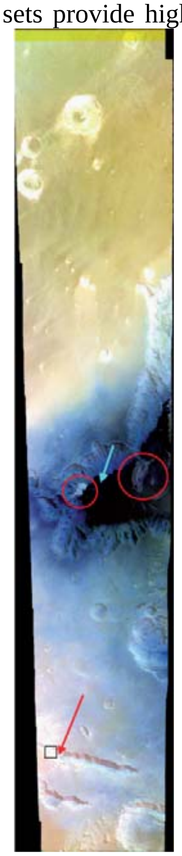

Figure 1: color composite of red, green and blue channel of HRSC orbit 243. Red arrow: location of bright material reference spectrum; cyan: location of dark material spectrum; Black rectangle: area used to derive spectrum of shade; Red circles: sulfate deposits from [1].

We chose regions like the sulfate deposits in Juventae Chasma [1] where OMEGA had identified a specific mineralogy as test area, and looked for spectral characteristics in the HRSC color dataset that are unique to these outcrops. We describe the procedures and the findings of this study using HRSC orbit 243 as an example. It is shown in figure 1.

The HRSC color dataset: The HRSC acquires images at various angles with respect to nadir [2]. The nadir-looking channel is centered at 650 nm and provides high-resolution imagery with up to 12.5 m ground resolution. The four color channels centered at 440 nm (blue), 530 nm (green), 750 nm (red) and 970 nm (infrared) have viewing angles of -16°, -3°, +3° and +16°, respectively. They are usually operated at a ground resolution of 50 to 100 m per pixel. We subsampled the nadir channel data to the resolution of the color channels to create a five-channel multispectral dataset.

Linear spectral unmixing [4, 5, 6]: To test if a specific surface unit like the sulfate outcrops in orbit 243 show a spectral signature in the HRSC color data that is unique to these outcrops, we model the measured spectra by a linear combination of known endmember spectra [5, 6]. A significantly higher modeling residual then means that the input spectra are not sufficient to model the measured spectra in that area, and that a further, previously unknown spectral component is present.

Input spectra: Most surface variations can be described by a linear combination of only three endmember spectra, as shown by [3]. These are: 1. Bright red material: iron oxide rich, covering most of the plains surrounding Juventae Chasma, 2. Dark material: unoxidized basalt covering parts of the chasma floor, and 3. a shade/shadow component. The spectrum of shade accounts for the impact of indirect light that is scattered by the Martian atmosphere as well as different amounts of shade present in the individual channels because of sub-pixel scale topography observed from different viewing angles.

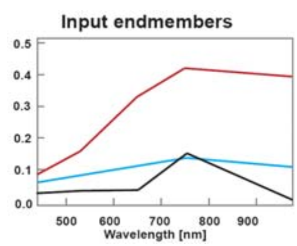

Figure 2: Input endmembers for linear unmixing method. Red: red material. Blue: dark material. Black: shade. The spectra were taken at the locations indicated in figure 1.

The spectra for bright and dark material were taken directly from the image at the locations shown in figure 1. The spectrum of shade was calculated from an image region that contains (presumably) only bright material but varying amounts of shade (black square in figure 1). The linear dependency between the individual channels is then used to calculate the shade spectrum. We subsequently applied the Multiple Endmember Linear Spectral Unmixing Model (MELSUM) described by [4,5].

Unmixing results: The results of the spectral unmixing are shown in figure 3. Brighter shades indicate higher values. Most of the planes surrounding Juventae Chasma are modeled by only the bright material endmember+shade. The valley floor and the immediate vicinity are modeled by a combination of the dark material+shade. The images of the bright and the dark endmember coefficient appear "flat", revealing only little information about the topography of the area, whereas the shade endmember coefficient image shows very distinct contrasts between well-lit areas and shaded areas in the canyon walls. This indicates that the spectral unmixing procedure was successful in separating the effects of surface endmember materials and illumination. Consequently, any further, linearly independent surface spectrum should be identifiable in the modeling residual, if present.

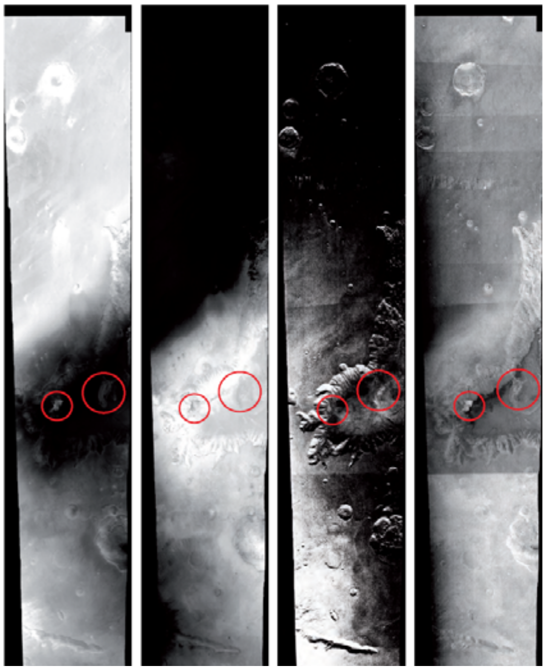

Figure 3: Coefficients of unmixing endmembers. Brighter shades of grey indicate higher values. Red circles: sulfate deposits.

The linear spectral unmixing residual shows some variations, their interpretation as the effect of a further material present at the surface is however difficult: The strongest errors are located along east-west trending lines, which are caused by image compression effects. Although the western sulfate outcrop displays an elevated modeling error, this error is probably not related to the presence of the sulfates, as the eastern outcrop does not show the same level of error. In this study, the impact of the illumination angle and changes in surface roughness on the shape of the spectra has not been accounted for. The reasons for the observed error variations therefore remain unsolved, but a spectral index for the sulfates in the wavelength domain detected by HRSC could not be found.

Spectral Angle Mapper [7]: The linear unmixing results suggest that the spectrally neutral, multi-scattering sulfate rich material is mixed with both red and dark material. Therefore, mixtures of these two components can perfectly mimic the spectral shape of the sulfates.

This effect is confirmed by the spectral angle mapper [7]. This analysis tool uses the angle between a given pixel in the five-dimensional parameter space, a reference spectrum and the coordinate origin as a similarity measure. It is therefore insensitive to overall brightness variations caused by (ideal) shadows.

The result of the spectral angle mapper is shown in figure 4. The reference spectrum was taken in the western sulfate outcrop. A broad zone of high similarity to the sulfate outcrops surrounds the chasma on the plains. The spectra in this zone are even more similar to the western sulfate outcrop then the eastern sulfate outcrop, which appears in a darker shade of grey. Dark, presumably windblown material mixes with the bright material of the plains to produce exactly the same spectral shape as in the sulfates itself.

Figure 4: Result of spectral angle mapper. Brighter grey indicates a higher similarity to the reference spectrum taken at the red arrow.

Conclusion: This study has confirmed that three spectral endmembers are sufficient to model most of the surface color variations observed by HRSC, as suggested by [3]. A unique specral index for the sulfate outcrops was not found. We are planning to expand this investigation to further areas to better understand and separate the influences of mineralogy, surface roughness, illumination and observation angles and aerosols in the Martian atmosphere on the observed HRSC color spectra.

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