Long Period Telluric – Magnetotelluric Measurements in the North East of the Rwenzori Mountains, Uganda

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Introduction

The survey is part of the DFG funded research project RiftLink, which addresses the causes of rift-flank uplift in the East African Rift since the late Miocene, its impact on climate changes in Equatorial Africa, and the possible consequences for the evolution of hominids. The immediate objective is to gain a process understanding of rift-flank uplift by investigating the origin of the more than 5000 meter high Rwenzori Mountains, which are located within the Ugandan part of the East African Rift (Fig.1).

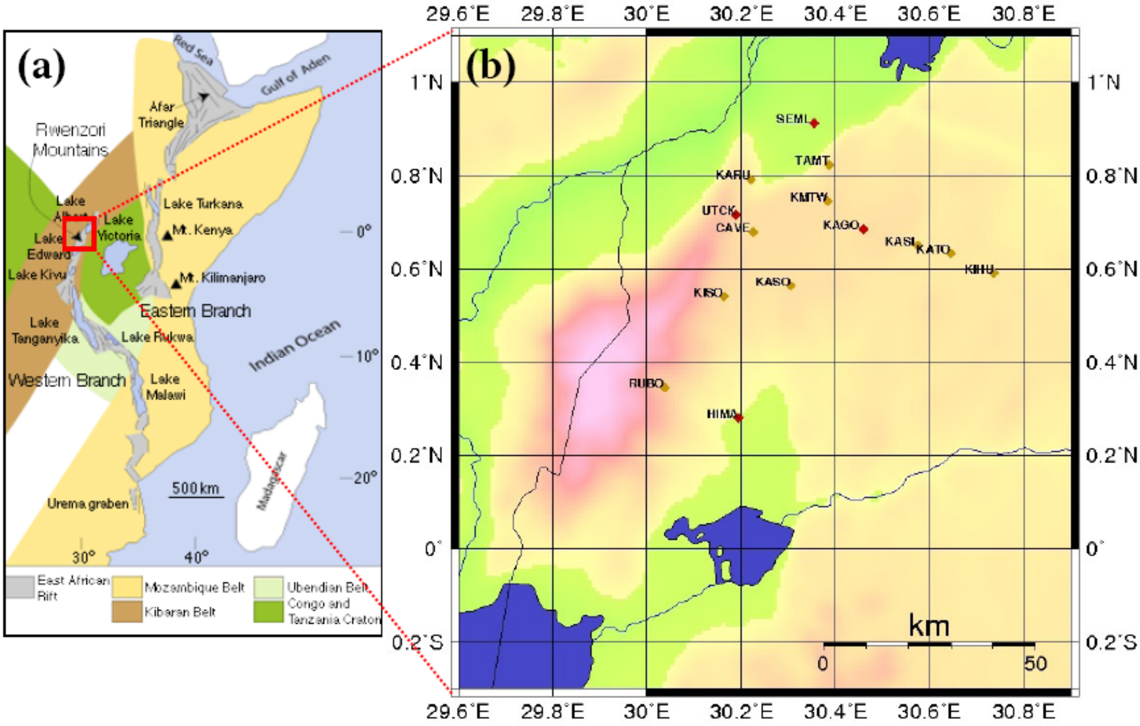

Fig. 1: (a) Geological situation, the red square shows the area of interest, (b) site distribution: orange diamonds refer to telluric sites, red diamonds to magnetotelluric sites

RiftLink is subdivided into four scientific themes including eleven projects.

Theme A: Lithosphere/ Asthenosphere Processes

Theme B: (Near-) Surface Processes

Theme C: Surface/ Atmosphere Processes

Theme D: Modeling

Within the project A2 the conductivity structure of the crust and upper mantle beneath and East of the Rwenzori Mountains was investigated with the magnetotelluric method. In the long run the measurements will give a detailed 3D image of conductive features from the upper crust down to several hundred kilometres into the upper mantle.

The following goals will be pursued:

a) Investigation of the geometry and depth range of conductive faults,
b) Correlation of conductive structures with the seismogenic zone,
c) Correlation of electrical anisotropy with fault plane solutions,
d) Mapping of the electrical astenosphere including anisotropy,
e) Investigation of conductivity mechanisms, especially the influence of water, using petrologic results,
f) Constraining geodynamic modelling.

In this contribution we show the measurement set up and first results.

Field Set Up

During our first field experiment we wanted to investigate the Rwenzori Mountains - Rift Shoulder Connection (RMRSC, Fig. 2). Thus 14 instruments were set up at an area around the North-Eastern Edge of the Rwenzori Mountains from April to July 2007, the distance between the sites varied from 10-15 km (Fig. 1). At all locations time variations of the natural telluric field were recorded continuously with 4 Hz sampling rate, at 4 sites additionally time variations of the magnetic field were observed by 3-component fluxgate magnetometers (GEOMAG 01, MAGSON). The horizontal telluric field was calculated from the voltage difference between pairs of electrodes (Ag/AgCl//KCl(aq)) buried in the ground and separated by 20-40m. The electrodes are installed in a saturated KCl solution within a PVC tube; small ceramic diaphragms guarantee electric contact to the soil. All the field components were recorded with the GEOLORE data logger (Roßberg, 2007); the internal clock was triggered by a GPS signal to enable synchronization of the field records.

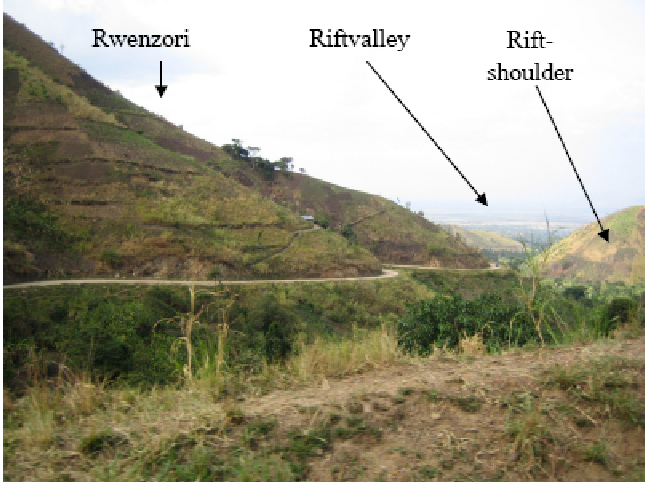

Fig. 2: *View to the North into the Riftvalley, view point close to site UTCK (Fig. 1), at the Rwenzori Mountains- Rift Shoulder Connection (RMRSC).*

For the telluric sites all cables were buried in the ground and the logger was wrapped in a waterproof PVC bag, while for the Magnetotelluric sites the electronic device was stored in a ZARGES box and the magnetometer was buried in the ground.

Logging the telluric field is less power consuming and the equipment is far less expensive than that for magnetic field observations – therefore the number of telluric sites is much higher than that of the magnetotelluric sites.

Time Series

Fig. 3 shows the simultaneous time series of the horizontal magnetic field components at the 3 Northern sites for 4 days. There is no influence by the equatorial electrojet on the daily variations as the dip equator is about 10° N (cf. Kuvshinov et al., 2007). Despite some spikes of artificial origin there is almost perfect correlation between the data for each component respectively. The spatial homogeneity of the magnetic field is also demonstrated for short oscillations of several minutes period. There is also a high correlation between the orthogonal telluric and magnetic field variations, although the amplitudes of the telluric fields vary significantly between different sites, reflecting the influence of lateral near surface variations of the electric conductivity.

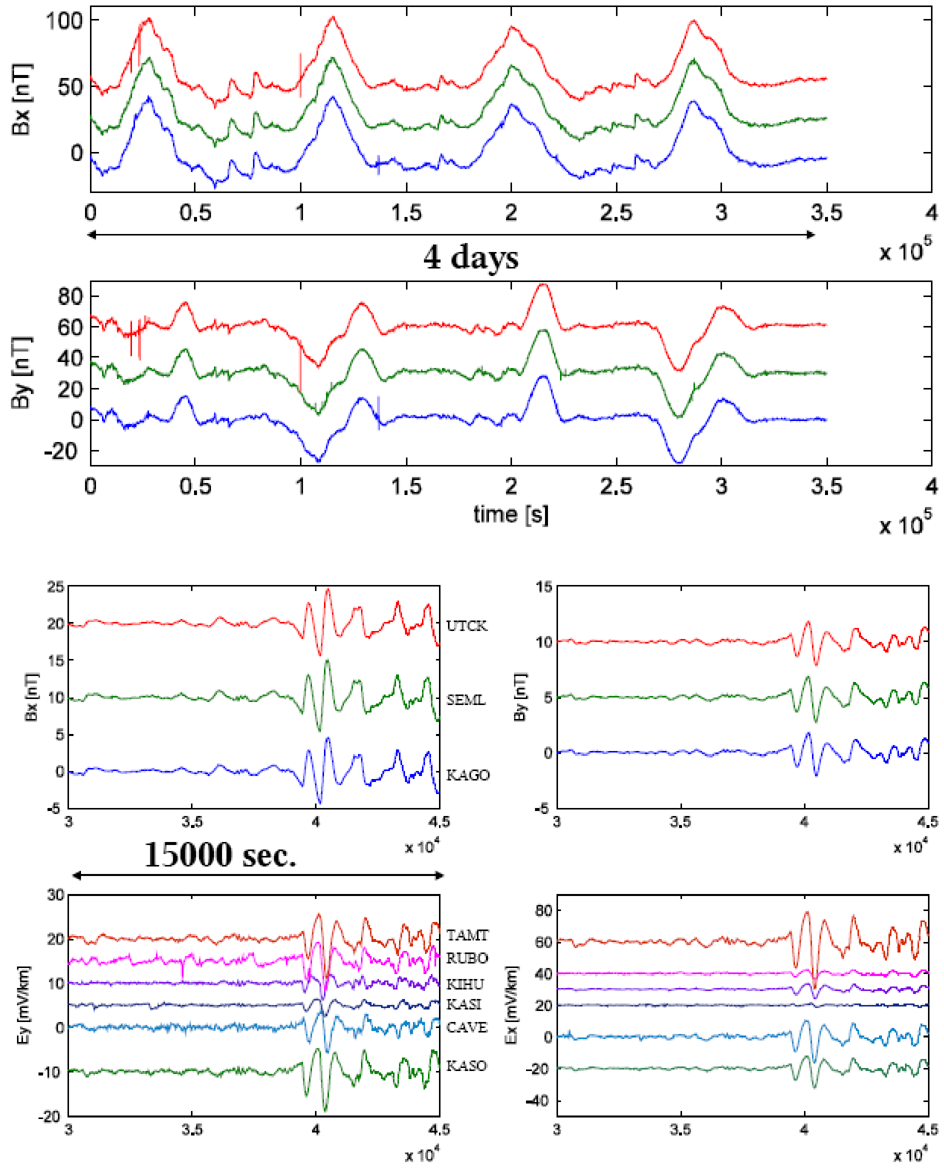

Fig. 3: Examples for time variations of magnetic and telluric fields at different sites: (Top) The horizontal magnetic field at 3 sites for a 4 days time interval, (Bottom) Magnetic and telluric fields at different sites for a 4 hours time interval.

Transfer Functions

Using the bivariate approach $\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \begin{pmatrix} B_x \\ B_y \end{pmatrix}$ in the frequency domain, the frequency dependent complex elements of the impedance tensor $\boldsymbol{Z}$, i.e. the transfer functions, contain the information about the conductivity structure of the subsurface. Fig. 4 shows the transfer functions at sites TAMT and CAVE (cf. Fig. 1). The complex values are displayed as apparent resistivity and phase. Note the significant differences between the 2 tensor elements and between the 2 sites with phases far above 90°. We take the high phases as an indication for an extreme current distortion due to high lateral conductivity changes in the vicinity of the sites.

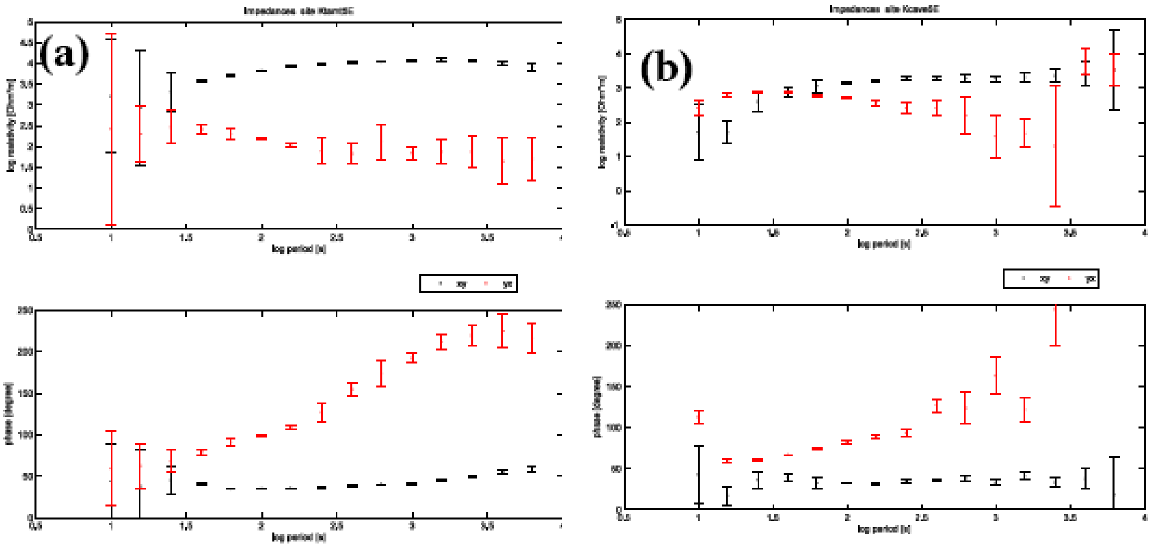

***Fig. 4:** Examples for transfer functions of the impedance tensor elements Z_{xy} (black) and Z_{yx} (red) at sites TAMT (a) and CAVE (b). The values are displayed as apparent resistivity (top) and phase (bottom).*

Phase Tensor

The telluric field and thus the transfer functions' magnitudes can be influenced by near-surface conductivity inhomogeneities, giving rise to strongly distorted estimates of the conductivity distribution (static shift). A more robust estimate is the phase tensor $\boldsymbol{\varphi}$ (Caldwell et al., 2004) which is derived from the imaginary and real part of the impedance tensor by $\mathbf{\Phi} = \begin{pmatrix} \Phi_{xx} & \Phi_{xy} \\ \Phi_{yx} & \Phi_{yy} \end{pmatrix} = \Im\begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix} \Big/ \Re\begin{pmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{pmatrix}$ and $\boldsymbol{\varphi} = \tan^{-1}\mathbf{\Phi}$. There are 3 rotational invariants of **φ,** which are the principal axis, $\varphi_{\min}$ and $\varphi_{\max}$, and the skew $\beta = \frac{1}{2}\tan^{-1}\left(\frac{\Phi_{xy} - \Phi_{yx}}{\Phi_{xx} + \Phi_{yy}}\right)$, which is a measure of the tensor's asymmetry. The aspect ratio of the ellipse is a measure for the influence of lateral conductivity changes on the data, whereas the skew angle β is an indicator for the existence of a 3 dimensional conductivity structure (β=0: 1D, 2D, β≠0: 3D), appearing within the range of the skin depth of the variation fields.

It is most convenient to represent φ in form of an ellipse which is normalized by its major principal axis $\varphi_{\max}$. Fig. 5 displays the phase tensor ellipses at some locations for the periods of 156 and 1000 seconds. The area of the ellipse is colour coded by the value of the minor axis, $\varphi_{\min}$, using a colour scale sensitive to the frequency of occurrence of the values. Thus the colours reflect the change of $\varphi_{\min}$ with period resp. depth. Each period reveals a spatially consistent pattern of the ellipses orientation and their colours, however, note the significant phase changes for sites close to and far from the RMRSC. In general there is an increase of $\varphi_{\min}$ towards longer periods (cf. Fig. 4). Furthermore the overall orientation of the ellipses is oblique to the Rift axis, but parallel to the well known geological strike direction of the main

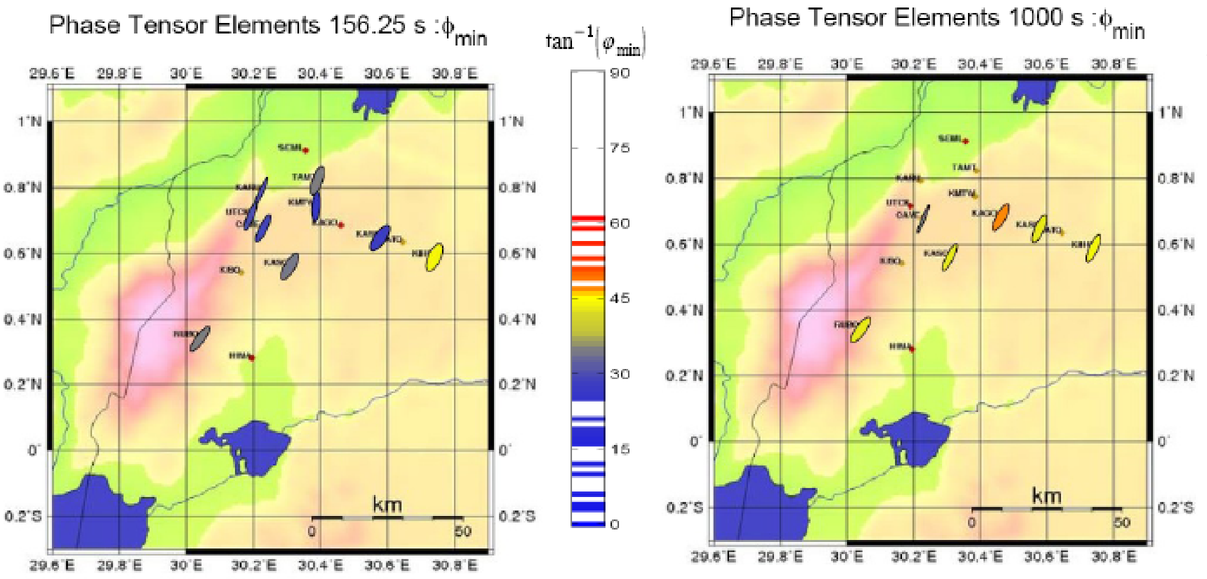

Fig.5: Phase Tensor Ellipses for the periods 156 seconds (left) and 1000 seconds (right). The colours represent the minor principal axis, φ_{min}.

fault system to the East of the Rwenzoris. However, there is also a small but significant change of orientation depending on the site location and the periods: The long period ellipses are slightly rotated clockwise, which is an indication for a rather homogeneous preferential current orientation at greater depth.

The skew angle β is displayed in Fig. 6 for the period of 156 seconds. Its pattern is spatially very consistent and it shows very impressively the increase of β at the RMRSC, thus pointing at the origin of a significant three dimensional distortion of the electric currents.

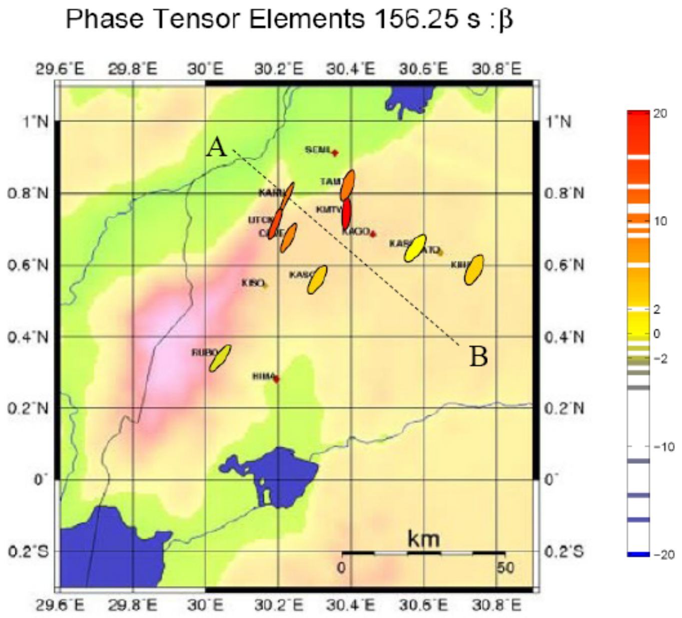

Fig. 6: Phase Tensor Ellipses for the periods 156 seconds. The colours represent the phase tensor skew β.

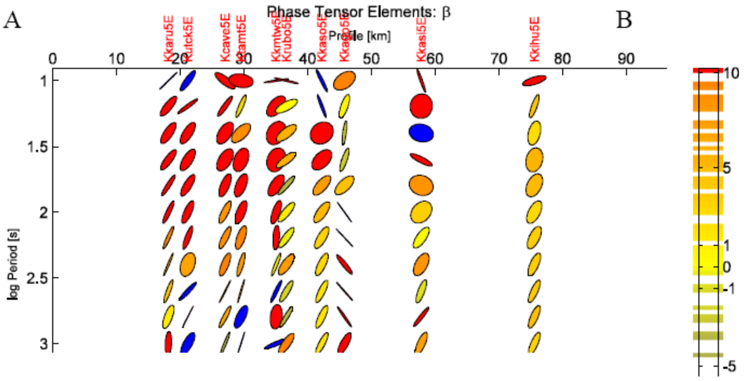

__Fig. 7:__ Phase Tensor ellipses coloured with the skew angle β along the profile AB (Fig.6) with all sites. Note the low values of β at the sites KIHU and RUBO (B) vs. high values at the sites near the RMRSC (A).

Fig. 7 presents a cross section of the phase tensor ellipses of different sites projected onto the profile AB (cf. Fig. 6) for the periods observed. The ellipses colour reflects the skew β. Despite the partly heterogeneous picture, it is evident that the high values of β concentrate towards A for shorter periods. Thus it may be concluded that the 3D distortion is limited to the upper crust.

Conclusion

This contribution gives first results: The spatial and frequency dependence of the transfer functions' amplitude and phase reveal information for the conductivity structure underneath the Northern Section of the Rwenzori Mountains, best shown by phase tensor ellipses. There is evidence for a strong distortion of the induced currents North of Fort Portal where the most Northern Part of the Rwenzori Mountains contacts the Eastern Part of the Rift Shoulder.

The preferential direction of the electric currents matches the direction of the major fault system to the East of the Rwenzori Mountains, whereby there is a slight clockwise rotation of the preferential direction for greater depths.

These findings open up the question, whether the current deviation is caused basically by the high resistive body of the Rwenzori Mountains, which at least partly block the high conductive sediments of the Rift Valley, or if there is a wide spread electrical anisotropy within the Earth Crust.

Therefore it is planed to extend the site array towards the Southern part of the Rwenzori Mountains in a 2nd field survey during spring 2008 to test these hypotheses.

Acknowledgments

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