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# Constraint 3D inversion of MT data with sparse and irregular station coverage: Example from the Namibian passive margin

Ute Weckmann[1,2] ,Naser Meqbel[1] and Oliver Ritter[1,3]
[1]GFZ – German Research Centre for Geosciences, Potsdam, Germany
[2] University of Potsdam, Germany
[3] Freie Universität Berlin, Germany

**SUMMARY**

In areas with poor accessibility, it is difficult to collect Magnetotelluric (MT) data on a sufficiently regular grid. Any subsequent 3D inversion has to be applied with caution as artificial structures tend to appear in areas without or with poor station coverage. Such artificial structures tend to fit the data but contradict other geological, geophysical or tectonic information. In this study we show that geological features outside of the study area but within the inductive range of the observations need to be considered to obtain a plausible model which still fits the MT and vertical magnetic transfer function (VTF) data.
Using an example from the Atlantic passive Margin in Namibia, we demonstrate that a well-conceived inversion strategy is required to jointly fit MT impedances and the vertical magnetic transfer functions. This strategy is based on resolution studies of conductive features outside our station coverage to identify areas where additional geological and/or geophysical constraints are required. We present and discuss several approaches adding constraints to the 3D inversion process. Structural properties are based on gravity data, whereas different assumptions for the electrical conductivity distribution within these features are tested. Vertical magnetic transfer functions and impedance tensor data show different sensitivities to these conductivity variations, which have to be considered in the course of finding a 3D inversion model fitting both data sets.

**Keywords**: 3D inversion, constraint inversion, irregular areal station coverage, case study

## INTRODUCTION

High-quality five-component magnetotelluric (MT) data were collected in North-western Namibia to investigate geodynamic processes related to the breakup of Gondwana. The entire study area extents from the Walvis Ridge in the Atlantic Ocean to the western boundary of the Kongo Craton crossing the entire Kaoko Mobile Belt (Figure 1). Off-shore data were acquired parallel and perpendicular to the Walvis Ridge and have been interpreted using a 3D inversion model (*Jegen et al., 2016*) and a 2D on-/off-shore model (*Kapinos et al., 2016*).
Due to its remoteness and difficult terrain in the Namibian desert, it was not possible to measure on-shore MT data on a regularly spaced grid, as we had to follow the existing sparse road system. This resulted in relatively good station coverage for 3D inversion in the western part of the survey area while the eastern part resembles data mostly along a profile. An additional complication for 3D inversion of the on-shore data set emerges due to the huge conductivity contrasts e.g. between the nearby Atlantic ocean with sea bed sediments and the resistive Proterozoic and Archean rocks present on land in the survey area. Such an environment is expected to have particularly large effects on the vertical magnetic transfer functions.

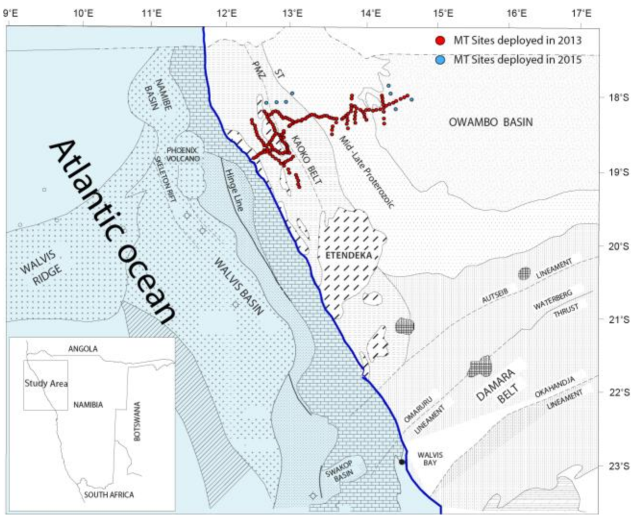


**Figure 1** On-shore station layout of the amphibian experiment across the Namibian passive margin. The geological background map (modified after Corner et al., 2002) shows the main geological features and tectonic elements in the study area: the Owambo and Walvis Basins as well as major share zones (e.g., PMZ; Purros Mylonite Zone, ST: Seisfontein Thrust)

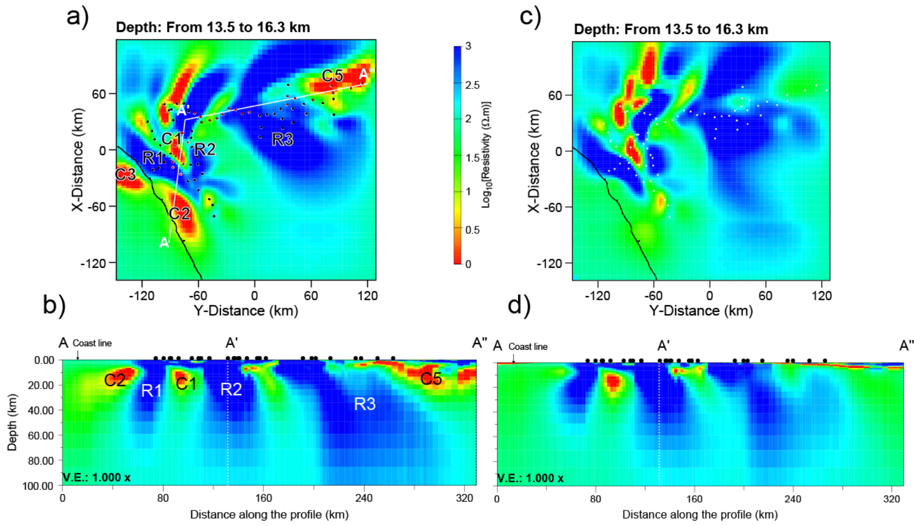


**Figure 2** Map views and cross section extracted from 3D models of the unconstraint (a) & b)) and constraint inversion (c) & d)). Both inversion results are obtained by jointly fitting impedance tensor Z and VTF data. The features C1-C5 and R1-R3 refer to conductive and resistive anomalies, respectively. Black (white) dots in the figures show the locations of the MT stations. The coastline is indicated by black solid line, the white line in a) marks the location of the derived cross section.

## NAMIBIAN MT DATA SET

The on-shore MT data set consists of 167 MT stations collected along a 100 km wide corridor, which in general allows 2D and 3D interpretation of the data. The five-component MT data were recorded in a frequency range between 8 kHz and 1 mHz. They are generally of good data quality; some stations exhibit strong 3D effects.

## 3D INVERSION

Unconstraint three dimensional inversion results of the MT and VTF data show electrical conductivity variations particularly between areas where we have good and evenly distributed station coverage in the west and mainly profile data in east (Figure 2a) ). The most prominent features within the 3D conductivity model seem to correlate tectono-stratigraphic boundaries and major shear zones in the study area and (conductive feature labelled C1 in Figure 2a) and b) ).

Towards the north-eastern end of the array, our MT stations cross the Kongo Craton boundary (Figure 1). From other cratonic areas in Southern Africa and elsewhere we would expect to find high resistivities typical for Archean cold continental lithosphere. Unconstraint 3D inversion results (Figure 2a) and b)) show that the eastern part of the study area is to great extend characterized by a resistive feature (R3). However, on top of R3 and to depths of ~ 20 km we observe a highly conductive anomaly (C5).
In the western part of the study area (Figure 2a) ) along the shoreline, the unconstraint 3D model indicates the presences of two anomalies (C3 and C2) with high conductivities that appear at mid-crustal depths.

Model resolution studies show clearly that the data are sensitive towards changes in the conductivity values of C2, C3 and C5. While we conclude that the data require conductive features in the area, these structures cannot easily be explained by geological or geophysical observations. Their properties (form and conductivity values) seem to be not well constraint when comparing results of different inversion runs. Hence, we suspect that they could be artificial structures required to fit a certain portion of the data,

Previous geophysical and geological studies indicate several regional scale sedimentary basins close to our study area. Towards its eastern end, the Owambo basin (Figure 1 and ) overlies Proterozoic and Archean rocks of the Kongo Craton. In the unconstraint inversion results, the basin is compensated by the conductive anomaly (C5) beneath our MT stations (Figure 2b). Resolution tests indicate that the conductive sediments of the Owambo basin mostly influence the impedance data, but hardly the vertical magnetic transfer function. It also seems sufficient to use an averaged conductivity value for the entire basin.
A similar situation seems to exist in the western part of our study area: Towards the coastline, several deep zones of high conductivity are observed (C2 and C3 in Figure 2a) and b)). Although the bathymetry is included in the 3D inversion as a-priori information, such features occur next to areas with good station coverage. Model resolution studies show that the off-profile conductive features close to the ocean (C2, C3) are mainly required to fit the VTFs, while the impedance tensor data are not affected. A possible geological explanation for conductive off-shore features is the more than 10 km thick Walvis Basin. Since the Walvis Basin is juxtapose to the resistive Proterozoic rocks of the Kaoko Belt (R1 in Figure 2), a strong lateral electrical conductivity contrast is created, affecting mainly the VTFs.

From a 3D density model (*Maystrenko et al., 2013*), we extracted the spatial distribution and extents of the on-shore (Owambo) and off-shore (Walvis) sedimentary basins and included them as prior information within constraint 3D inversions (Figure 3).

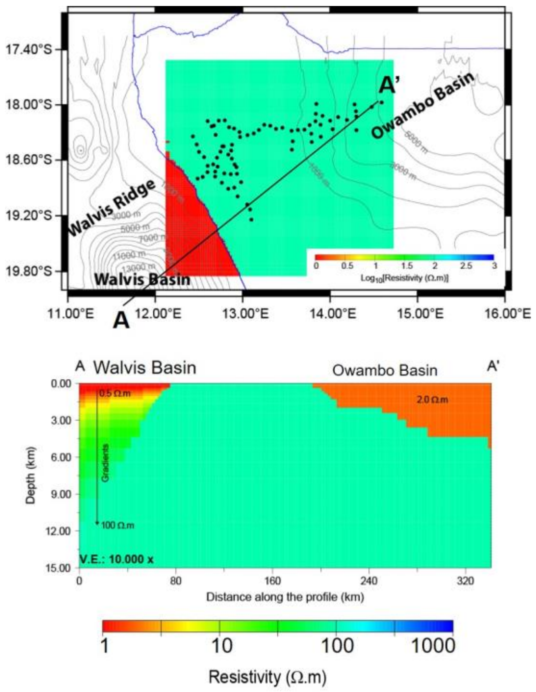


**Figure 3** Example for 3D starting model using the on-shore (Owambo) and off-shore (Walvis) sedimentary basins as a-priori constraints. With the gradual increase of conductivities for the off-shore basin we try to mimic sea water infiltration for the upper sedimentary layers. Contour lines on the map in a) indicate thicknesses of sediments as derived from 3D modelling and inversion of gravity data (*Maystrenko et al., 2013*)

Resolution studies revealed that controlling the conductivity distribution within these off-profile basins is a key parameter for the outcome of the 3D MT inversions. We have tested a variety of assumptions for the resistivity values, including a gradually increase of the resistivities of the sedimentary sequences from top to the bottom of the basin. In our final model (Figure 2c) and d)), conductivity anomalies C2 and C3 do not occur and anomaly C5 could be reduced to conductive sediments of the Owambo basin within the upper 3 km. The resistive features R1-R3 as well as the sandwiched zones of higher conductivities remain in the final 3D model as robust structures.

We argue that the use of these sedimentary sequences as a constraint significantly stabilizes the joint 3D inversion of the MT and VTF data (Figure 2c and d) and results in a conductivity model which also fits geological and geophysical observations.

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