Three-dimensional MT modelling for the Pomerania region in NW Poland

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1. Introduction

During recent years many magnetotelluric (MT) and magnetovariational (EM) soundings across the Northeast German and the Polish Basin have been realized. Two-dimensional (2-D) models were constructed for most of the obtained data of the study area. However, there are clear indications for three-dimensionality, particularly seen in the behaviour of induction vectors. Therefore 2-D modelling can only be regarded as a first step in interpretation that might even yield a false image of conductivity structures at depth. The primary objective of this work was to obtain a detailed, three-dimensional image of electrical conductivity distribution in the Earth's crust below the Trans-European Suture Zone (TESZ) in the northwest part of Poland (Pomerania). To achieve this purpose we applied a 3-D inversion code (Siripunvaraporn et al. 2005), which allowed us to obtain more realistic model geometries. We got a clearer image of the highly conductive rock complexes, which we tentatively connected to deformation fronts, as well as their position in relation to the margin of the East European Platform (Dadlez, 2000).

2. Geological background

The area covered by the survey is part of the Trans-European Suture Zone. It is the most interesting segment of this geologic structure because of the geotectonic processes which have been taking place there. This large tectonic transition zone extends from the North Sea to the Black Sea. The origin of this zone links to the collision of the Baltica Craton with younger terranes from the south and west, dating to the end of the Ordovician period. Also, more recently very significant tectonic movements occurred within this zone. As the TESZ represents a boundary of lithospheric scale separating the Precambrian East European Craton (EEC) from the Paleozoic Platform (PP), it has a fundamental importance for understanding the geodynamic processes in this part of Europe. Due to the significance of the TESZ it was subject to a number of large-scale, international seismic experiments as well as several international electromagnetic research programs (i.e., the EMTESZ project). These were conducted by the Polish Academy of Sciences in cooperation with Free University of Berlin and the Russian Academy of Sciences.

As a part of the Central European Basin System, the TESZ is covered by a thick layer of Quaternary-Paleozoic sediments along almost its entire length, so only geophysical data can provide valuable information about its deeper structures. Previous 2-D interpretation of MT profile data across the TESZ revealed a poorly conducting and deep-reaching EEC, a less resistive Paleozoic Platform and thick, highly-conducting sediments over the whole study area (Ernst et al. 2008, Habibian et al. 2010).

3. Methodology

During the recent EMTESZ project, all variants of electromagnetic methods, i.e., magnetotelluric and magnetovariational soundings were applied (Brasse et al. 2006, Ernst et al. 2008, Habibian et al. 2010, and Schäfer et al. 2011). Between 2004 and 2013 a large number of long-period soundings (T = 10 – 10 000 s) were carried out in Northwest Poland (Fig. 1). It allowed us to collect a unique, exceptional data set.

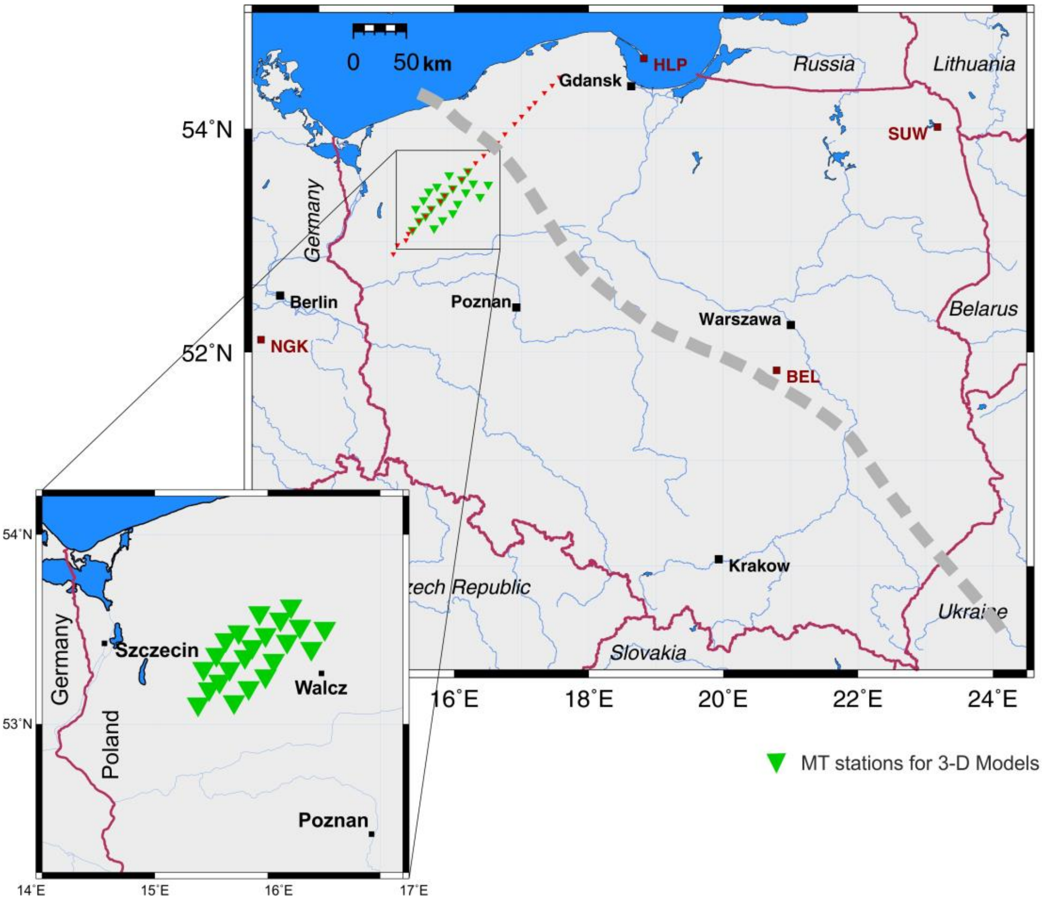

Fig. 1. Location of MT sites (red triangles represent profile LT-7 from the EMTESZ project). HLP, SUW and BEL refer to Hel, Suwalki and Belsk geomagnetic observatories which delivered data for remote reference. Approximate crude course of TESZ is outlined by grey, dashed line.

In addition to several profiles recorded earlier, we obtained 17 new sites over an area of approximately 100 km × 50 km. Data quality was usually excellent with the exception of sites which were built up in the vicinity of DC railways and commuter trains.

Induction vectors in the Polish Trough and easternmost part of the Palaeozoic Platform significantly deviate from simple 2-D behaviour, pointing even perpendicularly to the profiles (Fig. 1 and Fig. 2). The dimensionality and strike analysis employing the phase tensor method of Caldwell et al. (2004) additionally hint at a three-dimensional (3-D) subsurface beneath the TESZ (Fig. 2). 3-D behaviour of induction vectors appears in the centre of our mesh. Such effects are most likely caused by resistive salt domes, diapirs or pillows.

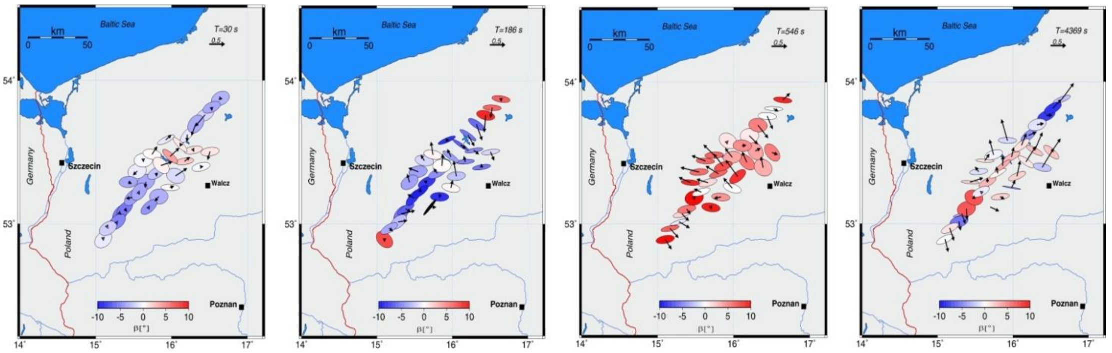

Fig. 2. Phase tensor plot and induction arrows (real parts) for selected periods. The colour code represents the skew angle as a measure of dimensionality β [°].

The WSINV3DMT code (Siripunvaraporn et al. 2005) is a full 3-D inversion program for magnetotelluric data (impedances). The inversion seeks the smoothest minimum structure model subject to an appropriate fit to the data. The 3-D modelling has been carried out for data at periods 10 - 10 000 s for the central profile alone as well as for the complete array. The overall RMS misfit was 2.03 (with 7.5 % error floor) for the full model and 1.35 for the model computed from the central profile (with 5 % error floor). An example of data fit (apparent resistivities and phases for the full impedance tensor) of the model depicted in Fig. 4 is shown in Fig. 3. Fit is very good for the minor diagonal (Zxy, Zyx) and only slightly worse for the main diagonal (Zxx, Zyy).

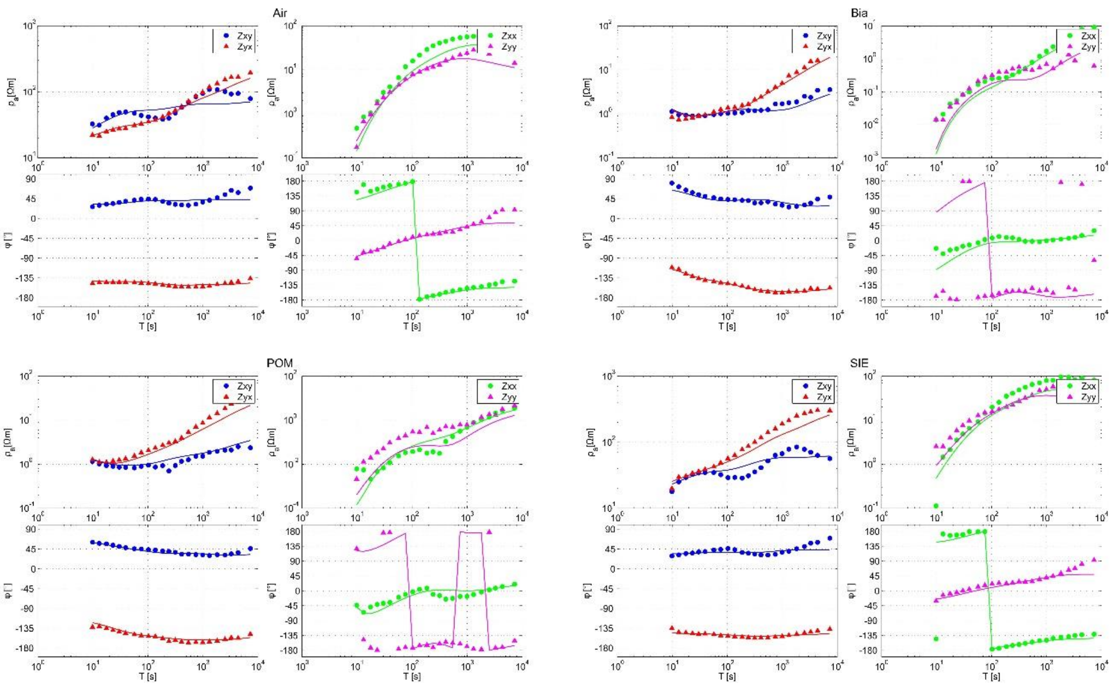

Fig. 3. Examples of data and model responses for selected sites.

The resulting model of electrical resistivity for the central part of our mesh and the full 3-D model are shown in Fig. 4. Both models show similar conductive features

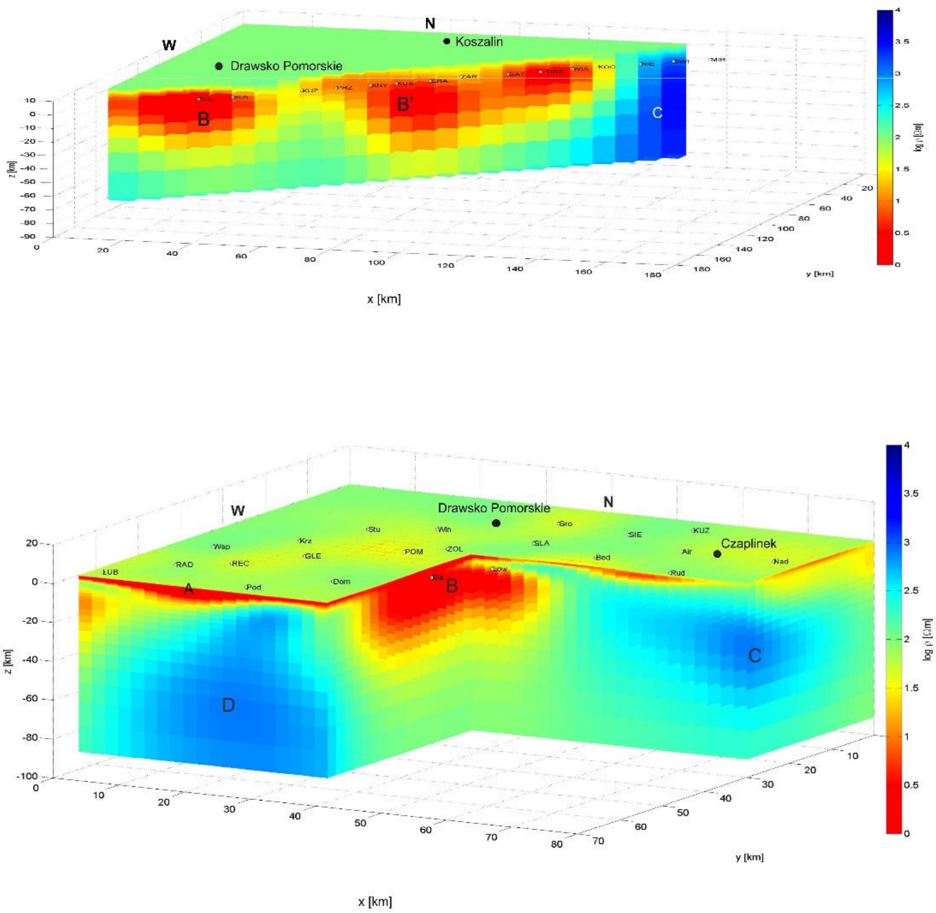

Fig. 4. Top: 3-D resistivity model along the central profile. Bottom: Section of the 3-D model, taking into account the full data set. A represents the highly-conductive sediments, B and B' are conductors associated with the Variscan and Caledonian deformation fronts, respectively. C and D point at the poorly conducting basements of the EEC and PP.

4. Conclusions

A well-conducting Cenozoic-Mesozoic sedimentary cover (A) appears in the full 3-D model (Fig. 4). Rocks in this layer with conductivity around 1-2 S/m are impregnated with saline waters, similar to findings in the NE German Basin (cf. Schäfer et al. 2011). Thickness of this layer varies throughout the model area. The higher resistive East European Craton (C) strongly marks here, and block (D) corresponds presumably to the Paleozoic Platform. Both models shown here include prominent, NW-SE striking, broad conductive lineaments which extend to depths of 10–30 km (B and B’). These structures are located in mid-crustal levels and they are related to the TESZ. The middle structure (B) in Fig. 4 we tentatively connect to the Variscan Deformation Front, the bigger N striking structure (B’) may be associated with the Caledonian Deformation Front.

In the near future we plan to enhance and complete our data set of the study area with additional measurements.

Acknowledgements

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