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Results of magnetotelluric surveyon reference geophysical profiles of the Karaton–Sarkamys block in Kazakhstan

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Abstract

A digital geoelectric model of the Karaton–Sarkamys block located in the southern (Kazakhstan) part of the Caspian Depression has been developed on the basis of processing and interpretation of magnetotelluric sounding data. Geoelectric sections and structural maps of geoelectric layers have been constructed. It has been shown that magnetotelluric sounding combined with seismic and GIS data can be efficiently used to obtain additional information on the lithologic and reservoir properties of petroleum plays.

Keywords: magnetotelluric (MT) sounding; petroleum potential; seismic prospecting; integrated interpretation; Caspian Depression; oil and gas

Introduction

The Karaton–Sarkamys tectonic block is located at the junction of two major tectonic structures—the southeastern border of the Caspian Depression and the North Ustyurt Depression. The junction zone is a structurally complex suture zone—a Palaeozoic paleotrough—which is responsible not only for the complex tectonic structure (pinch-out of Kungurian salt, spatial location of geological bodies in the block), but also for the widespread change in sedimentation conditions and the composition of coeval geological formations (Daukeev et al., 2002).

Exploration work at the block has been carried out since the 1920s. However, although the region is in many respects well studied, some fundamental questions of its geological structure remain controversial. The most important issues are the stratification of the lower (pre-Devonian and Devonian) part of the sedimentary cover, the formation of the so-called anomalous structures in Devonian–Carboniferous sediments, and the lithologic and stratigraphic heterogeneity of the suprasalt sequence.

In the study area, electrical exploration by magnetotelluric sounding (MTS) was carried out to obtain additional geological information. Magnetotelluric sounding is based on measuring variations in the natural alternating electromagnetic field of telluric currents with a period of fractions of seconds to day. The physical basis of MTS is the skin effect, according to which high-frequency components of the field that do not penetrate to great depths provide information on the subsurface, and low-frequency components on deep areas (Berdichevsky and Dmitriev, 1991).

Results of electromagnetic studies (after processing and interpretation) are represented as geoelectric models providing information on the physical and geological properties of the study section (conductivity, lithology, fluid saturation, etc.) (Hoversten et al., 2012).

In petroleum exploration, MTS efficiently complements seismic and drilling studies by providing additional information on the lithologic heterogeneity and reservoir properties of rock for solving structural problems. Great sounding depth makes it possible to use this method to study the deep sedimentary layers (Ingerov, 2014; Tikhonov, 1950).

Initial data

The Geoken scientific production center has carried out geoelectric investigations in Kazakhstan since 2005. In 2012, this company conducted field magnetotelluric sounding at the Karaton–Sarkamys block. The MT studies had the following objectives:

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– investigation and refinement of the geological structure of the suprasalt (Triassic and Jurassic–Cretaceous deposits) and subsalt sequences of the Karaton–Sarkamys block;

– identification of geoelectric heterogeneities in formations of the sedimentary cover and the upper part of the consolidated Earth's crust to evaluate their oil and gas potential;

– identification of anomalous conduction zones of the sedimentary cover that are favorable for petroleum accumulation;

– preparation of recommendations for further geological exploration.

The sedimentary cover of the explored Karaton–Sarkamys block is complex. The subsalt sequence is divided into two structural stages: pre-Eifelian and Eifelian–Artinskian. Drilling has exposed Devonian deposits composed mainly of argillaceous limestone. They are overlain by reef deposits from the Lower Carboniferous Tournaisian stage to the Middle Carboniferous Bashkirian stage. The section of the subsalt sequence is topped by Lower Permian Asselian–Artinskian deposits represented by carbonate and clastic-carbonate sediments (Pilifosov, 2002).

Above lies a Kungurian saliferous sequence with an average thickness of 4.0 km.

The suprasalt section is represented by the full sedimentary sequence characteristic of the whole Caspian Depression. Here oil layers are identified in a wide stratigraphic range from the Paleogene to the Triassic, inclusive, which can be divided into three regional petroleum plays: Middle–Upper Triassic, Middle–Upper Jurassic, and Lower–Upper Cretaceous.

A petrophysical feature of the sedimentary cover of the Caspian Depression is the presence of three geoelectric sequences: a suprasalt sequence with a conductivity of a few siemens to a few tens of siemens, a carbonate-halogen with a transverse resistivity of about 10^7 Ohm·m^2 and a longitudinal conductivity of a few siemens, and a subsalt sequence with a conductivity of a few siemens to 15–20 S. The crystalline basement of the depression is a very high-ohmic consolidated crust layer. The high resistivity of the dense host rocks of the sedimentary cover differs significantly from the resistivity of reservoir layers. The saturation of reservoirs with high-mineralized fluids is responsible for the clear correlation between the electrical properties of the layers and their permeability properties. To make use of these advantages, the MTS method has been successfully tested in the study area. However, the presence of a rigid nonconductive barrier in the form of a salt sequence sometimes complicates the identification of subsalt deposits using the MTS method alone (Dmitriev, 1969; Van'yan et al., 1984; Kondrat'ev et al., 2004).

Previous explorations have shown the commercial oil-and-gas potential of both the suprasalt and subsalt deposits of the Karaton–Sarkamys block. In the suprasalt sequence of the block, 15 deposits at depths of 500 m to 3200 m, with geological oil reserves of 1 million tons (Karasor Zapadnyi) to 70 million tons (S. Nurzhanov) have been established. In the subsalt sequence, the Tengiz field with one of the largest petroleum reserves in the world was discovered in 1979 (Fig. 1).

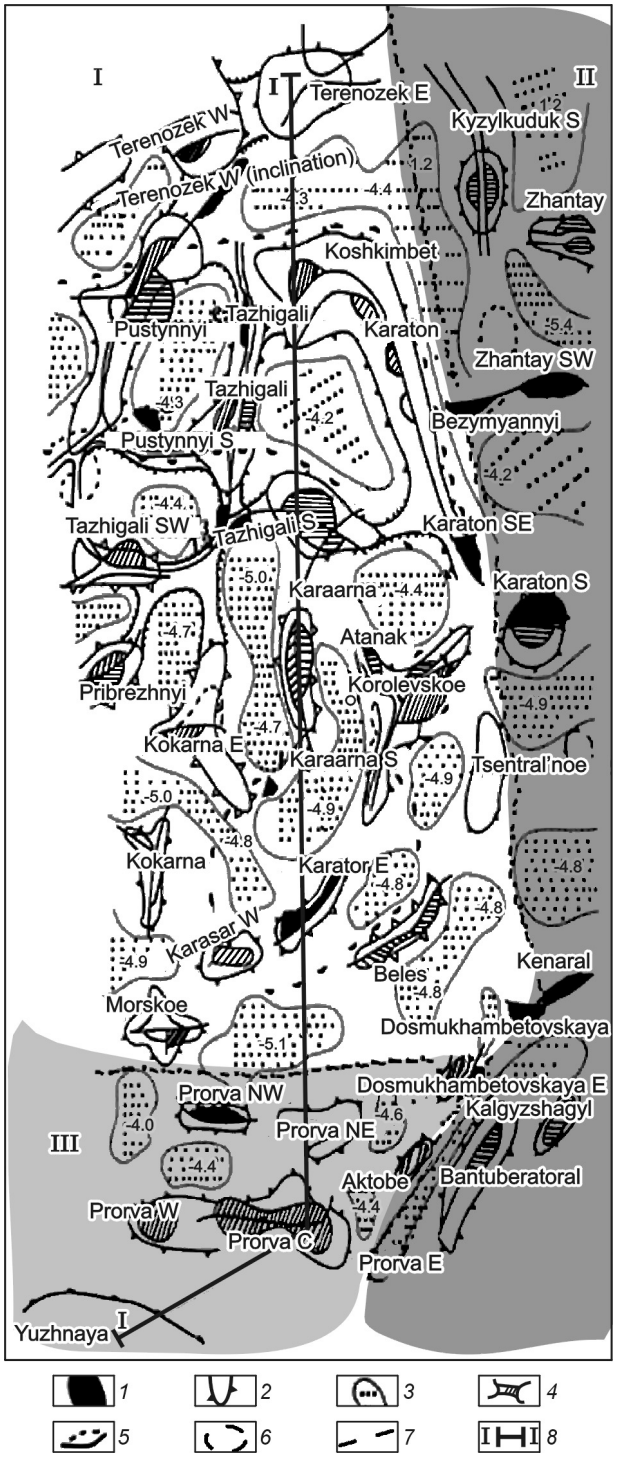

Fig. 1. Schematic of the oil geological zoning of the Karaton–Sarkamys block (Daukeev et al., 2002). Oil and gas accumulation zones: I, Zapadnaya (West); II, Vostochnaya (East); III, Yuzhnaya (South). *1*, prospective sites; *2*, salt domes; *3*, intercupillary zones (troughs), the maximum occurrence of the salt surface in the trough is indicated; *4*, salt isthmuses; *5*, proved and prepared structures; *6*, contours of subsalt carbonate uplifts; *7*, interfaces of oil-bearing zones; *8*, line of Terenozek Vostochnyi–Yuzhnaya structures.