Advanced hyperspectral analysis of sediment core samples from the Chew Bahir Basin, Ethiopian Rift in the spectral range from 0.25 to 17 μm: support for climate proxy information (EGU202-5233)

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ABSTRACT

This paper reports on the application of advanced hyperspectral analysis to support the non-destructive study of samples from long sediment cores (up to 280 meter below surface) collected under the Ihomín Sites and Paleolake Drilling Program (HSPP) in the Chew Bahir (CHB) Basin of southern Ethiopia. For this purpose, the bidirectional reflectance of 35 core samples from different core depths in the wavelength range from 0.25 to 17 μm was measured (VIR reflectance). It can be directly compared with spectral remote sensing data of the corresponding land surface areas. We examined the relationship between the derived mineralogical and geochemical properties of the core samples to test for linkage to the hydroclimatic history of the region.

In contrast to earlier approaches to the use of reflectance spectroscopy in mineralogical analysis, which were mostly limited to the visual and near infrared range, here the spectral properties are investigated over the entire spectral range from UV to MIR, which is also accessible in remote sensing. This enables detection of absorption bands of crystal field transitions of transition metal ions in the UV/Vis range and to detect the characteristic bands of OH, H₂O, M-OH lattice vibrations in the NIR. It also allows the study of the fundamental vibration bands as well as other typical MIR features like the Christiansen band or transparency features of silicates and thus helps to reconstruct weathering paths.

STUDY AREA AND DRILL CORE SAMPLES

Chew Bahir (CHB):

The ~ 280 m long CHB drill core was recovered from a tectonically-bound basin in the southern Ethiopian Rift. It covers the past ~ 600 ka of environmental history (Cohen et al., 2016).

Samples:

35 drill core samples from variable core depths and potassium concentration (high potassium, low potassium, intermediate potassium) from CHB sediment cores were used for the spectral investigations. For the measurements, the samples were ground into a fine particle size fraction (< 25 μm). For the comparison of the spectral data XRD analyses of the concentrations of potassium, iron, aluminum and other elements by Foerster et al. (2012 and 2018) were available.

MEASUREMENTS OF VIR REFLECTANCE

Method:

Bi-directional spectral reflectance has been measured at atmospheric pressure between 0.3 and 17 μm at the DLR Planetary Spectral Laboratory (PSSL – Murlis et al., 2018) with a Bruker Vertex®80 FTIR instrument at room temperature, at 15° incident and emergence angles, and with a spectral resolution of 2.4 cm⁻¹. For the spectral data analysis continuum removals were performed.

RESULTS

The UV-VIS spectral part is characterized by different spectral slopes and absorption bands. They are associated with electronic processes. An absorption band close to 1 μm can be caused by Fe²⁺.

IR absorption bands at ~ 1.4 μm, ~ 1.9 μm, ~ 2.7 μm, between 2.0 and 2.4 μm, around 3.0 μm and 6.0 μm are due to OH and H₂O vibrations. A band at 2.2 μm is caused by an Al-OH and at 2.3 μm and 2.4 μm by a Mg-OH vibration. This spectral structure corresponds to smectite with variable Al/Mg incorporation (Bishop et al., 1994; Arnold et al. 2019).

A band around 3.4 μm is associated with organic material and a band at 4.0 μm classifies the carbonate calcite present in the CHB spectra.

At about 8.0 μm local minima, called Christiansen Features (CF). This silicate spectral feature is masked by calcite and can only be detected for low carbonate contents (blue spectrum). Low-contrast double structured RestStrahlen Bands (RSB) occur around 11 μm. This spectral behavior is also consistent with 11 layer smectites (montmorillonites).

DISCUSSION

The spectral analysis have shown that the sediment mineralogy of all samples is dominated by smectites (montmorillonite) with variable Al and Mg incorporation. In addition, calcite is the major carbonate component present in the samples. Different crystal field, interstratification charge transfer and oxygen charge transfer transitions cause absorption bands in the UV to VIS spectral range.

Fig. 2 shows an excellent correlation between the hyperspectral and XRD results. During dry climate phases (larger potassium content) the incorporation of Mg is more pronounced, which is indicated by the fact that the band depths of the 2.5 μm band are higher than those of the 2.2 μm band. In the driest climate phases analcime can be detected and the content of calcite increases (Fig. 3).

CONCLUSIONS AND OUTLOOK

Conclusions

- The hyperspectral studies show a significant correlation of absorption band depth ratios 2.3 mm/2.2 mm with the samples’ potassium (K) concentration. The ratio increases with K and thus reflects the increased incorporation of Mg into Al montmorillonite during episodes of arid climate.

- Thus, hyperspectral analysis proves to be an independent and suitable method to confirm the obliteration by authigenic K-fixation and mineral alteration of the CHB smectites during arid conditions in the past.

- During the dry periods salts are formed, which are mainly calcites in the CHB samples. During the periods of maximum aridity, analcime can also be detected with greater abundance.

- These results of the hyperspectral analysis are an independent confirmation of earlier investigations by Foerster et al., 2018, which were derived from mXRF investigations.

- It could be shown that the presented hyperspectral investigations are an excellent non-destructive method to analyze the mineral alteration of the CHB samples and therefore can support climate proxy studies.

Outlook

- Further correlation studies of different spectral signatures with Fe, Al and others as well as the occurrence of organic matter that can be detected spectrally have been started.

- Spectral fine structure analyses in the MIR spectral range have begun.

- Correlations with hyperspectral remote sensing measurements are possible.

References


