Investigating sedimentary deposits in the East-African Rift Valley using Transient Electromagnetics

M. Seidel, P. Yogeshwar, B. Tezkan (Institute of Geophysics and Meteorology, University of Cologne, Germany)
Shimeles Fisseha (Institute of Geophysics, Space Science and Astronomy, University of Addis Ababa, Ethiopia)

CRC 806
Our way to Europe

Culture-Environment Interaction and Human Mobility in the Late Quaternary
Cluster A: Northeast Africa - Ways of Dispersal from the Centre of Origin

IGM Geophysik Köln

DFG Deutsche Forschungsgemeinschaft

Introduction

In the framework of the Collaborative Research Centre (CRC) 806 „Our way to Europe“, a 2D transient electromagnetic survey was conducted on three different sedimentary basins in southern and central Ethiopia. Combining geoscientific and archaeological methods, the CRC 806 is designed to reconstruct the passageway of Modern Man from eastern Africa to central Europe over the last 200,000 years. Geophysical measurements assist with the identification and definition of possible palaeoenvironmental archives such as sedimental deposits.

Survey area

Three sedimentary basins within the East-African Rift System (EARS) have been investigated, see Fig. 1. Lake **Chew Bahir** ("Salty lake" in Amharic, approx. 500 m a.s.l.) is a 30 x 70 km² saline mudflat that episodically fills to a shallow lake during rainy season. According to airborne gravity and seismic reflection data, the thickness of its sedimentary deposits is assumed to be of several kilometers. Therefore, the basin potentially provides sedimentary archives that extend far beyond the Quaternary.
The source area of **Bisare River** is located within the Hobitcha Caldera near Wolaita Sodo in southern Ethiopia. Former sedimentological results indicate a continuous sedimentation process and Tephra layers.
The double crater system of the **Dendi Lakes** is located at Mount Dendi (3,270 m asl) 80 km west of Addis Ababa. First drillings revealed holocene deposits within the lake sediments. Our results indicate sediment thicknesses comprising quaternary sediments.

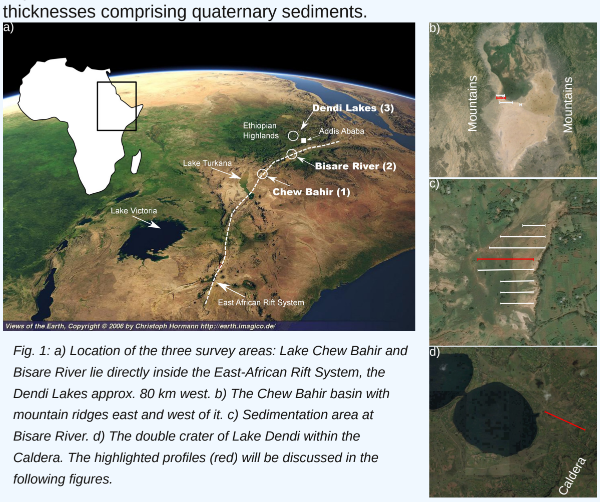

Fig. 1: a) Location of the three survey areas: Lake Chew Bahir and Bisare River lie directly inside the East-African Rift System, the Dendi Lakes approx. 80 km west. b) The Chew Bahir basin with mountain ridges east and west of it. c) Sedimentation area at Bisare River. d) The double crater of Lake Dendi within the Caldera. The highlighted profiles (red) will be discussed in the following figures.

Survey description

In December 2014 and February 2015, a total of 125 2D transient electromagnetic measurements were conducted in the central-loop configuration utilizing 50 x 50 m² and 100 x 100 m² transmitter loops. TEM/3 induction coils from Zonge International served as receivers of the vertical and one horizontal component of the time derivative of the magnetic field. All profiles are located perpendicular to the boundary of each basin to investigate possible 2D effects from the surrounding mountain ridges or calderas. The vertical component is used for the estimation of sediment thicknesses and stratigraphic layers. The horizontal component will be used to study 2D effects generated by lateral resistivity variations.
At Bisare River and Lake Dendi, 4-point DC soundings were additionally taken to enhance the quality of the estimation of sediment thicknesses.

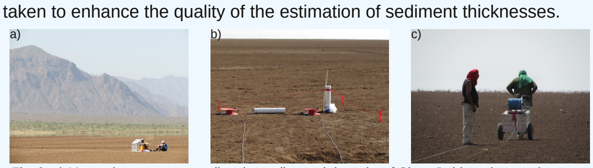

Fig. 2: a) Mountain range surrounding the sedimental deposits of Chew Bahir and transmitter station. b) Zonge TEM/3 receiver coils for the horizontal and vertical component of the magnetic field. c) Placement of a 100 x 100 m² transmitter loop.

Quasi-2D Results

Fig. 3 shows quasi-2D results of Chew Bahir profile P1, Bisare profile 3 and Lake Dendi profile P1 through the stitching together of the resulting 1D-models of the Marquardt inversions. The Chew Bahir profile (fig. 3a) starts on the western boundary of the basin, near the slope of the mountains see fig. 1b). Note that the resistivities vary between 0.3 and 1 Ωm which is due to the hypersalinity of the subsurface. No rock basement could be found. The same applies for profile P1 of Lake Dendi (fig. 3c). Only in the area of Bisare River, a rock basement may have been found (fig. 3b).

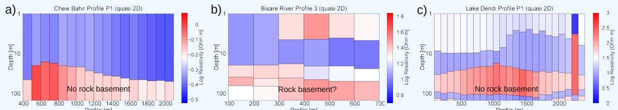

Fig. 3: Quasi-2D results of 1D inversion results (Marquardt), one exemplary profile for each survey location. a) Chew Bahir P1,b) Bisare River 3, c) Lake Dendi P1. The resistivities are displayed logarithmically.

Comparison: TEM, DC and Joint inversion

For station F3 of Bisare profile 3, we recorded an additional DC sounding. Fig. 4 shows the measured data and the fitting of the inversion. The last 6 to 7 data points cleary indicate a deep resistive layer which we interprete as the rock basement. Fig. 5a shows the according 1D inversion result (Marquardt). Fig. 5b shows the 1D inversion results of the TEM data (Marquardt and Occam). Slight indications of a deep resistive layer can be seen but not as clear as in the DC results. The result of the joint inversion of TEM und DC data is displayed in fig. 5c. Here, the resistivity of the last layer is not as resistive as in the inversion result of the single DC inversion.

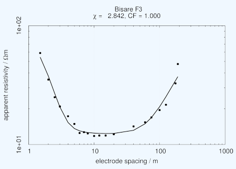

Fig. 4: Original DC data und fitting of Station F3 of Bisare River profile 3.

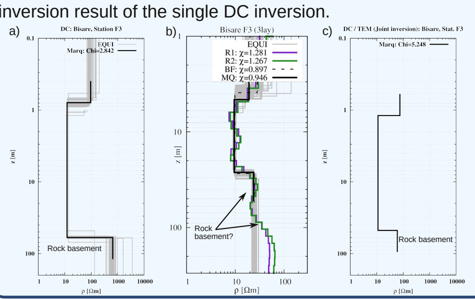

Fig. 5: Inversion results of Station F3, Bisare River profile 3. a) 1D inversion result of the DC measurement (Marquardt + equivalent models) . b) 1D inversion result of TEM (Marquardt, equivalents and Occam). c) 1D joint inversion result of DC and TEM (only Marquardt).

Horizontal component $\dot{H}_x$

With TEM, we recorded a horizontal component of the magnetic field for each station. Typically, we found one or more local minima in all transients (see fig. 6). Fig. 7 shows the time of the first local minimum (yellow), the time of the subsequent local maximum (green) and the respective magnitude of that maximum (purple) for each station of profile P1 in Chew Bahir. Station 4 is next to the mountains, station 20 towards the center of the basin.

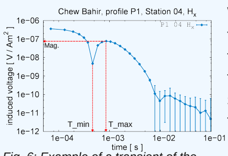

Fig. 6: Example of a transient of the horizontal component. T_min is the time of the first local minumum, T_max the time of the following local maximum.

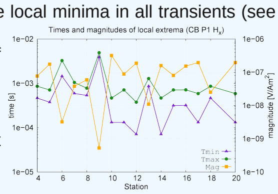

Fig. 7: Time of the first local minimum (yellow), the subsequent local maximum (green) and the magnitude of that maximum for the horizontal component of all stations of Chew Bahir profile P1.

Outlook

The horizontal components of the magnetic field will be subject to further investigations with respect to 2D effects of the surrounding and underlying bedrock. The results of the vertical component will be used to identify further suitable borehole locations for subsequent palaeoclimatological researches.

Acknowledgements

We thank the *Institute of Geophysics, Space Science and Astronomy (IGSSA)* of the University of Addis Ababa, Ethiopia, for the collaboration and the great assistance during our fieldwork.
We thank the *German Research Foundation* (Deutsche Forschungsgemeinschaft) for the funding of this project.