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Modeling of magnetotelluric fields within a block geoelectric model of the southern border of the Chu Basin (*Northern Tien Shan*)

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Abstract

Three-dimensional inversion of magnetotelluric fields made by 3D block modeling of magnetotelluric (MT) fields of geoelectric models permitted construction of alternative geoelectric models fitting real MT data. Based on their analysis, highly conductive zones have been identified at different depths of the crust. Their correct interpretation requires the use of reliable gravity, temperature, and seismic data. Sensitivity analysis of 3D MT model curves with respect to conductive crustal blocks has shown that it is advisable to use the maximum curves of the phase tensor to estimate the electrical conductivity of the crustal and mantle parts of the section. The information value of these curves is close to that of the maximum induction curve on mapping conductive blocks in the upper and middle crust. It is also shown that the real Wiese–Parkinson vectors provide high resolution on estimating the excess integrated conductivity of the crustal blocks. Therefore, magnetovariational sounding in the Northern Tien Shan should be continued.

Keywords: magnetotelluric sounding; 2D-3D inversion; conductor; resolving power; the impedance tensor

Introduction

The concept of the deep geoelectric section of the Chu Basin has been based so far mainly on the results of two-dimensional interpretations of MT soundings carried out in the 1980–1990s using a TsES-2 system with a rare observation network (Batalev et al., 1989; Belyavsky et al., 2002; Bragin et al., 2001; Gordienko et al., 1990; Trapeznikov et al., 1997). However, the schematized two-dimensional geoelectric models developed by the authors have made it possible to identify a conductive layer in the lower crust beneath the Chu Basin at a depth of 30–35 km and evaluate the effect of the high-resistivity border of the basin on the behavior of MT curves (the so-called edge effect). At the same time, in terms of the measurement frequency range and the detail level of the constructed interpretation models, these studies clearly do not meet the current requirements and opportunities for application of magnetotellurics to objects of this kind.

The assumption that the increased-conductivity layer is close to the position of the waveguide at depths of 35–40 km (Sabitova and Adamova, 2001; Sabitova et al., 1998) beneath the southern border of the basin is very hypothetical because later seismotomographic studies (Sabitova et al., 2005) have shown that layers with a longitudinal wave velocity deficit $\Delta v_P = 0.3–0.8$ km/s may be located at depths of 25 and 50–55 km.

To ensure a detailed study of the deep structure of the complex Northern Tien Shan region and understanding of the current geodynamic setting in the area of the Kyrgyz Range thrust on the Chu Basin, numerous magnetotelluric soundings along a number of profiles (Fig. 1) using wide-band magnetotelluric Phoenix MTU-5 systems were performed in 2004–2006 by the Research Station of RAS within the framework of the INTAS international project “Three-dimensional electromagnetic and thermal tomography of seismically active zones of the Earth’s crust” (supervisor Doctor of Sciences (Phys.-Math.) V.V. Spichak). Using these data, it became possible to pose problems of developing three-dimensional regional geoelectric models and evaluate the influence of the dimension on the interpretation of MT data.

The aim of our studies was to identify crustal blocks and layers in the lithosphere of the region with anomalous geoelectric parameters (i.e., to determine its stratification and block-fault structures), detect conductive zones associated with fluid-saturated faults or the areas of possible graphitization-sulfidation. This study presents additional interest due to

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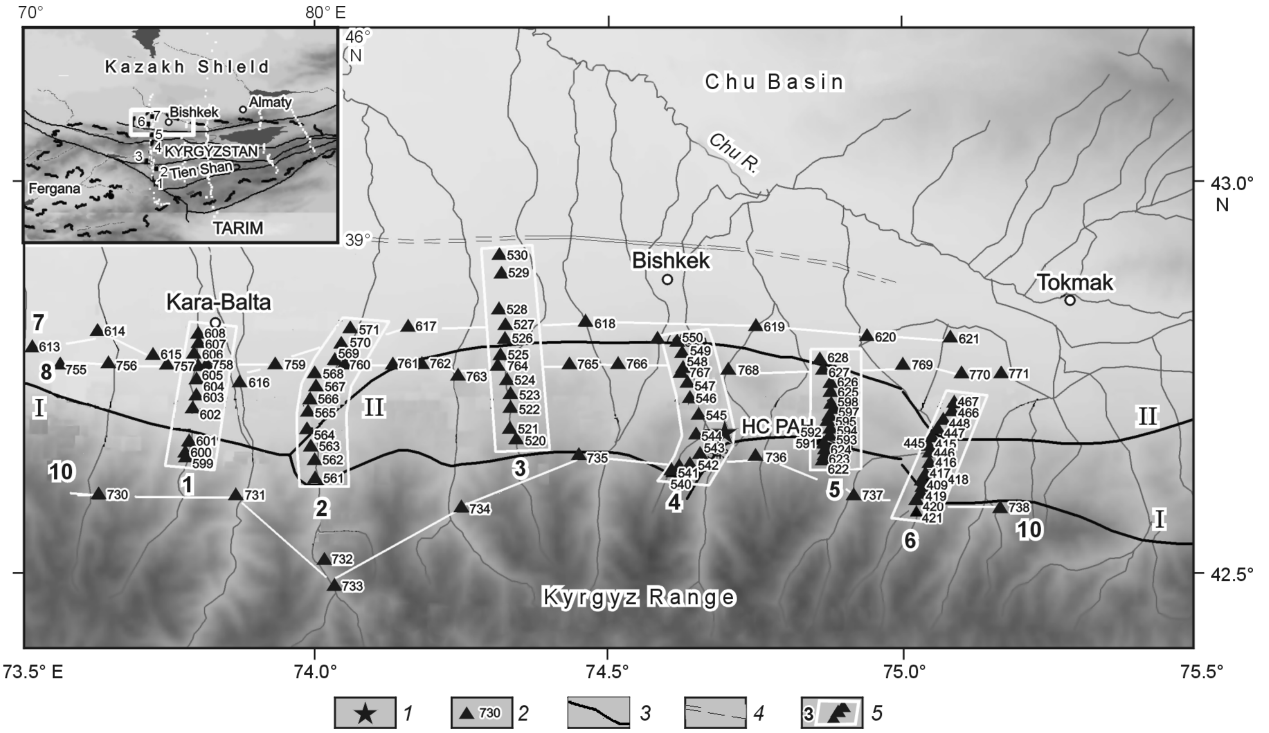

Fig. 1. Schematic location of MT points (Rybin et al., 2008). *1*, RAS Research station; *2*, MT points and their numbers; *3*, faults: I, Issyk-Ata, II, Shamsi-Tyundyuk; *4*, Central Chu flexural fracture zone; *5*, MT profile numbers. The light rectangle in the inset shows the location of the RAS Research station and regional profiles (white lines). 1–7, MV–MT sounding curves.

differences in the interpretation of the geological and structural-tectonic situation at the junction of the Kyrgyz Range and the Chu Basin by different researchers (see, e.g., Bakirov, 2005; Batalev, 2014; Bragin et al., 2001; Gordienko et al., 1990; Sabitova et al., 1998, 2005) and the insufficient state of geophysical knowledge of the region, particularly its deep structure.

Geological and geophysical characteristics of the Chu Basin

Elements of geological structure. The Chu Basin overlies a roughly east–west trending graben-syncline. It is bounded by mountain ranges in the east and opens toward the Chu-Sary syneclise in the northwest. In the northeast, it is surrounded by the mountain structures of the Kendyktas Range and in the south by the Kyrgyz Range, from which it is separated by a system of roughly east–west trending faults. From the Jurassic to Late Paleogene, the structure developed in the platform regime. In the Late Oligocene, the regime of platform was disturbed by tectonic movements.

The thickness of coarse clastic sediments with $\rho = 200$–800 Ohm·m is 1600 m in the southern parts of MT profiles and decreases to zero in the northern parts. The thickness of Meso-Cenozoic sediments in the basin reaches 5 km. Within the work site, the Pre-Mesozoic basement plunges from the depth of 0.5 to 4 km near the Shamsi-Tyundyuk fault. The Paleozoic basement in the frame of the basin is elevated to an altitude of 3–4 km above sea level. The Moho in the work site is located at a depth of 50 km, and at the center of the Chu Basin, it is at depths of 40–45 km (Krestnikov et al., 1992; Yudakhin, 1983). The upper mantle beneath the Kyrgyz Range is the low-velocity one. Within the range, there are hydrothermal vents with a maximum isotope ratio ^{3}He/^{4}He = 4–7, indicating the mantle origin of the faults (Polyak et al., 1990).

The MT sounding site is located in the Kyrgys Trough (Fig. 1) south of the Central Chu flexural fracture zone, near which lies the Northern Tien Shan marginal fault separating the Tien Shan from the Turan Plate (Tal'-Virskii, 1964). A characteristic feature of the latter is a decrease in the Moho depth to 40 km beneath the plate. In the north of the Issyk-Ata region, the fault extends from profile 2 to profile 6, separating the Chu Basin from the foothills. The Shamsi-Tyundyuk fault located to the south separates the mountains from the trough and runs parallel to profile 10.

Geodynamic activity and seismicity. Within the Northern Tien Shan adjacent to the Chu Basin in the south, the Holocene upward vertical displacements were 80–120 m, and in the basin, 0–30 m. This is the zone of maximum activity of the Northern Tien Shan fault and the most likely occurrence of crustal earthquakes with a magnitude M > 8 (Krestnikov et al., 1992). Mass movements in the southern frame of the basin are northward (Kuchai and Kozina, 2015). Horizontal reverse-fault displacements associated with the pressure from the south reach 10 mm/yr at the Kyrgyz Range and 1–2 mm/year in the Chu Basin (Reigber et al., 2001). Maximum