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STUDY OF THE DEEP CONDUCTIVITY STRUCTURE OF THE LAKE-LADOGA REGION: QUASI 3D AND 3D MODELS

Golubtsova N. S.[1], Kovacikova S.[2], Sokolova E. Yu.[3], LADOGA WG

[1]Lomonosov Moscow State University, Moscow, Russia

[2]Institute of Geophysics CAS, Prague, Czech Republic

[3]Schmidt Institute of Physics of the Earth RAS, Moscow, Russia

Summary

We present results of the modelling of the conductivity distribution for the Lake-Ladoga conductivity anomaly area and the contiguous areas. We used a database of geomagnetic induction vectors across the Baltic Shield region. These data were then used in the quasi-3D modelling of the conductance in the thin sheet approximation and compared with the results of the full 3D modelling. The electrical model of the Lake-Ladoga conductivity anomaly area is presented and discussed in relation to other geophysical data available and with respect to the basic regional geological units. The modelling allowed us to constrain both the geometry and electrical properties of the anomalous electrical structures within the studied area.

Introduction

Lake Ladoga conductivity anomaly (LLA) traversing the Baltic Shield, represents one of the most prominent crustal conductors in the East-European craton, associated with the boundary of Archaean and Proterozoic blocks. The area representing one of the oldest parts of the Earth‘s crust has been studied by MT/MV methods more than 3 decades by many field campaigns, however the question of nature and origin of the anomaly source are still debated – the most often discussed are the fluid-geothermal vs. electronic (graphite-sulphide bearing material) hypotheses and, respectively extensional (rifting) environment and the collision tectonics explanations [7, 2, 5, 6, 1].

The complicated geoelectric structure formed by the presence of the suture zone between the Svecofennian and the Karelian geoblocks [3, 4] suggests application of the 3D modelling and inversion. We present the conductivity model created as a result of the quasi-3D inversion of the vertical geomagnetic induction vectors obtained in recent years by the depth electromagnetic soundings including the AMT-MT investigations of the crust and mantle along the Vyborg-Suoyarvi profile crossing the suture zone, complemented with many other MVS and MT measurements covering the Fennoscandian Shield (fig. 1). The quasi 3D model, based on the thin sheet approach, can represent a partial step to developing a volume 3D geoelectrical model of the studied area and resolving the relations of anomalous geoelectrical features to the geological structures of the region.

Applied technique

The quasi-3D modeling and inversion was based on the study of distribution of the anomalous currents in the thin sheet, placed in a horizontally layered medium [9]. In the thin sheet approximation of the crustal structures the anomaly source was replaced by a thin horizontally inhomogeneous sheet with the anomalous conductance buried at a specified depth in a layered Earth model. The conductivity in the current sheet is replaced by the depth integrated conductance S. In the thin sheet with the unimodal induction no vertical currents are present and horizontal currents can be expressed as derivatives of the current stream functions. Distribution of the current stream functions within the thin sheet can be obtained using the Price equation [8]. The magnetic field (and the induction vectors) at the Earth's surface can be calculated gradually from the boundary conditions at the layers' boundaries [12]. The non-linear inversion was solved by minimising the Tikhonov parametric functional with the weighted norm of the difference between the observed data and the model transfer functions and the maximum smoothness stabilizing functional was applied. The minimisation of the parametric functional was solved by an iterative procedure using the conjugate gradient method.

Application in the ladoga project

The 1D layered medium applied in the inversion as a-priori information was adopted with respect to the previous 1D and 2D modeling results. The thin sheet was situated at the depth of 15 km with the normal conductance at the margins of the thin sheet 1000 S. The model consisted of 61 x 63 cells in the east and north direction respectively with the beginning (lower left corner) at 58°N and 21°E. The cell size 16km x 16 km was selected with respect to the used period range (100–1000s). Starting with the normal conductance in the thin sheet, the inversion was performed up to 15 iterations (fig. 2).

Conclusions

The work represents current results of modelling of the conductivity distribution over the Lake Ladoga area. The presented quasi-3D thin sheet model can be applied as a starting a priori model for the subsequent full 3D modelling (fig. 3) which can bring desirable resolution of crustal conductivity distribution and satisfies actual demand in high quality geophysical constrains for evolutionary models of Precambrian structures.

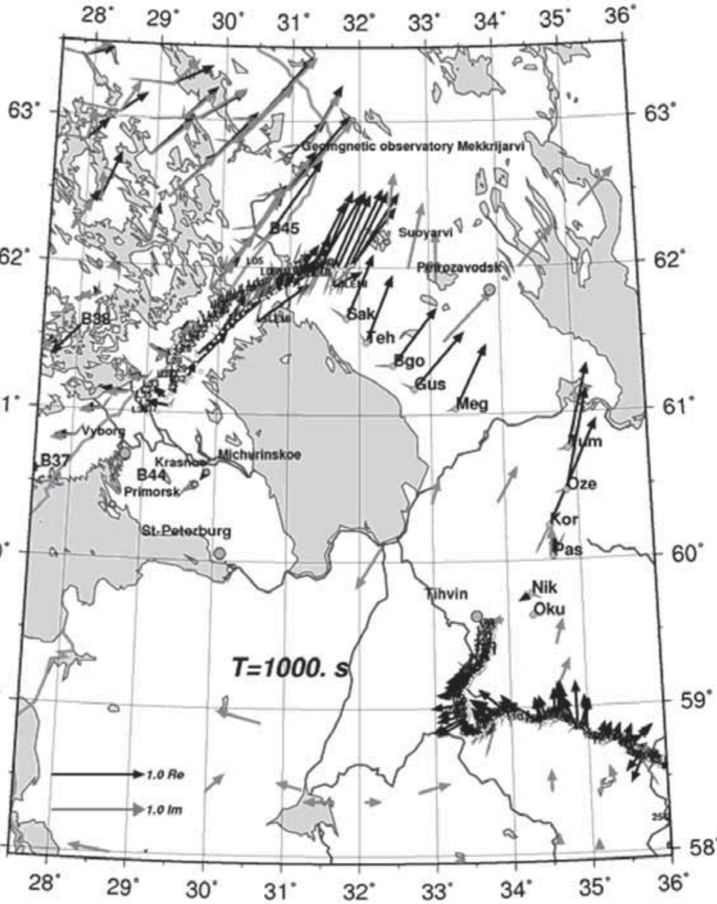

Fig. 1. Induction vectors distribution over the studied area: Re/Im IV at Vyborg-Suoyarvi and NE Ladoga profiles in Russia (T=1024 s); in Finland – Kari Paunpaa data (reversed: Az–180, T=1000 s) [11], and ReIV according to Wibranec T = 1000–1800 c

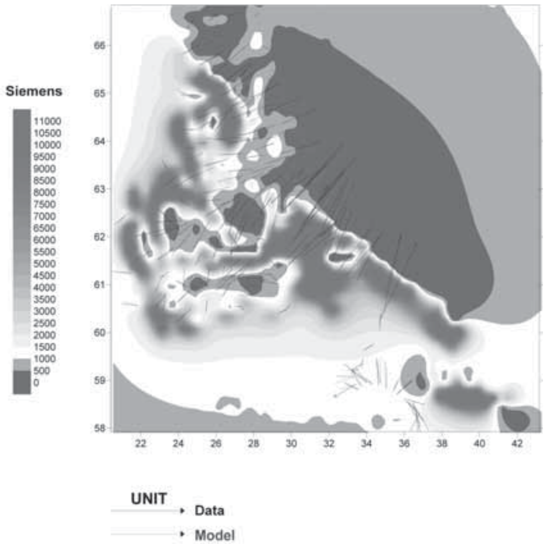

Fig. 2. Conductance model for the thin sheet at 15 km and the data and model Re IV for the period of 1000 s

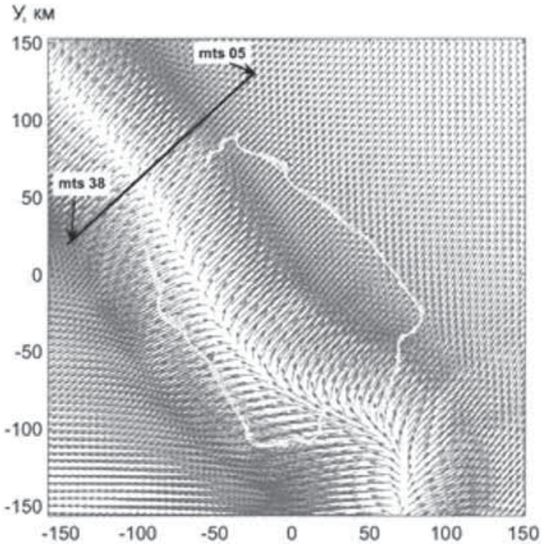

Fig. 3. Results of he 3D modelling of the geoelectric crustal structure of Ladoga Lake anomaly according to the Mackie code [10]: induction vectors at the period of 1024 s and the lake Ladoga shape (black line – the Vyborg–Suoyarvi profile)

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