

GEOLOGIC SURFACE COMPOSITIONAL MAPPING FROM THERMAL INFRARED SEBASS DATA

C. A. Hecker

International Institute of Geo-Information Science and Earth Observation (ITC), Department of Earth Systems Analysis,
Box 6, 7500AA Enschede, The Netherlands - hecker@itc.nl

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ABSTRACT:

The Spatially Enhanced Broadband Array Spectrograph System (SEBASS) is one of the few systems that acquire hyperspectral data sets in the thermal infrared (TIR). Many rock forming minerals display distinct spectral features mainly (or exclusively) in the 8-12 μm range ("Reststrahlen bands"). Hence, development of good TIR instruments and algorithms are of high importance for geologic remote sensing. With 128 contiguous bands each in the 2.5-5.2 μm as well as in the 7.5-13.5 μm wavelength range, SEBASS has great potential for geologic mapping and mineralogic mapping. We investigate SEBASS data acquired in September 1999 over an area near Yerington, Nevada (USA). Preprocessing of SEBASS involves an in-scene atmospheric correction, noise removal/data reduction, as well as an emissivity/temperature separation. However, band-to-band noise and residual atmospheric features still remain in the dataset and make interpretations difficult for wavelengths <8.5 μm and >11 μm .

1. INTRODUCTION

In order to solve many earth science related problems, understanding the composition and distribution of silicate minerals is imperative. Most silicate minerals show little to no information in the visible, near infrared and short-wave infrared (VIS/NIR/SWIR) wavelength bands. Their main interaction with electromagnetic radiation takes place in the wavelength region that is referred to as the Reststrahlen band, which occurs in the thermal infrared (TIR) around 8-12 μm . Hence, development of good TIR instruments and algorithms are of high importance for geologic remote sensing.

Historically, geological applications have made much more extensive use of the VIS-SWIR wavelength than the TIR. This is because of the non-availability of operating remote sensing systems in the TIR region and the complexity of the physics associated with analyzing and interpreting these TIR data sets. However, when Lyon and Hunt published thermal spectra of rocks in the 1970's and 1980's showing the merit of exploring the TIR region, this type of remote sensing received attention and as a result Landsat TM was equipped with a TIR band. It was only until recently with the launch of the ASTER satellite that the TIR region received more attention from the science community. With five bands and 90m pixel size in the TIR, ASTER allows for identification of various rock types. In order to identify individual rock-forming minerals, however, an improved spectral and spatial resolution in the TIR would be necessary.

In this paper we will be using data from the Spatially Enhanced Broadband Array Spectrograph System (SEBASS) of an area near Reno, Nevada (USA). With 128 bands in the TIR and a ground resolution around 2-3m, this airborne sensor has great potential to advance our abilities in geologic remote sensing - from detecting variations in rock types to actually identifying silicate mineralogy and potentially even mineral chemistry. In this paper we will show some instrument and data characteristics, pre-processing techniques and first results towards mineralogic maps to aid in alteration studies and prospecting.

2. THE SEBASS INSTRUMENT

The SEBASS instrument is an airborne thermal imaging spectrometer that was developed by the Aerospace Corporation (Hackwell et al., 1996). It measures radiance with two liquid He cooled detector arrays that cover the ranges of 2.5-5.2 μm and 7.5-13.5 μm with 128 contiguous bands each. Each of the arrays contains 128 detector elements in the cross-track direction. SEBASS is a pushbroom instrument where imaging is achieved by the along-track movement of the airborne platform.

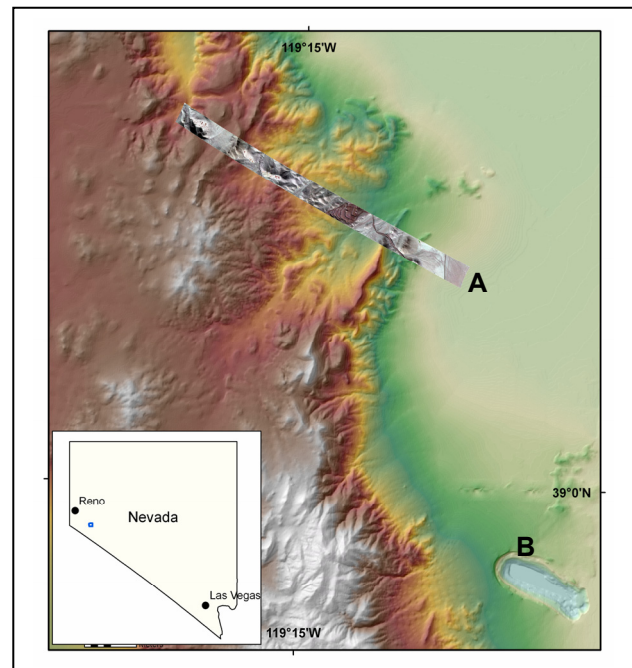


Figure 1. Location of study site. A) McArthur SEBASS strip with McArthur open-pit mine; B) Yerington open-pit mine.

The instantaneous field of view (ifov) of a single detector is 1.1mrad and the total field of view (tfov) is 128mrad. When flown at a typical altitude of 3000m above ground, SEBASS produces a swath width of roughly 400m and a pixel size of about 3m.

3. STUDY SITE

The SEBASS scene used in this study was acquired in September 1999 under clear sky conditions over the McArthur open cast mine near Yerington, Nevada, USA (Figure 1). Most of the scene is covering the morphologic high of the Singatse Range that protrudes the quaternary sediments of the Yerington Basin. Outcrop situation is good, with very little brushy desert vegetation and thin soil cover. Lithologically, most rocks are part of the middle Jurassic Yerington batholith, which intruded Triassic to lower Jurassic volcanic rocks and sediments (Dilles et al., 2000). Associated with the last stages of the batholithic intrusion are granite porphyry dikes along which magmatic brines caused extensive alteration and formed economic porphyry copper deposits. Mineralization in this area is associated with K-silicate alteration, which causes Biotite, Epidot and Quartz to replace Hornblende crystals (Dilles et al., 2000).

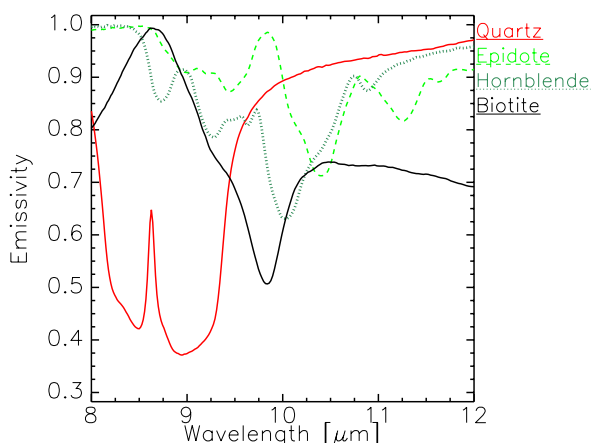


Figure 2. JPL TIR library spectra of common mineral reaction in the study area

All four minerals mentioned above show features in TIR spectra (Figure 2). Through carefully mapping the abundance of these minerals using SEBASS imagery, we have a “vector to ore” and a powerful tool to assess large areas for their prospectivity.

4. DATA PROCESSING

Pre-processing of SEBASS datasets requires the following steps:

- Atmospheric correction
- Noise removal / Data reduction
- Emissivity / Temperature Separation

Atmospheric correction is achieved without radiative transfer modeling by using information embedded in the dataset itself (In scene atmospheric correction; Young et al., 2002). It removes an additive radiance component (upwelling radiance) as well as a multiplicative component (atmosphere transmissivity).

While this technique is hardly useful for multispectral thermal data, it works sufficiently well for hyperspectral SEBASS data, if no auxiliary data on the state of the atmosphere during acquisition are available.

With the atmospheric effects removed, the data cube still shows distinct striping and banding in along-track direction. Striping caused by sharp detector noise (e.g. slight calibration error of an individual detector element) can be corrected for by normalizing the means of each image column (i.e. acquired by the same detector element) over a homogeneous target. Banding is mainly present in the shortest and longest wavelength channels. Its effect is systematic and can be removed or greatly reduced by eliminating the most affected components in MNF space.

In order to compare the SEBASS pixels with library spectra, we need to convert the radiance image into emissivity. This can be done by any of the commonly used emissivity-temperature separation algorithms. We decided to use an emissivity normalization procedure (Gillespie et al., 1986). However, Cudahy et al. (2000) have shown that for a hyperspectral thermal scene, a simple continuum removal algorithm gives nearly identical results, which could make an E/T separation for most applications obsolete in the future.

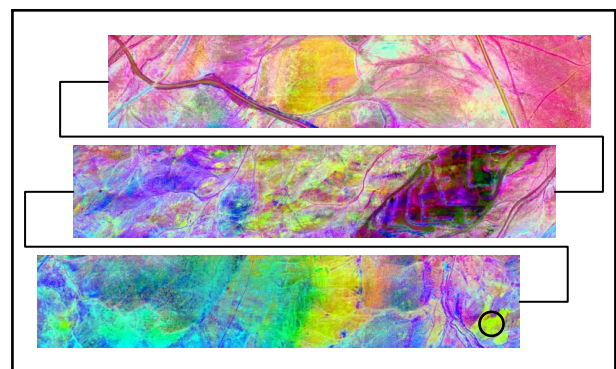


Figure 3. Decorrelation stretched colour composite of RGB = 67,36,25. Swath is 400m wide. The circle indicates the origin of the spectrum in figure 4.

5. RESULTS

After the described pre-processing steps, SEBASS reveals spatially coherent bands with good information contrast. We illustrate here the wealth of information in the scene through a simple colour composite (figure 3) of RGB = bands 67, 36, 25 (11.1, 9.6, 9.0 μ m resp.). These bands are chosen to differentiate areas rich in quartz (yellow shades) from clay-rich areas (magenta). The combination of quartz, feldspar and clay appears in orange-brown shades (Vaughan et al., 2003). The colour composite was decorrelation stretched to enhance the colour saturation in the image while preserving the colour information as much as possible.

Unfortunately, the spectra of individual pixels show less coherency than the bands do spatially. The spectra contain areas that display lots of band-to-band noise that was not removed by the pre-processing procedure used here. The offset between bands is relatively systematic and, therefore, does not disturb the appearance of a single band when displayed. The off-set values do, however, change not only from band to band but also gradually between image columns within the same band. Figure 4 illustrates this on an example spectra extracted from the image data over an area rich in Quartz (for location see figure 3).

The main emissivity low at $9\mu\text{m}$ is attributed to quartz. However, the second half of the quartz feature (compare figure 2) is obscured by band-to-band noise in the wavelengths shorter than about $8.5\mu\text{m}$. The two features at 9.6 and $9.9\mu\text{m}$, resp. are most likely originating from feldspar. Above $11\mu\text{m}$ the noise increases again.

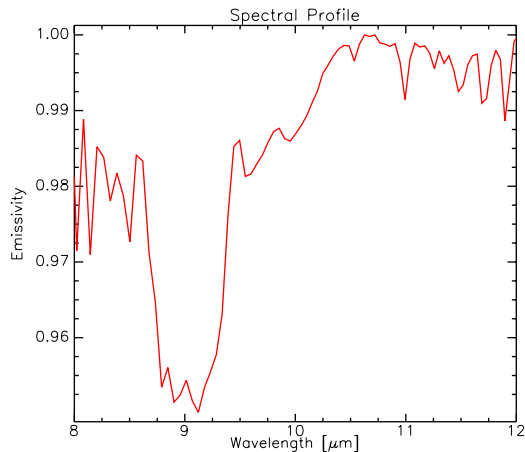


Figure 4. Image spectrum of quartz rich area indicated in figure 3 with circle.

With the current pre-processing, we are able to detect the main mineral constituents in the rocks. Minerals with features below $8.5\mu\text{m}$ or above $11\mu\text{m}$ are difficult to be differentiated from the noise.

More detailed work is needed to understand and remove this effect that greatly deteriorates the signal in the affected regions. If the band-to-band noise is common to an entire band (e.g. remaining atmospheric absorption features), they could be removed by looking at the scene average. If the noise repeats itself at certain frequencies in the across-path direction within a band, removal in the Fourier transform domain could be a possibility.

6. CONCLUSIONS

SEBASS is a useful instrument that produces images with high TIR information content. With the proper pre-processing, images with good spatial coherence can be produced; but they still lack coherence in shortest and longest wavelength parts of their spectral domain. Not until these systematic errors are corrected for, can more sophisticated analyses that use the full range of these hyperspectral thermal data, be possible.

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