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Geoelectrical inhomogeneities of the Pre-Dobrudzha Depression and Northern Dobrudzha as markers of the Trans-European Suture Zone

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SUMMARY

For the first time, a geological and geoelectrical interpretation of the three-dimensional resistivity distribution model in the interior of the Earth's crust and upper mantle was carried out for the Pre-Dobrudzha Trough and adjacent areas. It was built on the basis of experimental observations of the Earth's low-frequency electromagnetic field, which were carried out in 2009-2012. In this paper we considered confidently indicates that the detected anomalies of high electrical conductivity are confined to sub-vertical channels (from the surface to 10 km) that are galvanically connected with sediments, or sub-vertical contact zones of different resistivity, which are observed not only in the Earth's crust (10-40 km), but also at crust/mantle depths (40-60 km) and in the upper mantle (110-160 km), and may cause the inflow of ultra-deep fluids. The territory of Dobrudzha and the Pre-Dobrudzha Trough, as well as the entire southwestern margin of the East European craton, is abundant in anomalous objects of high electrical conductivity in the crust, and the distribution of electrical conductivity in the upper mantle reflects the position of the zone of articulation of the East European craton and the Scythian plate of different ages. Such a geoelectrically regional structure in a fairly wide and long area is a marker of the Trans-European suture zone.

Keywords: Geoelectromagnetic methods, interpretation of a three-dimensional model, electrical conductivity anomalies, Trans-European suture zone.
Introduction

The nature of the deep geoelectric anomalies revealed by observations of the Earth's low-frequency electromagnetic field of external ionospheric-magnetospheric origin may be the result of fluid migration in the interior of the southwestern East European Craton (EEC) and its rim (Burakhovich et al, 2015). Thus, in 2006, S.M. Kulik predicted the existence of a chain of high electrical conductivity anomalies in the crust of the Eurasian region, which correlates with the side fragmentary northern Dobruzhynsko-Crimean-Caucasian branch of the known Alpine-Himalayan moving belt.

Method

In 2009-2012, magnetotelluric sounding (MTS) and magnetovariational profiling (MVP) observations were made over a wide range of periods in the Reni-Bilyaivka, Kilia, Izmail, DOBRE regional profiles and in the vicinity of Zmeinyi Island. Based on the generalized data, a three-dimensional geoelectric model of the resistivity distribution in the earth's crust and upper mantle of the North Dobrogea (ND) and Pre-Dobrogea Trough (PDT) was built. The heterogeneities at different depths from the crustal surface to the upper mantle were identified (Fig. 1). The 3D modeling methodology was performed using the Mtd3wd software, and the calculations and general analysis of the geoelectric model are described in detail in (Burakhovych et al, 2015).

Figure 1. Distribution of resistivity based on the results of 3D modeling of the Predobrudzha Trough and North Dobrudzha according to (Burakhovych et al, 2015). 1 - deep fault zones of different rank: 1 - Franzensky, 2 - Chadyr-Lungsky, 3 - Saratsky, 4 - Bolgradsky, 5 - Alibeysky, 6 - Chornomorsky, 7 - Sulynsky, 8 - Odessky, 9 - Kahulsko-Izmailivsky; 2-6 - parameters of geoelectric heterogeneities: 2 - depth (h) from the surface to 1 km, ρ = 2 Ohm-m, 3 - h = 1-10 km, a - ρ = 2 Ohm-m, b - 10 Ohm-m, 4 - h = 10-40 km, ρ = 10 Ohm-m, 5 - h = 40-60 km, ρ = 10 Ohm-m, 6 - northern boundary of the asthenospheric layer h = 110-160 km, ρ = 70 Ohm-m, 7 - interpretation profile I-I - “Reni-Bilyaevka”. Abbreviations: KVZU - Kiliysko-Vilkovo-Zmiinoostriwne Uplift, MZ - Moldavian Depression, LDD - Lower Dniester Depression, PR - Prut Rise, ND - Northern Dobrudzha, PDT - Pre-Dobrudzha Trough, EEC - East European Craton, SP - Scythian Plate.
Geological and geoelectric interpretation

Currently, there are a large number of options for the location of the southwestern border of the EEC in the area of the PDT and the ND. Its placement is envisaged in a strip about 500 km wide. The most comprehensive overview of the history of research with critical remarks is given in (Mokriak, 2014).

According to the deep geoelectric model, the boundary between two normal sections (the northern one, which corresponds to the generalized EEC section (Fig. 2), and the southern one, where the section of inactivated Crimean kimerides is taken as the host medium, where the "asthenosphere" at depths from 110 to 160 km is characterized by an electrical conductivity of 700 S) best corresponds to the position of the Precambrian craton boundary according to M. Vysotsky 1959 and Tectonic map of Ukraine, UkrDGRI 2007. According to the Vysotsky, the boundary runs along the northern edge of the Jurassic basin, i.e., coincides with the axial part of this trough. Similarly, according to the mind of who create tectonic map in 2007, it is drawn along the axial part of the PDT, which is considered to be a component of the SP. The last tectonic line crosses all geological boundaries, the selection of which is based on a comprehensive interpretation of all available geological and geophysical information.

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*Figure 2. Vertical section of the 3D model of resistivity distribution in the subsurface of the Predobrudzky Trough along the Reni-Bilyayivka profile. 1 - resistivity value, 2 - change in spatial orientation of the profile. For other symbols, see Fig. 1.*
The study (Amashukely et al., 2019) examines the deep structure of Dobrudzha and the PDT in terms of reflecting the development of the Trans-European Suture Zone (TESZ). It is known that the boundaries between the Paleozoic hercynids of Central Europe and the Tertiary Carpathians are characterized by a significant contrast in the electrical conductivity of the crust. The northeastern contact of the hercynids and the Archean EEC system, known as the TESZ, is marked by the North German-Polish anomaly in bay-like geomagnetic variations. This regional structure is geoelectrically distinguished by a layer of high electrical conductivity in the middle mantle as well. Here, in a fairly wide (approximately 15° to 40° E) and long area, the electrical conductivity increases to 100 kS (Semenov and Jozwiak, 2006). The depth of the roof of this layer varies from 600 to 800 km.

In 2001-2003, the CEMES project obtained a smoothed image of the integrated electrical conductivity (in kS) of a two-hundred-kilometer-thick mantle. It is shown that the electrical structure of the upper mantle differs between the EEC and the Phanerozoic plate of Western Europe; a transition zone coinciding with the TESZ is separated.

According to the depth to lithosphere-asthenosphere map of Europe (Korja, 2007), the European lithosphere is Phanerozoic with significant thickness variations from 45 to 150 km, but it is much thinner than the Precambrian lithosphere; The TESZ is the main geoelectric and geophysical-geological boundary in Europe, separating two rather different regions; the thinnest lithosphere (45-90 km) is located beneath the extended Pannonian basin; most cratons in Eastern Europe show no signs of high conductivity in the upper mantle.

As a result of numerous MTS and MVP studies, the western edge of the EEC is traced by anomalous objects of high electrical conductivity in the subsurface of the Earth's crust and upper mantle (Burakhovich et al., 2015), including the structures of the PDT and the ND.

According to modern geological and geophysical studies (Amashukely et al., 2019), with an emphasis on the deep seismic soundings (DSS) data from the DOBRE-4 and PANCAKE profiles, it is shown that the TESZ is an inclined fault system; its north-eastern border passes near the surface under the NDT, and the south-western border is adjacent to the Pecheneg-Kamen fault zone, which possibly crosses the upper and middle crust at depth. The entire crust within the TESZ has reduced velocity characteristics and the largest deflection in the Moho Division.

According to the results of seismic tomographic studies (Gintov et al., 2023), the mantle structure of the TESZ has a complex structure. It is noted that, on the one hand, the TESZ goes deeper into the mantle to a level of about 700 km as a sub-vertical limitation of the EEC, and on the other hand, inclined layers - slabs - are clearly visible, dipping to the southwest to a depth of 350-600 km, i.e., traces of subduction processes.

**Conclusion**

The main result of the analysis of the resistivity distribution model of the PDT and ND is the identification of areas of high electrical conductivity both in the Earth's crust and in the upper mantle, which are characterized by different conductivity and depth of occurrence, configuration, and differently characterize geological structures.

Sub-vertical conductive zones or contacts of different resistivity in the near-surface layers mostly coincide with deep faults of different ranks and their intersections: Frunzensky, Saratsky, Bolgradsky, Kagulsko-Izmailivsky, Chadyr-Lungsky, and others.

Deeper in the Earth's crust (10-40 km) and at crust/mantle depths (40-60 km), local geoelectric anomalies have a complex volumetric shape in space, some of which coincide with the location of the above deep fault zones. In the Paleozoic PDT and the studied part of the northwestern Black Sea shelf, the upper mantle at depths (110-160 km) is manifested by a regional conductivity anomaly, namely, an asthenosphere with $\rho = 70$ Ohm-m, which is characteristic of the normal distribution of $\rho$. 

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of the inactivated Cimmerian SP. Thus, the territory of the ND and the PDT, as well as the entire south-western outskirts of the EEC, is replete with anomalous objects of high electrical conductivity in the crust, and the distribution of electrical conductivity in the upper mantle reflects the position of the zone of articulation of the different-aged EEC and the SP. This geoelectrically regional structure may reflect the deep structure of the TESZ in a fairly wide and extended area, which updates and details the idea of the depth to the lithosphere-asthenosphere boundary.

Heterogeneities at crustal and mantle depths may indicate high permeability to deep fluids and determine the pathways of their migration as one of the factors of manifestation of geodynamic processes related to the search for mineral prospects (Myrontsov et al, 2021, 2022).

Geoelectric heterogeneities in the Earth's crust and upper mantle are, one way or another, confirmed by the presence of various anomalies in other geophysical fields. For example, the manifestation of sub-vertical mantle columns in the interval (28°-30°E longitude) × (45°-46°N latitude) according to the 3-D P-velocity model based on seismictomography data. The position and geometry of velocity boundaries in the Earth's crust, obtained from the interpretation of DSS data along the DOBRE-4 and DOBRE-5 profiles, are also consistent. The increased heat flux, electrical conductivity anomalies in the Earth's crust and upper mantle, positive mantle gravity field anomaly, and the result of 3D P-velocity modeling of the mantle beneath Eurasia based on seismic tomography data can be explained by the existence of a mantle plume and associated fluids and their migration paths.

References


