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)

Gabriele E. Arnold (1,2), Claudia Szczech (1, 2), Asfawossen Asrat (3), Andrew S. Cohen (4), Verena Foerster (5), Frank Schäbitz (5), Henry Lamb (6), and Martin H. Trauth (2)

(1) German Aerospace Center (DLR), Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, Germany; (2) University of Potsdam, Institute of Geosciences, Potsdam, Germany; (3) Addis Ababa University, School of Earth Sciences, Addis Ababa, Ethiopia, (4) University of Arizona, Department of Geosciences, Tucson AZ, USA, (5) University of Cologne, Institute of Geography Education, Cologne, Germany; (6) University of Aberystwyth, Department of Geography and Erath Sciences , UK

Gabriele.Arnold@dlr.de

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 Hominin Sites and Paleolake Drilling Program (HSPDP) 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 hydroclimate 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, H_2O, 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.

MEASUREMENS 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 (PSL – Maturilli et al., 2018) with a Bruker Vertex80V FTIR instrument at room temperature, at 15° incident and emergence angles, and with a spectral resolution of ≥ 4 cm^{-1}. For the spectral data analysis continuum removals were performed.

RESULTS

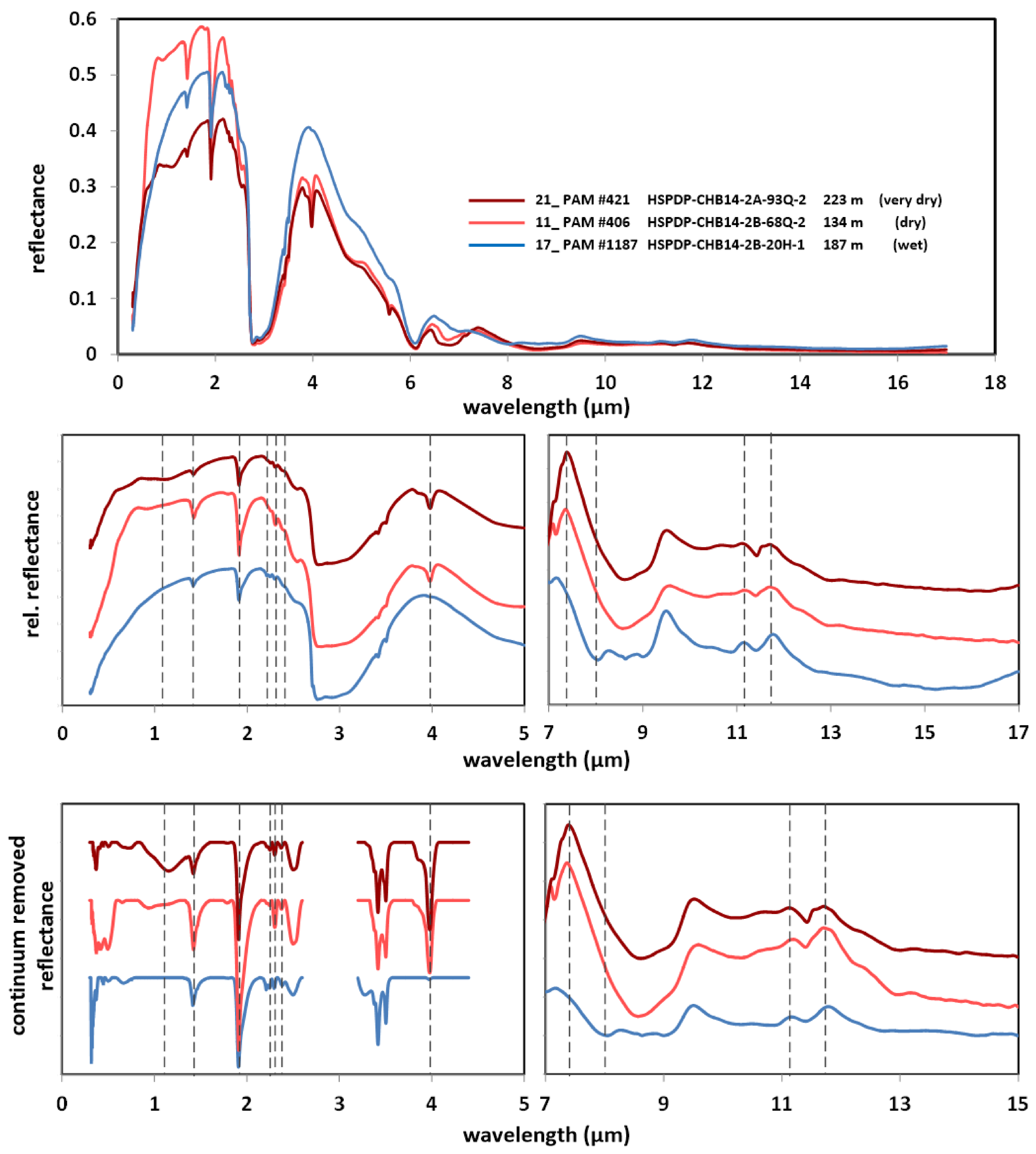

Fig. 1. *Top* - Typical reflectance spectra of three selected HSPDP drill core samples (different depths) in the wavelength range from 0.3 to 7 µm. *Middle* – Detailed view in the 0.3 to 5 µm and the 7 to 17 µm range. *Bottom* – Continuum removed spectra. For reasons of clarity, the spectra are provided with an offset in reflectance (left and right offsets are different)

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 Fe^{2+}.

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 H_2O 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 2:1 layer smectites (montmorillonites).

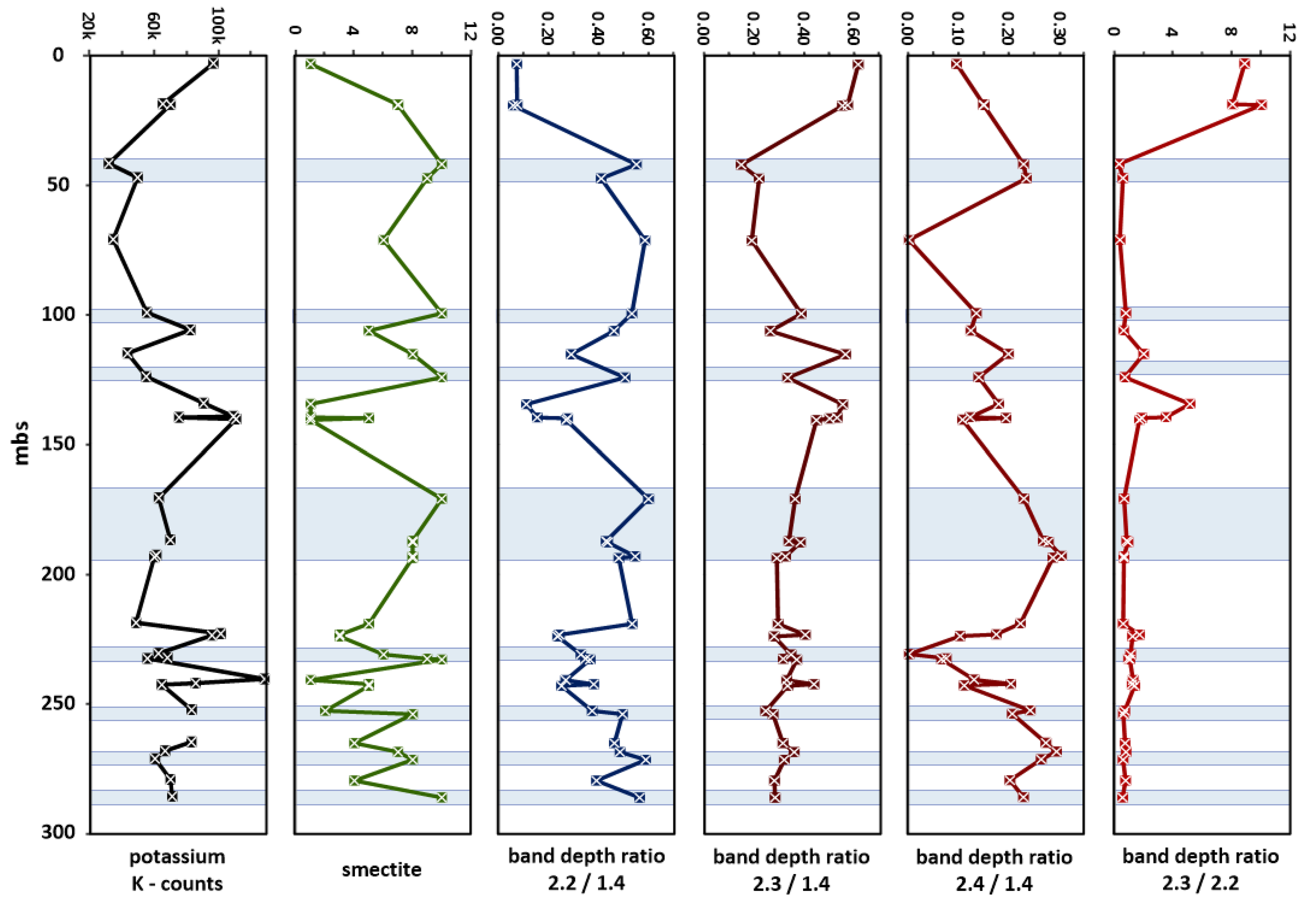

Fig. 2. Comparison of the drill core depth (meter below surface -e mbc) depended XRD results from Foerster et al., in preparation (first column: potassium counts, second column: smectite) with rationed NIR absorption band depths at 2.2; 2.3, and 2.4 µm (third to sixth column, Al/Mg smectites) derived from continuum removed spectra. The drill core depth ranges marked in grey correspond to more humid climate periods.

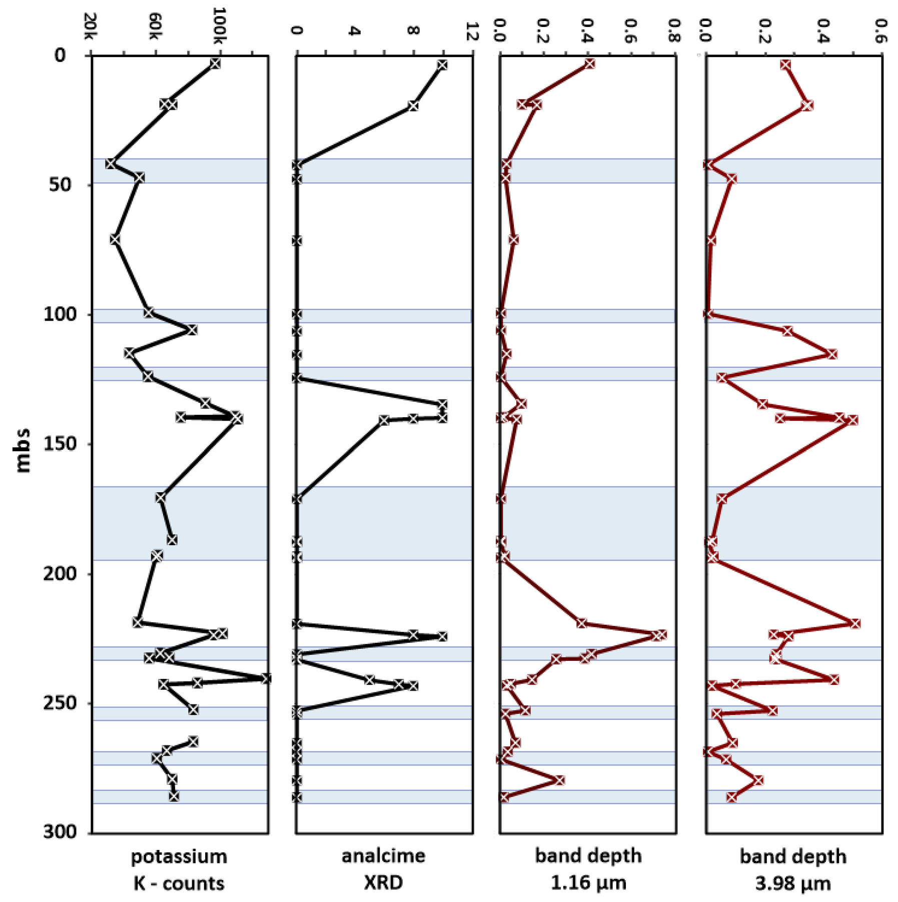

Fig. 3. Comparison of potassium XRD counts (first column) and analcime after Foerster et al. (2018) with the drill core depth depended absorption band depths at 1.16 µm (analcime) and 3.98 µm (calcite). The drill core depth ranges marked in grey correspond to more humid climate periods.

DISCUSSION

The spectral analysis have shown that the sediment mineralogy of all samples is dominated by smectites (montmorillonite) with variable Al and/or Mg incorporation. In addition, calcite is the major carbonate component present in the samples. Different crystal field, intervalence 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 2.3 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 µm/2.2 µm with the samples' potassium (K) concentration. The ratio increases with K and thus it reflects the increased incorporation of Mg into Al montmorillonite during episodes of an arid climate.**
- **Thus, hyperspectral analysis proves to be an independent and suitable method to confirm the illitization by authigenic K-fixation and mineral alteration of the CHB smectites during arid conditions in the basin.**
- **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 µXRF 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.**

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