https://doi.org/10.33271/nvngu/2023-3/005

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GEOELECTRICAL MODEL OF THE EARTH'S CRUST ALONG THE SHU-SARYSU GEOTRAVERSE ACCORDING TO MAGNETOTELLURIC SOUNDINGS

Purpose. To study and assess the possibility of effective application of electrical prospecting by magnetotelluric sounding (MT-sounding) and to determine the range of geological problems to be solved in the geoelectric conditions of the Shu-Sarysu geotraverse.

Methodology. The issues of methodology of modern technologies of field observations, peculiarities of processing and interpretation of MT-sounding data are considered, which showed that modern instrumental and methodical electrical survey technologies of MT-sounding allow obtaining results of field measurements of increased reliability, due to their accuracy, productivity, mobility, noise immunity, level of automation. To identify the main features of the geoelectric structure of the Earth's crust and the upper mantle, the modern technique of interpreting MT data allows for 1, 2D inversion of the effective curves of apparent resistivity and impedance phase.

Findings. Based on MT-sounding data, a geoelectric section of the Shu-Sarysu geotraverse was constructed, characterizing the position and morphology of five geoelectric boundaries in the crustal section in the 0–40 km depth interval. The identified five geoelectric horizons show good coincidence with the conventional seismic horizons and confidently correlate with the geological references established by GIS data.

Originality. On the basis of MT-sounding studies, the geological interpretation of the structure of suprasalt and subsalt structural-formation complexes is presented; the geological efficiency of MT-sounding electrical prospecting in revealing the complex structures in the conditions of the Shu-Sarysu geotraverse is shown. On the basis of model constructions of the geoelectric section, new data on the deep geological structure of the Shu-Sarysu geotraverse were obtained: new data on the structure of Mesozoic terrigenous-sedimentary rock complexes and the Paleozoic part of the section with the allocation of the supposed faults; on the basis of MT-sounding results, recommendations for further detailed geological exploration work were given.

Practical value. A comprehensive interpretation is recommended of the obtained MT-sounding data together with the results of geological and geophysical research on the regional profile in order to establish search criteria for the discovery of mineral deposits and the prospects of gas content in the area.

Keywords: *geotraverse, sedimentary cover, basement, Shu-Sarysu sedimentary basin, magnetotelluric sounding, geoelectric section*

Introduction. At present, the study on the deep structure of the Earth's crust and upper mantle is important not only in terms of the use of geophysics for further development of natural sciences about the Earth. The results of regional studies are used in the construction of deep geological and geophysical 3D models in order to obtain the basis for the assessment of unexploited resources of mineral and hydrocarbon raw materials at the stage of forecasting and prospecting tasks. In some cases, research on geotraverses is even used in the search for new mineral deposits.

Along with national projects aimed at solving these problems and carried out by scientific centers of the United States, Great Britain, Germany, India, Spain, Canada, China, France, Japan, and other countries, there are also a number of international programs and projects implemented on the basis of a corporate combination of efforts of scientists and practitioners from different states. An example of the implementation of such programs in Kazakhstan is geophysical research along the line of the geotraverse that crosses the southeastern part of the Syrdarya basin, the Karatau mountain system and the Shu-Sarysu sedimentary basin (Fig. 1).

The study area under consideration is the only purely gas-bearing area in Kazakhstan. The presence of known gas fields such as Amangeldy proves the prospect of the area for the presence of hydrocarbons. Thus, the interest of the state and the prospects of the area in the gas-bearing area show the indisputable relevance of research.

Modern geophysics is characterized by rapid breakthroughs due to the emergence and use of high-precision and high-resolution technologies, allowing for a detailed understanding of the structural features of objects under study [1].

Electrical magnetic-telluric sounding (MT-sounding) is a tool that can successfully solve a range of problems associated with the search for mineral deposits, including hydrocarbon deposits, acting as an essential complement to seismic exploration

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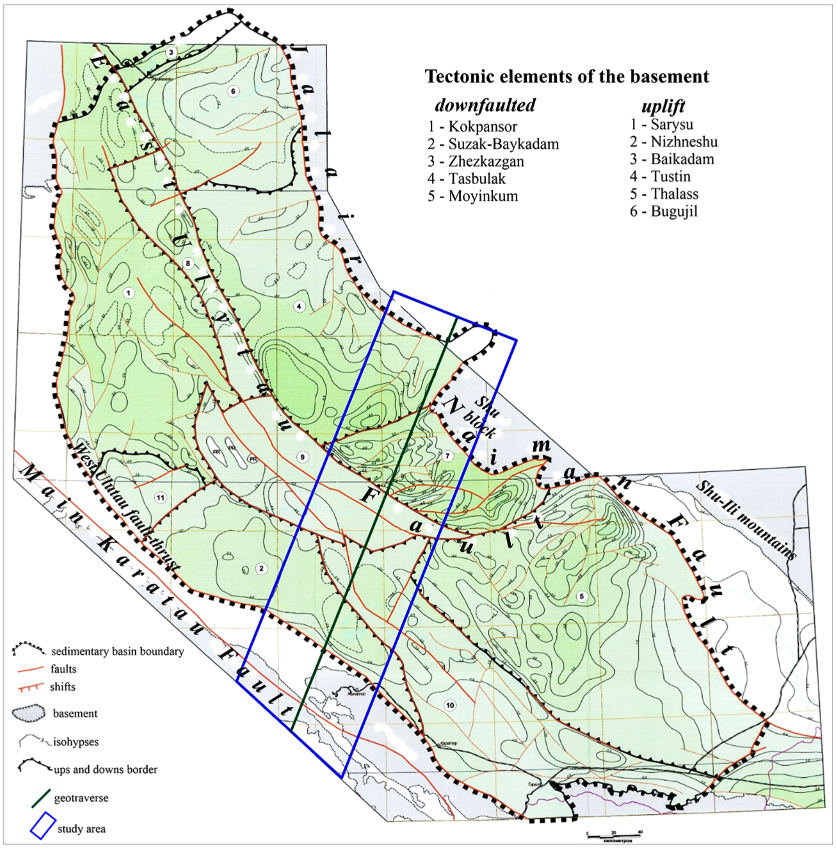

Fig. 1. Structural map of the basement surface of the study area

[2]. Structural constructions are close to seismic surveys in terms of accuracy, and constructions when interpreting MT-sounding do not depend on any a priori data (as, for example, in the method of seismic CMP (common midpoint) from velocities).

MT-sounding is not comparable with seismic survey in terms of resolution, but nevertheless allows one to identify specific resistivity anomalies associated with epigenetic changes in rocks above the hydrocarbon reservoir, conduct a lithological partitioning of sedimentary complexes, identify deep faults, large anticlinal uplifts, foundation structures [3]. In addition, according to the MT-sounding by indirect signs it is possible to predict the zones of horizons, prospective for oil and gas [1]. And in the field of regional electrical prospecting, the technology of magnetotelluric sounding is the leading one [4].

The purpose of the research presented in the article is to define the range of tasks and study the geological effectiveness of MT-soundings in real geoelectric conditions.

To achieve this goal, the following tasks were accomplished:

1. Collecting, analyzing and summarizing information on the geological characteristics of the fields of the Shu-Sarysu gas-bearing region and adjacent areas.
2. Studying primary geophysical criteria along the Shu-Sarysu geotraverse line.
3. Identifying geoelectric horizons, basement of sedimentary cover, basement roof, identifying structural and material heterogeneities of the consolidated crust and weakly delocalized complexes of the Paleozoic, tracing of faults according to MT-sounding data.
4. Determining the material composition and isolating local geoelectric heterogeneities.

The Shu-Sarysu basin is located in the central part of Kazakhstan, and is geologically connected with the basin of the same name, stretching in the north-west direction for 700 km with a width of 200–250 km. The sedimentary basin in the west and north is bounded by the Ulytau mountain-fold structures and the Sarysu-Teniz uplift, in the northeast it borders on the Shu-Ili anticlinorium, in the south and southwest – the mountain ranges of the Big and Small Karatau, in the east and southeast it borders with the Kendyktas massif and the Kirghiz Alatau. The depression is composed of a complex of Devonian-Permian and Meso-Cenozoic sediments with a maximum thickness of up to 6000 m.

The basement is composed of metamorphic rocks of the Proterozoic, and within the individual blocks of the central part of the basin in the upper sections of the basement there are intensely dislocated and intruded strata of Lower Paleozoic rocks.

The sedimentary cover of the basin includes deposits from the Middle-Upper Devonian to the Neogene and forms two structural stages separated by large stratigraphic and angular unconformities: Paleozoic (Middle-Upper Devonian-Permian) and Mesozoic-Cenozoic (Upper Cretaceous-Paleogene).

The basement of the Shu-Sarysu basin is characterized by a block structure of different ages. A number of subsided (Kokpansor, Suzak-Baykadam, Zhezkazgan, Tasbulak, Moyinkum troughs) and uplifted (Sarysu, Nizhne-Shu, Betpakdala, Tastin, Talas and Bugujil ledges) blocks are distinguished in the basement of the depression. The basement of the basin was formed at the end of the Ordovician, it is composed of metamorphic Precambrian formations of the Lower and Upper Proterozoic, in some sections of the basement there are intensely deformed intrusive strata of the Lower Paleozoic.

The Shu-Sarysu Paleozoic basin is bounded in the west by the West Ulytau shear-thrust, in the northeast by the Zhalair-Naiman fault of the reverse fault type. In the central part of Kokshetau-Zhezkazgan (in some sources called the East Ulytau) fault of the northwestern direction. The territory of the basin is divided into two equivalent parts.

On the southwestern side of the Kokshetau-Zhezkazgan fault, a system of uplifts extends, successively from the northwest to the southeast, consisting of the Betpakdala, Tastin and Talas uplifts. To the southwest of this system of uplifts, the Kokpansor and Suzak-Baikadam troughs are distinguished, separated by the Bugujil uplift.

On the northeastern side of this system of uplifts, the Zhezkazgan trough, the Sarysu uplift, the Tasbulak trough, the Nizhne-Shuskoe uplift, and the Moyinkum trough are located sequentially from northwest to southeast.

The articulation of uplifts with troughs practically occurs along high-amplitude faults of a thrust and shear-thrust character. Structural plans of Paleozoic deposits for different horizons coincide.

The gas-bearing fields of the Shu-Sarysu basin are located in the middle-upper Paleozoic. The sedimentary cover, more than 5000 m thick, is mainly represented by carbonate, terrigenous and saline sediments of the Devonian, Carboniferous and Permian. In the Paleozoic section, two salt strata are distinguished: the lower Famennian and the upper Lower Permian. The Lower Shu salt-dome region is characterized by manifestations of the Famennian diapirism, and the Lower Permian salt is represented as lenses and strata.

On the eroded surface of the Paleozoic there is a thin (200–300 m) mesocainozoic, represented by the sand-clay rocks of the Cretaceous, Paleogene and Neogene, which experts characterize as unpromising in oil and gas bearing respect [5].

The intermediate structural complex, which lies between the basement and the typical platformary cover of the Meso-Cenozoic (Lower Paleozoic, quasiplatform), has some characteristic features of both the basement and the overlying typical platformary cover [5].

Regional gas-bearing complexes (GC) are sediments of the Upper Devonian (Famennian deposit), Lower Carboniferous (Upper Tournaisian, Lower Viseian, Serpukhovian) and Lower Permian (Lower Permian deposit). The Lower Carboniferous GC is a regional primary gas-bearing complex, the Famennian GC is a mixed complex, and the Lower Permian GC is a secondary gas-bearing complex. Their gas content is due to the presence of the Lower Carboniferous GC in the section and is controlled by the development zones of the Famennian, Serpukhovian, and Lower Permian saline strata, respectively.

Famennian GC is distributed in the areas, which are territorially combined with the zones of development of Famensky salt formations, which serve as a cover for it – this is the eastern part of the Kokpansor trough and the Tasbulak-Nizhneshusky zone with inclusion of the northwestern part of the Moyinkum trough, where salt formations are replaced by sulfate rock facies. Reservoirs are represented by red-brown, feldspathic quartz, fine- and medium-grained sandstones. Cement clay-siliceous, ferruginous, rarely weakly carbonate.

The Lower Carboniferous GC is regionally distributed, and its producing capabilities and gas content are controlled by thickness parameters greater than 300 m and zones of development not only of zonal and local coverages in the complex itself, but also of the Permian regional capping. It should be noted that the vast majority of commercial gas accumulations are identified in the area of development of the Lower Permian salt-bearing section. HC gas occurrences are found throughout the stratigraphic range of this lithologic complex up to the Taskuduk formation and are mainly due to the presence of reservoirs and capes.

The covers are layers of halite, anhydrite or sulfated carbonate and terrigenous non-permeable rocks, there are interlayers of halite.

The reservoirs in the Turnean and Lower Visean sediments of the Lower Carboniferous are represented by fine- and medium-grained feldspathic quartz sandstones on carbonate-hydrosludite cement of film and regeneration types.

The reservoirs in the Middle-Visean, Upper-Visean, and Serpukhov stages of the Lower Carboniferous are represented by calcareous sandstones.

The Lower Permian GC is isolated within the boundaries of the Permian saline sequence, which acts as a regional cover.

The reservoirs studied along the anticlinal structures are represented by fine-grained sandstones and siltstones of the Lower Permian subsalt sequence, less frequently by inter-salt terrigenous interlayers. Sandstones are widely fractured on the vaults of structures; feldspathic quartz sandstones are on siliceous-carbonate and sulfate cement. In the underlying part of gas reservoirs, reservoirs are often sealed with halite and secondary minerals. This sharply reduces the permeability of rocks in the gas-water contact zones and creates impermeable barriers between the gas- and water-saturated parts of the deposit. For the most part, such barriers are responsible for the gas-energy mode of the fields.

Single deposits have commercial gas accumulations in the weathering crust of the Caledonian basement (Ortalyk shale deposit) [6]. Gas fields of the Shu-Sarysu gas-bearing region is confined to the fields of domed and brachianticlinal uplifts, complicated by fractures. The uplifts controlling the deposits are complexly built, tense in morphology, often truncated in section, sharply asymmetric, near-faulted.

Information about the parameters of the geoelectric section of the geotraverse area is based on the materials of parametric vertical electrical soundings and on the data of resistivity logs. For sedimentary formations, the value of electrical resistivity depends on the facies composition of rocks: clay facies and rocks with high porosity have low resistivity (the first units of Ohm·m), carbonate and effusive – high (hundreds and thousands of Ohm·m). At depths of more than 3–4 km due to increasing temperature and pressure there is a significant decrease in porosity and displacement to the surface of free water, the resistance of rocks increases [7].

The electrical properties of deposits of Cenozoic-Mesozoic age have been most fully studied in connection with earlier electrical prospecting work to determine the depths to the Paleozoic. The Paleozoic rock complex proper is poorly studied. The Lower Paleozoic, represented by the sedimentary and intrusive complexes of Cambrian and Ordovician rocks, has a high electrical resistivity and is firmly fixed by the output of the VES curves on the asymptote at an angle of 45°. In the area of development of Lower and Middle Carboniferous sedimentary strata (sandstones, siltstones, mudstones, limestones, dolomites) Paleozoic formations often have low resistivity (from 10–30 to 50–100 Ohm·m), close to the resistance of overlapping loose formations of Meso-Cainozoic [6]. The averaged values of the resistivity of rocks of the quasiplatform rock complex of the Upper Paleozoic are shown in the Table.

Analysis of a priori geological and geophysical information allowed us to conclude that the rocks in this section are contrasting in their electrical parameters and are favorable for MT-sounding.

Research methodology. The presented geological and geophysical criteria were the basis for conducting magnetotelluric soundings along the Shu-Sarysu geotraverse.

The basis of the method is the study on the natural electromagnetic field of the Earth of a cosmic nature. The sources of these fields are the ionosphere and near-Earth space. Under the

Table

Average values of electrical resistivity of rocks

Age	Lithology of rocks	Electrical resistances, Ohm · m
C_1–C_2	Sandstones, clays, limestones	50–80
C_1v	Massive limestones and sandstones	200–300
C_1t	Sandstones, limestones, mudstones	70–80
C_1t	Sandy-argillite pack	20–30
C_1t	Lime-sandy strata	200–300
	Coal-bearing strata	20–30
	Rock salt	100
D_3	Sandstones	70–60
$D_{1\text{-}2}$	Porphyrites, quartz porphyrites, sandstones	300 and more

influence of a powerful flux of charged particles there are variations in the magnetic field of the earth and there are current vortices in the ionosphere. This results in a magnetotelluric field, which contains a wide range of frequencies. Ultra-low frequencies penetrate hundreds of kilometers deep, making this method one of the deepest of all electrical exploration methods [8].

The measured quantities are the electrical (Ex and Ey) and magnetic (Hx, Hy and Hz) components. The resistance value of the medium is determined by the impedance – the ratio of the horizontal components of the electromagnetic field – electric to magnetic (Ex/Hy) and (Ey/Hx) at different periods (frequencies) of the field fluctuations [9].

Submeridional direction of the geotraverse was chosen and justified based on the results of large-scale works on "Comprehensive Study of Sedimentary Basins of Kazakhstan. Shu-Sarysu Basin" performed in 2012. Gravimetric and aeromagnetic surveys were conducted in the area of the 60- to 100-km wide geotraverse, and seismic and electrical surveys were conducted along the axis of the profile. The study on deep horizons of the Earth's crust along regional profile lines (geotraverses) by a complex of methods is one of the most effective ways to study the tectonic development of the Earth, its geodynamic regime, the connection between deep processes and surface phenomena, the development of deep criteria for prediction of minerals and, in the future, to combine these factors within a unified theory of deposit formation processes [10].

MT-sounding is performed on the profile with a step of 1 km. The detailing was carried out along the line of interpretation and binding profile, laid through 5 parametric wells, drilled on the areas of structural and tectonic elements distribution.

During the field work we used Phoenix Geophysics equipment (Canada), MTU-5A stations designed to record five components (Ex, Ey, Hx, Hy, Hz) of the MT field in the range from 0.0001 Hz to 10 kHz.

The station consists of an autonomous MTU recorder with a built-in GPS system, complete with a set of broadband inductive magnetic sensors MTS-30 and MTS-50 and electric dipoles with non-polarizing electrodes.

A total of 15 stations were involved in the work.

The MTU recorder is a specialized computer based on the Intel 386 processor, made in the PC110 standard.

The station uses a 24-bit analog digital converter (ADC), which significantly reduces the analog part of the meter. Due to the high resolution of the ADC there is practically no need to use analog filters. There is a digital notch filter tunable to an industrial interference frequency of 50 Hz (or 60 Hz). The sampling frequency for MTU-5A stations is 24 kHz.

The station has no keyboard and display. The operator controls the station by computer, creating a start table with the operating settings and writing it on the station flash card. The control program reads the start table, and the station begins to perform its specified mode of operation, recording the results of measurements also on the flash card. Registration is performed offline without operator's participation. At the same time, the operator has the ability to monitor its status in real time with a computer, interrupt the station and change the settings of the start table.

Processing and interpretation of MT data. Data processing was conducted in two stages. At the first stage (primary processing) the express-processing of data of MT-sounding records was carried out, the preliminary cuts were built. The second stage (in-depth) included editing the results of primary processing using a priori geological and geophysical information, construction of spline approximations.

Interpretation of electrical prospecting data consists of two main steps: inversion with obtaining geoelectric models of the medium (solving the inverse problem, that is, the transition from the dependence of the apparent electrical resistivity on frequency to the dependence of the specific resistance depth) and the subsequent "geological interpretation" of geoelectric sections [11].

According to the results of the analysis, the medium has a structure close to two-dimensional one. At longer periods, there is a 3D effect caused by regional inhomogeneity of conductivity distribution. Thus, to obtain reliable data on the electrical resistivity distribution in the target depth interval it is necessary to apply a 2D inversion [4]. Application of the 1D approach is limited because the mismatch of the inverse problem dimensionality with the medium dimensionality can lead to incorrect definition of the electrical resistivity of the layers. However, the transition to an inverse problem of a larger dimension leads to an increase in the instability of its solution. Compared to one-dimensional inversions, two- and three-dimensional inversions are less stable. This is because the adequate description of 2D and 3D models requires a much larger number of parameters than for a 1D model. Therefore, to keep the detail of the dissection, on the one hand, and to ensure the reliability of the electrical resistivity determination, on the other hand, a staged interpretation was applied, which included both 1D and 2D (controlled multistage 2D inversion with a starting model built from the results of one-dimensional fitting) [12].

Using this approach allows us to obtain a single geoelectric model for the entire depth interval under study, including a detailed horizontal-layered top and a heterogeneous bottom. In this case, the model satisfies the observed data in the whole range of periods, and there is no loss of model detail in the upper horizontal-layered part, nor loss of validity of results in the lower inhomogeneous part, related to the incompatibility of the dimensional inversion procedure and the medium model, to which the MT field corresponds.

Research results. The results of magnetotelluric soundings along the Shu-Sarysu geotraverse line are presented in the form of the electrical resistivity geoelectric section. The electrical resistivity of the section varies in a very wide range from 0.1–1 to 10,000 Ohm-m. In this regard, the isolines on the geoelectric section are given in values of the decimal logarithm of resistance (LgR from -1 to +4). In order to improve the clarity and information content of the obtained electrical survey data, a generalized parametric geoelectric model was built in addition to the geoelectric sections, on which the lineaments of the tracing axes of the logarithm of resistance gradient zones were superimposed. To calculate additional parameters (transformant) of the geoelectric section, specialized software packages Epi-Kit, MTS Prof Inv, MT 2D Tools, Geosoft Oasis MontajTM, COSCAD 3D and several others were used. Above the geoelectric section there are diagrams of magnetic and gravitational field parameters; elements of geological structures of the first and higher orders (Syrdarya and Shu-Sarysu sedimentary basins, Karatau mountain system, borders of Zhalair-Naiman folding zone, Baikadam and Tasbulak troughs, Leontiev graben, Talas-Tasty uplift system, Lower Shuskaya saddle, etc.) are marked), crossed by the geotraverse line (Fig. 2).

In the southwestern part of the profile (interval from 0 to 80 km) in the upper part of the geoelectric section a contrasting well conductive horizon is mapped by the Meso-Cenozoic sediments. Within the Arys trough of the Syrdarya sedimentary basin, the resistivity of this horizon is 3–10 Ohm-m, up to 1.5 km thick. These formations lie on rocks, for which the resistance with depth increases gradiently from 10 to 50–60 Ohm-m. In the depth range of 4–11 km, the resistance varies within a small range (60–160 Ohm-m) and averages 100 Ohm-m. In the depth interval of 10–20 km, there is a relatively conductive horizon, with resistance values ranging from 10–30 Ohm-m. Below this horizon, at depths of 20–40 km, the resistivity of the geoelectric section is relatively elevated and is 300–500 Ohm-m.

The interval of the geotraverse profile (interval 80–160 km), which crosses the Karatau mountain massif on the geoelectric section is characterized by a general anomalously high level of values of resistivity 1000 Ohm-m. The block has a complex geoelectric structure, with sub-vertical zones of maximum resistance (up to 10000 Ohm-m) alternating with zones of low resistance (from 1000 to 100 Ohm-m). In the upper part of the section, a local anomaly of reduced resistivity (10–100 Ohm-m) marks the position of the Leontiev graben. A certain zonality of

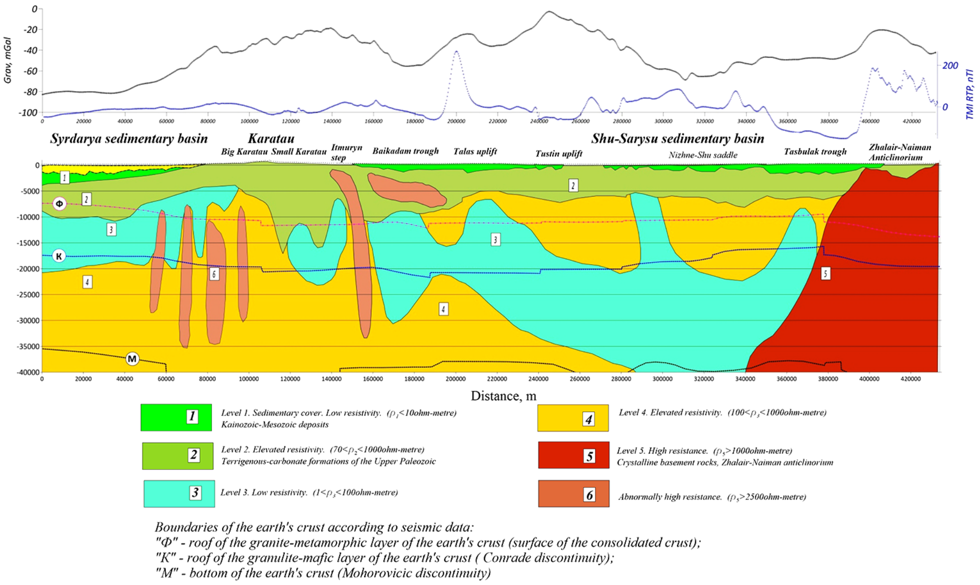

Fig. 2. Generalized parametric model of the geoelectric section of the study area, supplemented by lineaments tracing the axes of gradient resistivity zones

electrical properties of the block is also noted in its subhorizontal-layered structure. In the depth interval of 0–5 km stands out a horizon with resistance from 500 to 1500 Ohm-m, the underlying horizon (depth 5–17 km), divided by subvertical boundaries into zones of low and high resistance, in general, has a reduced level of average resistance. The lower horizon (from 17–20 to 40 km depth) is of relatively high resistivity; in the southwestern part of this interval of a profile, resistance reaches 1000–5000 Ohm-m, in the northeast it goes down to 120–150 Ohm-m.

In the interval of the profile (160–200 km) corresponding to the northeastern slope of the Small Karatau, the Itmuryn stage and the southwestern part of the Baykadam trough are distinguished as a conductive horizon (resistivity 2–10 Ohm-m) in the upper part of the geoelectric section. The Paleozoic roof is marked by a high gradient zone, below which, in the interval of depths from 2 to 10–12 km, a high-resistance horizon (100–10,000 Ohm-m, with an average value of 1000 Ohm-m) is distinguished. In the depth interval from 10–12 to 25–30 km, the average resistivity of the section decreases to 100 Ohm-m. By subvertical gradient zones, the horizon is divided into high-resistance (up to 1000 Ohm-m) southwestern and low-resistance (10–100 Ohm-m) northeastern parts. The lower part of the section in the depth interval from 25–30 to 40 km is characterized by moderate resistance values of 150–300 Ohm-m.

The profile interval (200–360 km) corresponds to the central and eastern parts of the Shu-Sarysu basin, crosses the Baikadam trough, Talas and Tasty rises, the Lower Shu saddle and the southern end of the Tasbulak trough in the southwest-northeast direction. The upper part of the section in the depth interval of 0–2 km stands out as a conductive horizon with resistivity from 4–5 to 100 Ohm-m, the base of the horizon almost coincides with the Paleozoic roof. The underlying high-resistance (resistance from 700 to 2000–3000 Ohm-m) horizon occupies the interval of depths from 1–2 to 5–8 km, its upper gradient part corresponds to the sediments of the Upper Paleozoic quasiplatform stage. Below the 5–8 km depth level, the horizon without sharp geoelectric boundaries is underlain by a horizon of moderate resistivity (700–1200 Ohm-m). In the interval of depths from 15 to 35 km, a relatively conductive horizon with a resistance of 50–100 Ohm-m is distinguished.

The northeastern part of the geoelectric section corresponds to the Zhalair-Naiman anticline and stands out as a high-resistance block with resistivities from 1000–3000 to 30,000–50,000 Ohm-m throughout the depth interval from 0 to 40 km.

Generalization of the materials of previously performed electrical exploration and electrical logging in the Shu-Sarysu sedimentary basin allowed us to perform a geological interpretation of the MT-sounding electrical exploration data. The generalized geoelectric section of the work area is presented in a five-layer structure (from top to bottom):

Layer 1 (upper) is represented by proluvial, alluvial and aeolian deposits of Quaternary age (clays, loams, sandy loam, crushed stone, gravel, boulders, and pebbles). Its resistance varies from 2–20 to 300–600 Ohm-m. Layer thickness up to 10–20 m. According to the logging data, the following resistance values were obtained for different rocks: clay 3–5 Ohm-m; sandy loam, loam 5–20 Ohm; boulder and pebble 100–200 Ohm and more.

Layer 2 of increased resistance is represented by Neogene sands, conglomerates, boulders, and pebbles. According to drilling data, their thickness reaches 50 m. Resistivity of the layer (by VES) 10–25 to 650 Ohm-m. According to well logging data, resistance of clayey sands 5–10 Ohm-m; sands 10–15 Ohm-m; gravel-pebbles, sandstones, conglomerates 30–70 Ohm-m. In outcrops of conglomerates in the Kutyrgan area, parametric measurements yielded values of 1300–1400 Ohm-m.

Layer 3 has relatively low resistances. This layer is marked by the Paleogene and Upper Cretaceous deposits poorly differentiated by electrical properties, represented by a complex of interstratified rocks - clay, sand, clayey sand, gravel and pebble deposits, siltstones, sandstones on clay cement, porcelain-like limestone, breccias, as well as bauxite-like rocks and bauxites. The electrical resistance of the entire thickness is characterized by values of 2–50 Ohm-m. Its thickness varies from the first tens of meters to hundreds of meters, reaching 400–600 m. When probing in this stratum, only rock horizons of sufficient thickness can be detected in separate layers.

Layer 4 of high resistivity (80–280 Ohm-m) is associated with conglomerates, boulders, and pebbles of the lower horizons of the Upper Cretaceous and weathering crust of Jurassic sediments. It is distinguished only in the case of high thickness. It often lies on the surface of Paleozoic sediments and plays the role of a reference horizon, which sometimes leads to errors in determining the depth of occurrence of the roof of the Paleozoic sediments.

Layer 5 of "infinitely" large resistance serves as a reference electrical horizon, which allows the methods of field electrical prospecting to determine the depth of occurrence of the Paleozoic roof. Paleozoic limestones and dolomites, whose resistivity varies from 700 to several thousand ohm-m (according to MG PP at AB = 2000 m to 30–40 thousand Ohm-m). Sandstones, siltstones, marls, and limestones of the Carboniferous are in most cases marked by increased values of electrical resistivity up to 100 Ohm-m. There are cases where on the VES curves, the reference horizon is marked with final resistivities from 30 to 120–220 Ohm-m, which is apparently due to the presence of clayey limestone, Carboniferous siltstones and gypsiferous Upper Devonian sequence.

It should be noted that, in general, the entire upper part of the geoelectric section of the Shu-Sarysu sedimentary basin is low resistivity, often the formations of the quasiplatform Paleozoic have a resistance of the same order as that of the Meso-Cenozoic sediments overlying it.

Conclusions. Thus, the use of MT-soundings has shown a high efficiency of the method. Interpretation of MT-sounding data allowed us to clarify the geological structure of the sedimentary complex of rocks of the Meso-Cenozoic platform cover, to assess the depth of occurrence of the roof and basement formations of the quasiplatform stage, the lithological composition, to study the tectonic elements (Syrdarya and Shu-Sarysu sedimentary basins, Karatau mountain system, borders of Zhalair-Naiman folding zone, Baikadam and Tasbulak troughs, Leontiev graben, Talas-Tasty uplift system, Lower Shu saddle). For a meaningful interpretation of MT-sounding data, an analysis of the petrophysical properties of the study area was carried out using a significant amount of data – the results of drilling and geophysical well studies. Spatial geoelectric heterogeneities in the geoelectric sections of the MT-sounding have been established, allowing one to observe subvertical transcrustal channels of increased permeability, which are probably the pathways of transport of deep thermal flows and fluids.

It is recommended to carry out further exploration and comprehensive interpretation of the obtained geological and geophysical data in the studied area.

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Геоелектрична модель земної кори вздовж геотраверсу Шу-Сарису за даними магнітотелуричного зондування

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Мета. Полягає у вивченні та оцінці можливості ефективного застосування електророзвідки методом магнітотелуричних зондувань (МТЗ) і визначенні кола розв'язуваних геологічних завдань у геоелектричних умовах геотраверсу Шу-Сарису.

Методика. Розглянуте питання методики сучасних технологій польових спостережень, особливостей обробки та інтерпретації даних МТЗ, які показали, що сучасні апаратурно-методичні електророзвідувальні технології МТЗ дозволяють отримати результати польових вимірів підвищеної достовірності завдяки своїй точності, продуктивності, мобільності, перешкодозахищеності, рівню автоматизації. Для виявлення основних особливостей геоелектричної будови земної кори й верхньої мантії сучасна методика інтерпретації МТ-даних дозволяє проводити 1, 2D-інверсію ефективних кривих уявного опору та фази імпедансу.

Результати. За даними МТЗ побудовано геоелектричний розріз геотраверсу Шу-Сарис, що характеризує положення й морфологію п'яти геоелектричних границь у розрізі земної кори в інтервалі глибин 0–40 км. Виділені п'ять геоелектричних горизонтів вказують на гарний збіг з умовними сейсмічними горизонтами та впевнено пов'язуються з геологічними реперами, встановленими за даними ГІС.

Наукова новизна. Полягає в тому, що на основі досліджень МТЗ представлене геологічне тлумачення будови надсольового й підсольового структурно-формаційних комплексів; показана геологічна ефективність електророзвідки МТЗ при виявленні складнозбудованих структур в умовах геотраверсу Шу-Сарис. На основі модельних побудов геоелектричного розрізу отримані нові дані про глибинну геологічну будову геотраверсу Шу-Сарису: отримані нові дані про будову мезозойських теригенно-осадових комплексів гірських порід і палеозойської частини розрізу з виділенням передбачуваних розривних порушень; на підставі результатів МТ-зондувань надані рекомендації щодо подальших детальних геологорозвідувальних робіт.

Практична значимість. Рекомендується комплексна інтерпретація отриманих даних МТЗ спільно з результатами геолого-геофізичних досліджень регіонального профілю з метою встановлення пошукових критеріїв виявлення родовищ корисних копалин і перспектив газоносності району.

Ключові слова: *геотраверс, осадовий чохол, фундамент, Шу-Сарисуйський осадовий басейн, магнітотелуричне зондування, геоелектричний розріз*

The manuscript was submitted 10.01.23.