Helmholtz Centre Potsdam
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First 3D inversion results from magnetotelluric data of the Eastern Karoo Basin, South Africa

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Aim of project

- *General:* Fundamental understanding of the geology, petrology and hydrology of the Karoo Basin
- *Magnetotellurics (MT):* 3D-model of the subsurface

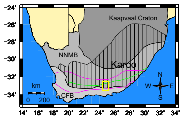
→ Imaging potential shale gas bearing formations

→ Imaging shallow aquifers for a better understanding of fresh and brackish water reservoirs

Photo of the Karoo Basins landscape in the study area (M. Schüler, GFZ Potsdam)

Study area

- *Eastern Karoo Basin:* Sedimentary basin stretching across most of southern Africa with a size of nearly 600,000 km^2
- *Geology:* The basin contains two supergroups: Cape & Karoo Supergroup
- *Karoo Supergroup:* Contains Whitehill Formation with carbon rich shales



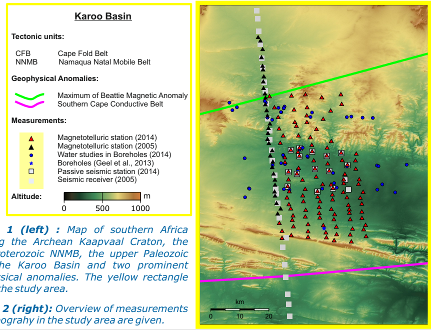


Figure 1 (left): *Map of southern Africa showing the Archean Kaapvaal Craton, the Mesoproterozoic NNMB, the upper Paleozoic CFB, the Karoo Basin and two prominent geophysical anomalies. The yellow rectangle marks the study area.*

Figure 2 (right): *Overview of measurements and topograhy in the study area are given.*

Conclusion and future work

- 3D inversions started with standard single-site processing results → conductive layer (Whitehill?) mapped
- At shallow depth the Whitehill Formation is weathered and therefore not conductive
- Indications for shallow conductivity anomalies → aquifers?

→ Advanced processing of data

→ 2D inversion models along all profiles

→ 3D inversion models

→ Constraints from lithology/ hydrology

MT experiment 2005

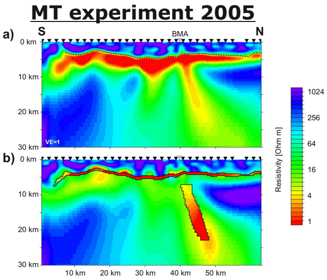


Figure 3: *2D inversion results from Weckmann et al. (2007) without (a) and with (b) tear zones. The rms of 2.3 for model a) could be reduced to 1.8 in model b) with the inclusion of tear zones. The most prominent conductivity anomalies are a shallow sub-horizontal high conductive band in the upper 5 km and a sub-vertical conductive feature beneath the maximum of the BMA going down to middle/ lower crust.*

Geology study

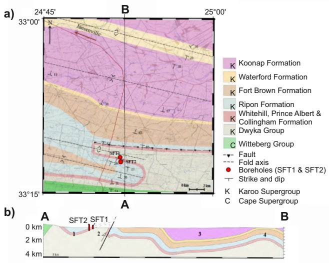
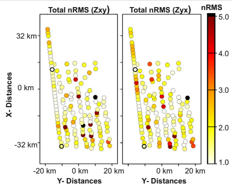


Figure 4: *(a) Geological map and (b) cross section after Geel (2013). Both were developed by using data collected from field outcrops and borehole logs. The Whitehill Formation in the metaanthracite window has a high total organic carbon content and correlates with a high electrical conductivity. The two boreholes reached a depth of 100 m (SFT1) and 300 m (SFT2) and intersected the Whitehill Formation.*

Data fit

Figure 5 (below): *Data fit of two sites for Model 1 and one site for Model 2. Site 0104 is located in the south of the study area. Site 0323 represents the middle part and is located near the maximum of the BMA. The data fit is quiet good except for the long periods at site 0323 for Model 1. For the same site the data might explained by Model 2. The reason is the high horizontal smoothing parameter of 0.4 in Model 1, which „smooths away" vertical structures. Furthermore, due to the high smoothing parameter the shallow conductivity horizon is interconneted even between profiles and sites in Model 1.*



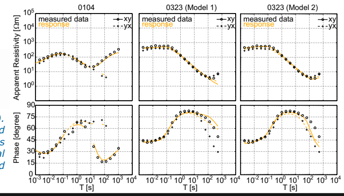


Figure 6 (above): *Total normalized rms for both off-diagonal components for each station for Model 1. Blacks dots mark stations for which all data for the special component are masked. There is no concentration of high rms values in one specific region or for one of the component. Site 0104 and 0323 are marked with thicker black circles.*

3D Inversion results

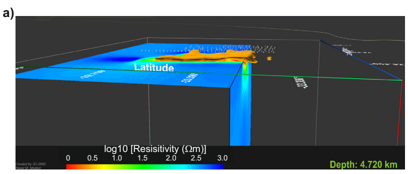
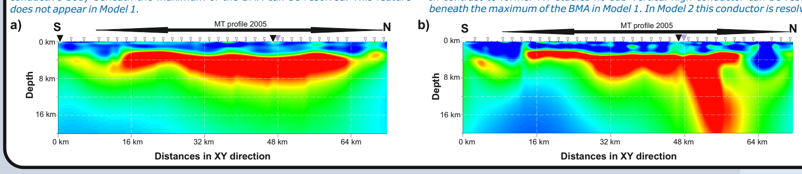


Figure 7 (above): *3D inversion results for a) Model 1 after the 91st iteration with a total rms of 2.4 and b) Model 2 after the 54th iteration with a total rms of 2.7. Off-diagonal components of the impedance tensor for MT data from 2005 and 2014 are used for the inversions. The isosurfaces of 3 Ωm are plotted in orange-brown. Furthermore a XY-slice is plotted together with a ZY-slice. In Model 2 a sub-vertical conductive body beneath the maximum of the BMA can be resolved. This feature does not appear in Model 1.*

Figure 8 (below): *2D sections along the MT profile from 2005 (see Figure 3) including the additional three sites measured in 2014. The maximum of the BMA is marked with a purple triangle and the sites depicting the data fit are shown as black filled triangles. A shallow sub-horizontal high conductive band in the upper 3-8 km is visible in both models, very similiar to the results from Weckmann et al. (2007). In contrast to former MT studies no sub-vertical high conductor can be resolved beneath the maximum of the BMA in Model 1. In Model 2 this conductor is resolved.*



More 2D sections of Model 1

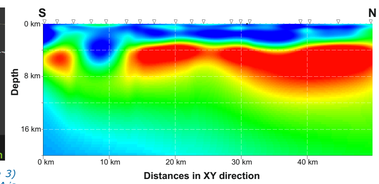


Figure 9 (above): *2D section along the third profile from the West. This profile is shorter than the most western profile and therefore it does not cross the maximum of the BMA. The sub-horizontal high conductive zone can be resolved in a depth of 3-10 km. Some shallow zones of reduced resistivities are observed in the high resistive body in the upper 2 km.*

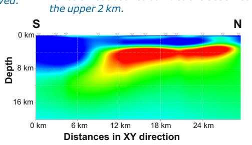


Figure 10 (left): *2D section along the most eastern profile. This profile is the shortest of all. The sub-horizontal high conductive zone is resolved in a depth of 3-8 km. Shallow zones of higher conductivity, as in the other profiles, can be resolved.*

MT 2014

- 111 five component stations
- 2-3 km site spacing along, and 5 km between profiles
- Frequencies: 10kHz-1mHz

Photo of the Karoo Basin and a flock of sheep in the study area (A. Dingle)

3D Inversion settings

- Using ModEM inversion code (Egbert & Kelbert, 2012; Meqbel 2009)
- Start from homogenous half-space with 400 Ωm (Model 1) and 500 Ωm (Model 2)
- Cells in x,y and z-direction with boundary cells : 100, 100, 55 (Model 1) and 110, 110, 60 (Model 2)
- Only use off-diagonal components of impedance tensor with 5% errorfloor on Zxy, Zyx
- Smoothing ($\alpha x, \alpha y$, αz): 0.4, 0,4, 0.2 (Model 1) and 0.3, 0.3, 0.3 (Model 2)

Literature

Weckmann, U., Jung, A., Branch, T. and Ritter, O., 2007. Comparison of electrical conductivity structures and 2D magnetic modelling along two profiles crossing the Beattie Magnetic Anomaly, South Africa, *South African Journal of Geology*, 449-464

Geel, C., 2013. Shale gas characteristics of Permian black shales in the Ecca Group, near Jansenville, Eastern Cape, South Africa, *Unpublished Master thesis*, NNMU, South Africa

Egbert, G.D. and Kelbert, A., 2012. Computational recipes for electromagnetic inverse problems, *Geophy. J. Int.*, 189, 251-267

Meqbel, N., 2009: The electrical conductivity structure of the Dead Sea Basin derived from 2D and 3D inversion of magnetotelluric data, *Dissertation*, Freie Universität Berlin, Germany

Acknowledgments

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