

MINERAL MAPPING BASED ON AUTOMATIC DETECTION OF MULTIPLE ABSORPTION FEATURES

Veronika Kopačková, and Lucie Koucká

Remote Sensing Department – Czech Geological Survey, Prague, Czech Republic;
[veronika.kopackova\(at\)seznam.cz](mailto:veronika.kopackova(at)seznam.cz)

ABSTRACT

In comparison with multispectral image data, hyperspectral (HS) imagery with higher spectral resolution provides sufficient spectral resolution to describe diagnostic absorption signatures. Specific chemical bonds in materials, whether solid, liquid or gas, determine the surface reflectance and emittance, as variations in material composition often cause shifts in the position and shape of absorption bands in the spectrum. In addition, detecting the exact absorption wavelength position is a key factor not only for mineral identification but also for tracking diverse environmental processes and pathways. A couple of techniques to identify absorption parameters have been suggested, however, they are capable of a quantitative characterization of just one major absorption feature and, due to the techniques they use, limited to the SWIR region.

In this paper, new tools are presented allowing automatic detection of multiple absorption feature parameters (absorption maximum wavelengths and depths). The tools employ methods based on a trend analysis of the spectra, while bad bands (e. g., noise, error bands) are detected at first and excluded from further analysis. The tools – e.g. called QUANTools – have been created using IDL programming language and can be used under ENVI/IDL (version 5.0 and higher). As multiple absorption features are detected within the VNIR/SWIR/TIR regions and their wavelength positions, respectively, the newly suggested method has a potential to become a new mapping technique suitable for environments with high heterogeneity and dynamics.

INTRODUCTION

In comparison to multispectral image data, hyperspectral (HS) imagery with higher spectral resolution provides sufficient spectral resolution to describe diagnostic absorption signatures (1). Therefore, remote hyperspectral sensors such as airborne systems (e.g., HyMap, AVIRIS, HySpex or APEX) and the upcoming spaceborne satellites (e.g., EnMap, (2)) offers the opportunity to estimate the mineral composition of the surface under examination without having a direct contact with the field. Specific chemical bonds in materials, whether solid, liquid or gas, determine the surface reflectance and emittance, as variations in material composition often cause shifts in the position and shape of absorption bands in the spectrum. Basically, the wavelength position of the absorption maximum allows material identification, while the absorption depth reflects the material quantity. Therefore, absorption-band parameters such as the position, depth, width, and asymmetry of the feature have been used to quantitatively estimate the composition from hyperspectral field and laboratory reflectance data as well as image reflectance data. (3) proposed a simple linear interpolation technique in order to derive absorption-band position, depth and asymmetry from hyperspectral images. Such image-derived parameters were used to interpret the data in terms of the known alteration phases characterizing the area. (4) proposed a simple quadratic method to estimate the wavelengths of absorption features in the short wave infrared (SWIR) spectral region. These two methods are suitable for the SWIR region only.

In heterogeneous or dynamic environments minerals exist in diverse variations; therefore, the dominant absorption feature occupies a spectral range rather than a single location. For instance, the position of the absorption maximum between 2.1 and 2.3 μm reflects the amounts of aluminium present in the mica. Considering the VNIR region, the shift to longer wavelengths of the absorption maximum centred between 0.90 and 1.00 μm is the main parameter that allows differentiation among the ferric minerals and this trend was found to be still visible, if the minerals are part of mix-

tures and the key factor allowing pH modelling for substrates exposed to mining sites (5). Thus, tracing the exact absorption wavelength position is a key factor not only for mineral identification but also for tracking diverse environmental processes and pathways.

The methods introduced by (3) and (4) are suitable for the SWIR region only. In this paper, new tools are presented allowing automatic detection of multiple absorption feature parameters within the VNIR/SWIR/TIR regions. The tools employ methods based on a trend analysis of the spectrum, while bad bands (e. g., noise, error bands) are detected at first and excluded from the further analysis.

METHODS

The new tools – e.g., called QUANTools – were created using IDL programming language and can be used under ENVI/IDL (version 5.0 and higher). The inputs can be field spectra as well as hyper-spectral image data. These tools consist of the basic modules (GUI's), Figure 1.

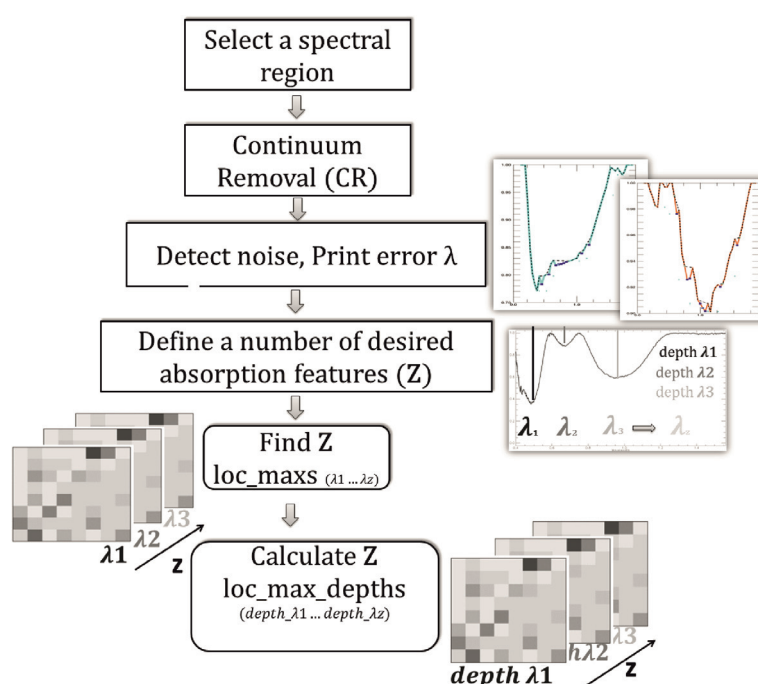


Figure 1: A simplified processing scheme (CR: continuum removal, loc_max: local absorption feature maximum, loc_max_depth: absorption feature depth).

The modules allow users to:

- **Define a spectral range** – it is expected that a user first defines a spectral range to be analyzed (VIS-VNIR, SWIR or TIR spectral region). However, the width of a set spectral region should depend on the sensor spectral resolution as well as on spectral properties of desired absorption features (position, width, depth).
- **Employ Continuum Removal (CR)** – a standard method to normalize the spectrum.
- **Detect bad bands** – a user can use the graphical interface to detect bad bands and exclude these from the further analysis (Figure 2). This unfavourable parameter differs for different HS datasets, as sensors differ from a level of noise as well as from the atmospheric conditions during data acquisition. Therefore, a user can define an optimal spectral window size (number of neighbouring bands/wavelengths that are being statistically assessed to detect deviating bands/wavelengths).
- **Define a number of desired absorption features to be detected** within a set spectral range: The user can decide to either detect an absolute absorption with the biggest depth or define a number of multiple absorption features that can be identified within a set spectral range.

- **Calculate absorption maximums/depths:** After exclusion of bad bands a trend of a spectral curve is being analysed and saddle points – the local absorption maximum wavelengths - are detected and assigned to an image matrix. Additionally, a corresponding depth is also calculated for each absorption maximum. For Z absorption features, two matrixes with Z bands are created, one has the absorption wavelengths assigned, while the second one has corresponding absorption depths assigned, respectively.

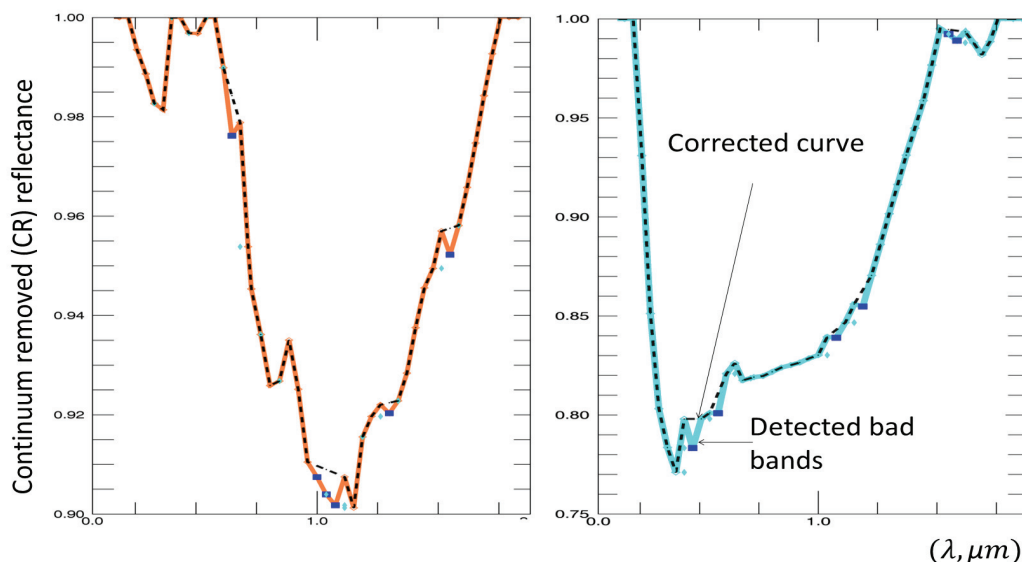


Figure 2: Bad band detection: detected bad bands (square points) and corrected curve – dashed line (set spectral window: 3 neighbouring bands).

As multiple absorption features are detected within the VNIR/SWIR/TIR region and their wavelength positions, respectively, the newly suggested method has a potential to become a new mapping technique suitable for environments with high heterogeneity and dynamics. Furthermore, the derived depths of detected absorption features then can be correlated with abundances of corresponding minerals/materials.

RESULTS

In Figure 3, an example of mineral mapping is demonstrated using the 2009 HyMap reflectance data acquired for the Sokolov lignite mines, NW Bohemia (5): a kaolinite content (Figure 3A) (most abundant mineral found in the Sokolov basin lithologies), carbonate content (Figure 3B) and the jarosite-goethite mineral stack (3C, D). To demonstrate a general applicability of the newly developed tools more mineral mapping examples utilizing the VIS/NIR/SWIR/TIR will be further conducted using the multi-temporal HyMap (2009 and 2010) and AHS (2011) data acquired over the Sokolov lignite basin.

CONCLUSIONS

The presented QUANTools, which have been developed, represent a new expert system allowing materials to be identified based on extraction of key spectra features and their parameters. Spectral absorption features are automatically extracted either from a spectral library or from a hyper-spectral image.

The key issue lies on detection of bad bands (e.g., noise, effect of the atmosphere), as these can cause false absorption maxima detections. This unfavourable parameter differs for different HS datasets, as sensors differ from a level of noise as well as from the atmospheric conditions during data acquisition. The QUANTools are designed in such a way that users first analyze sample spectra (either libraries or image spectra) and then set a spectral window size which is being statistically assessed to detect deviating bands/wavelengths.

There is a big potential for using such an expert system; it can be used for determining secondary iron minerals (5), estimating rare earth elements (6), tracing alteration processes (7), and even for vegetation studies (8). Therefore, such tools implemented into the ENVI SW may have implications not only for mineral mapping but also for a wide range of environmental applications.

To demonstrate a general applicability of the newly developed tools, further mineral mapping examples utilizing the VIS/NIR/SWIR/TIR regions will be conducted using the multi-temporal HyMap (2009 and 2010) and AHS (2011) data acquired over the Sokolov lignite basin.

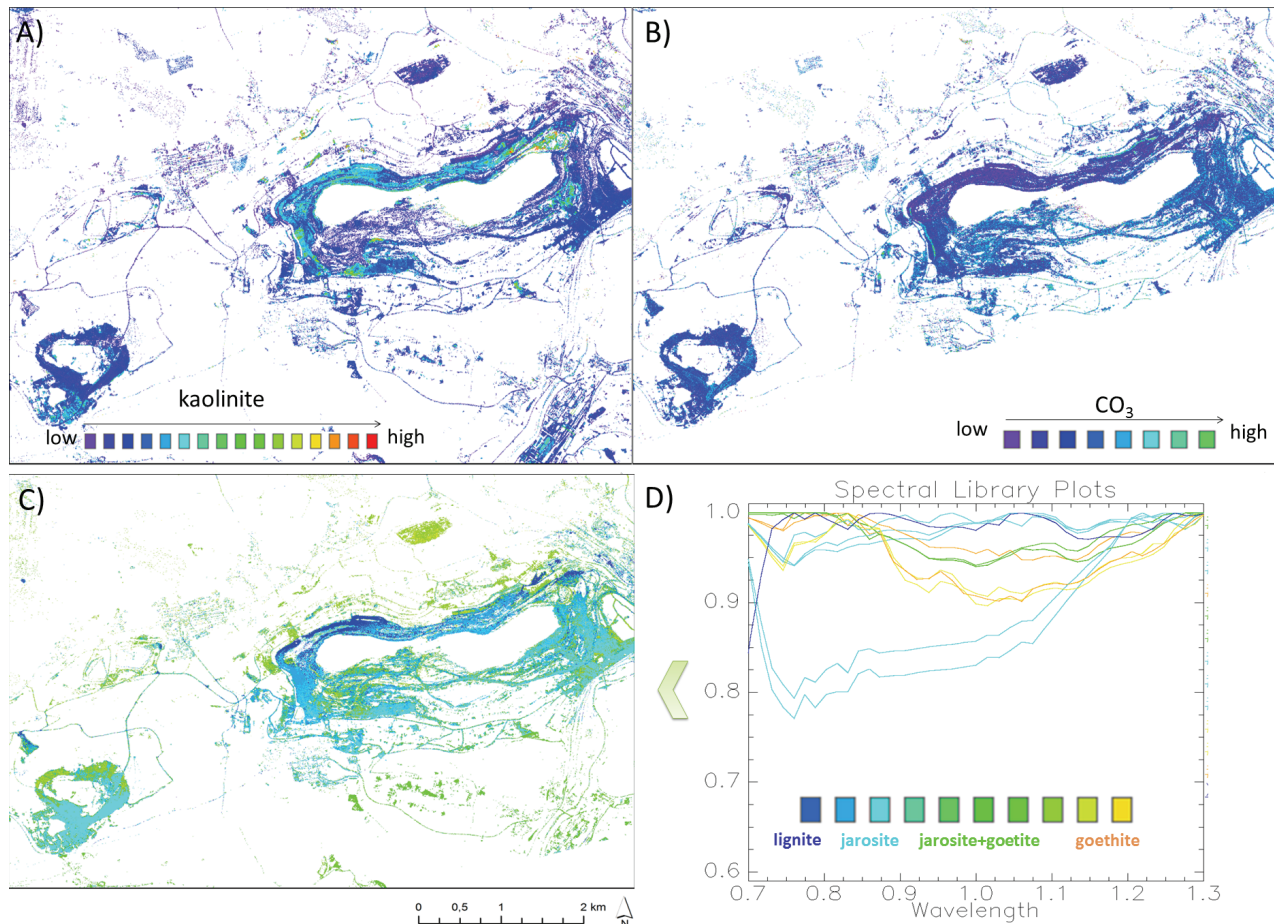


Figure 3: Mineral mapping using the QUANTools (2009 HyMap reflectance data acquired for the Sokolov lignite mines: Litov – Medard): a kaolinite content (Fig. 3A), carbonate content (Fig. 3B) and the jarosite-goethite mineral stack (3C).

ACKNOWLEDGEMENTS

The present research is being undertaken within the framework of the grant n° LH13266 (Hyper Algo) funded by the Ministry of Education, Youth and Sports, the Czech Republic. The new technique was tuned and tested using the hyperspectral data sets acquired under the following grants: Grant n° 205/09/1989 (HypSo) funded by the Czech Science Foundation, EO-MINERS, Grant n° 244242 funded by the European Commission (FP7) and the DeMinTIR project funded by EU-FAR.

REFERENCES

- 1 Clark R N, T V V King, M Klejwa & G A Swayze, 1990. High spectral resolution reflectance spectroscopy of minerals. *Journal of Geophysical Research*, 95(B8): 12653-12680

- 2 Kaufmann H, K Segl, S Chabrillat, S Hofer, T Stuffer, A Mueller, R Richter, G Schreier, R Haydn & A Bach, 2006. EnMAP a hyperspectral sensor for environmental mapping and analysis. IEEE International Conference on Geoscience and Remote Sensing Symposium, IGARSS 2006: 1617-1619
- 3 Van der Meer F, 2004. Analysis of spectral absorption features in hyperspectral imagery. International Journal of Applied Earth Observation and Geoinformation, 5: 55-68
- 4 Rodger A, C Laukamp, M Haest & T Cudahy, 2012. A simple quadratic method of absorption feature wavelength estimation in continuum removed spectra. Remote Sensing of Environment, 118: 273-283
- 5 Kopačková V, 2014. Using multiple spectral feature analysis for quantitative pH mapping in a mining environment. International Journal of Applied Earth Observation and Geoinformation, 28: 28-42
- 6 Dai JJ, D H Wang, R S Wang, Z H Chen, 2013. Quantitative estimation of concentrations of dissolved rare earth elements using reflectance spectroscopy. Journal of Applied Remote Sensing, 7: 073513
- 7 van Ruitenbeek F, P Debba, F van der Meer, T Cudahy, M van der Meijde, & M Hale, 2006. Mapping white micas and their absorption wavelengths using hyperspectral band ratios. Remote Sensing of Environment, 102(3-4): 211-222
- 8 Sykioti O, D Paronis, S Stagakis & A Kyparissis, 2011. Band depth analysis of CHRIS/PROBA data for the study of a Mediterranean natural ecosystem. Correlations with leaf optical properties and ecophysiological parameters. Remote Sensing of Environment, 115 (2): 752-766