

## ANNOTATION

Thesis for a degree of the philosophy doctor (PhD) on  
profession 6D070600 – Geology and exploration of mineral deposits

Gulzada Umirova

Allocation of geoelectric heterogeneity in formations of sedimentary cover within the Karaton-Sarkamys block on the basis of magnetotelluric sounding technology

**Relevance.** The Karaton-Sarkamys tectonic block is located in east part of the Caspian Sea (seaside part) and characterized not only complexity of a structural and tectonic structure (attenuation of salts of the Kungur epoch, spatial arrangements of geological objects in the block) but also widely developed change of sedimentation conditions and structure of coeval geological formations.

The region is studied detail, however single fundamental issues of its geological structure remain debatable so far. It is known that under favorable conditions and high differentiation of rocks on electric properties the MT-sounding shows good results when studying the lithologic and stratigraphic heterogeneity of suprasalt sequence and geological structure of the Upper Paleozoic deposits (Devonian - lower Permian) in conjunction with seismic exploration, magnetic and gravimetry survey, well logging and drilling data.

The current state of process of development of oil and gas fields in Kazakhstan is characterized by certain difficulties at the choice of optimum technologies of exploration and investigation for hydrocarbons fields. It is connected with studying of the deposits which are formed in difficult mining-and-geological conditions, increase in overall balance of a share of the hardly removable stocks including connected with the low-porous carbonate collectors, confinedness of a number of fields to zones with a specific mode of environmental management having restrictions for subsurface use. At the same time, there were high-precision and high-resolving geophysical technologies allowing to give a detailed idea of features of a structure of studying objects. These technologies actively take root at a stage of exploration and investigation and often when developing oil and gas fields that allows to obtain reliable information for creation of detailed models of a structure of productive objects and to correct the directions of their effective development.

Magnetotelluric sounding allow to reveal the specific anomalies of specific resistance connected with epigenetic changes of rocks over a hydrocarbons fields, to carry out a lithologic partition of sedimentary complexes, to allocate deep breaks, large anticlinal raisings, structures of the base. According to MT-sounding data it is possible to predict zones of the horizons perspective for oil and gas.

**The purpose of researches** consists of studying and assessment of a possibility of effective application of magnetotelluric sounding at the solution of oil prospecting tasks in conditions of the Karaton-Sarkamysky block of Caspian Depression.

For achievement of a goal the following main objectives are solved:

- analysis of condition of geophysical surveys by MT, MOGT and Well logging methods at the solution of oil prospecting tasks;
- petrophysical objectivation of application of complex geophysical surveys around works area;
- analysis and interpretation of MT data with use of modern specialized software and hardware complexes;
- complex analysis of electrometric data, its comparison with results of the executed seismic, gravimetric, magnetometric researches, drilling materials;
- assessment of efficiency of combined use of MT, MOGT and Well logging methods by exploration of oil and gas traps;
- development of methodical recommendations of the complex analysis of results of geophysical surveys at the solution of oil prospecting tasks in the conditions of Caspian Depression in Kazakhstan.

Object of researches are lithologic and stratigraphic heterogeneity of suprasalt sequence and subsalt structural and formational complexes of rocks of the Karaton-Sarkamys block of Caspian Depression southeast board.

**Scientific novelty of researches** presented in the thesis consists of the following:

- on the basis of the MT researches in a complex with geologic-geophysical methods executed by the author: a) it is presented geological interpretation of structure of suprasalt sequence and subsalt structural and formational complexes; b) geological tasks are defined and classified, shown geological efficiency of MT at prospecting stage of identification of oil and gas potential structures of complex structure in the conditions of the Karaton-Sarkamys block of a southeast board of Caspian Depression;
- for sequence of complex structure the author has developed methodical approach to the complex analysis of results of geologic-geophysical methods including grav-magnetic explorations, well logging data and drilling results;
- it is performed the analysis of petrophysical properties of researches area with involvement of well logging and drilling data;
- it is marked out features of the MT-geolectric section which give the chance to observe subvertical channels of the increased permeability which can be agents of transfer of a deep thermal stream and fluids .

#### Research methods

For the solution of objectives the technique of complex interpretation of data gravimetry, electric and magnetic explorations has been developed and tested. These methods are successfully applied to studying of structural and tectonic features of oil and gas potential zones and large stratigraphic intervals for a long time. Seismic exploration, well logging and drilling data were used with MT data for the solution of delicate problems of allocation of oil and gas potential intervals

**Practical importance.** On the basis of model dependences of geoelectric and seismic cross section new data of a deep geological structure of the Karaton-Sarkamyssky block are obtained:

- the structure of Paleozoic complexes with allocation of alleged explosive violations is characterized;

- perspective sites in mesozoic terrigenous and sedimentary complexes of rocks are allocated;
- the assessment of efficiency of the structures revealed by seismic exploration is carried out and sites of profiles with the improved collection properties are confirmed;
- on the basis of MT-sounding results recommendations of further detailed exploration works are made.

The researches conducted in recent years by request of the private oil companies in Kazakhstan with use of this technique have shown a possibility of increase in efficiency of oil prospecting works.

Results of MT differ in rather good correlatability with a geology at an assessment of suprasalt sequence and subsalt structures and in complex with seismic exploration and drilling allow to give a quality and quantitative standard of prospects of oil-and-gas content of researches objects.

**Approbation.** Basic provisions and results of theoretical and pilot studies, conclusions and recommendations of the thesis were reported at annual scientific republican and international conferences and symposiums. The presented work was a basis for creation of the educational module of a course of lectures of Electric Prospecting which the author reads since 2016 to students geophysicists of Institute of distance learning at KAZNRTU named after K.Satpayev.

**Publications.** On a thesis 16 printing works, including 1 article are published in the magazine with a nonzero impact-factor, 3 articles in the magazines recommended to MES of RoK, 12 articles in the collections published by results of scientific international and republican conferences and theses of three reports.

**Structure and volume of dissertation.** Dissertation consists of introduction, six chapters, main conclusions and recommendations, bibliography including 90 names. Material of the thesis is stated on 153 pages, includes 8 tables and 44 drawings.

In introduction are disclosed relevance of researches, the questions connected with the studied subject are concretized. The objects, tasks and methods of researches are set, scientific novelty and the practical importance of work are shown.

The first section of dissertation researches is devoted to the review of the current state of electroprospecting methods when studying prospects of oil-and-gas content of sedimentary basins. The possibilities and the current state of magnetotelluric sounding method, urgent problems of MT at the solution of oil prospecting tasks are considered, petrophysical justification of complex interpretation of geophysical data is given.

On the basis of presented in the thesis the review of application of the MT method abroad and in Kazakhstan for the solution of geological tasks by the author it is shown that magnetotelluric sounding (MT) method is the tool which can successfully solve all of tasks. It allows:

- to solve problems of allocation of deep breaks, structures of the base, large anticlinal raisings;

- to reveal the specific anomalies of specific resistance connected with epigenetic changes of rocks over a hydrocarbons deposits;
- on the database of drilling and well logging lithologically to dismember sedimentary complexes;
- in the presence of favorable external factors indirectly to allocate zones of the improved collection properties of the studied productive layers.

In Kazakhstan in a complex with airborne magnetic and gravimetric survey, seismic exploration and geophysical surveys, electric prospecting makes the significant contribution to the solution of the general geological tasks, explorations and investigation of oil-bearing and gas-bearing structures in recent years. However efficiency of magnetotelluric interpretation is in direct link with the volume of aprioristic geologic-geophysical information, in particular with seismic exploration, well logging, magnetic explorations and gravimetry data.

The petrophysical analysis of the researches area of has shown that the geoelectric structure of a sedimentary cover of Caspian Depression is characterized by favorable conditions for application of a method of magnetotelluric sounding for the solution of geological and expected tasks.

1. The main feature is existence of three geoelectric complexes: suprasalt sequence with conductivity from units to the first tens siemens, carbonate and halogen with a cross resistance about 107 Ohms • sq.m and longitudinal conductivity in units of Cm and subsalt with conductivity from units to 15-20 Cm. The crystal base of a hollow is characterized as very high-resistance layer.

2. High electric resistance of the dense containing rocks of a sedimentary cover considerably differs from resistance of layers collectors.

3. Saturation of collectors by highly mineralized fluids causes accurate correlation of electric properties of the horizons and their capacitor parameters.

**Chapter 2** represents short geological characteristic of Karaton-Sarkamys block with the description of the main stratigraphical intervals and its physical characteristics, tectonic structure of the territory and oil-and-gas complexes. It is executed review of geologic-geophysical study of the explored territory.

The review of results of geologic-geophysical study of the Karaton-Sarkamys block has shown high efficiency of application of geophysical methods during the studying of sedimentary deposits and assessment of oil and gas prospects of the area. The analysis of study of the Karaton-Sarkamys block shows that if the area of a research is well explored by seismic survey then study level of electroprospecting survey rather low.

The geological structure of the Karaton-Sarkamys block is characterized by the reflecting horizons "Φ" – (surface of the base); P3 – the surface which is presumably connected with a roof of the Upper Devonian terrigenous deposits; P1 – a roof of subsalt deposits; P21 – a sole of the Bashkir deposits; P2d – a roof of the Devonian deposits; R – roof of the Devonian carbonate reservoir; VI – surface of saliferous Kungur; V – base of the Jurassic complex; III (base of the lower Cretaceous). The sedimentary cover is presented by the diverse terrigenous and carbonate rocks divided by saliferous deposits of the Kungur tier of the lower Perm on subsalt and suprasalt sequence.

Territory of the block on features of oil-content of a suprasalt sequence is divided into three zones: southern, western and east. According to the analysis of geologic-geophysical materials it is noted accurately expressed regularity in spatial placement and stratigraphical allocation of oil and gas basin;

Prospects of oil-and-gas content of sedimentary deposits on fields of the Karaton-Sarkamys block are assessed positively but demand deeper studying with use of 3D-MOGT, MT data and coordinations of results of these survey with well logging materials for possible subsequent modeling of a basin and the choice of the optimum scheme of development.

**Chapter 3** describes basic methodical principles of research by magnetotelluric sounding . It is considered the questions of a technique of modern technologies of field operations, features of processing and technique of qualitative and quantitative interpretation of MT data.

The main results and conclusions of chapter 3 consist in the following:

1. MT modern hardware and methodical electroprospecting technologies allow to receive results of increased reliability thanks to the accuracy, productivity, mobility, noise immunity, automation level.

2. Advanced technologies of processing and interpretation of magnetotelluric researches on the basis of the modern software have shown that the results of MT executed in oil and gas prospects can serve as essential addition to the data obtained by seismic exploration and drilling.

3. The modern technique of interpretation of MT-data allows to carry out 1D-inversion of effective curves of the apparent resistivity and a phase of an impedance for detection of the main features of a geoelectric structure of a sedimentary cover of the Karaton-Sarkamys block.

4. Complexing of MT methods, MOGT 3D and well logging by explorations of oil and gas fields shows good results at the decision of regional and prospecting tasks at favorable factors. The geoelectric horizons allocated according to MT coincide with the seismic phantom horizons and surely coordinate with the geological reference points established according to the well logging.

5. The salt base and subsalt deposits are correlated with MT data rather conditionally. The reason of discrepancy of the reflecting horizons and geoelectric borders is that seismic borders are formed on borders of change of acoustic impedance and the frequency of its change less than the frequency of change of the geoelectric borders which are formed by integrated properties of intervals of big competency.

**Chapter 4** describes the technique of complex interpretation of geophysical data when studying a geological structure and assessment of oil-and-gas content of the Karaton-Sarkamys block. It is proved expediency and efficiency of use of differential and rated and complex parameter at creation of geological cross sections according to electric-seismic exploration and deep drilling . Geodensity cross section of the suprasalt and subsalt sediments are constructed and the provision of magnetoactive masses in structure of Upper Paleozoic deposits and the base is specified, the binding technique on depth of electroprospecting data and well logging materials, core is approved. It is constructed the physio-geological

model of a target section of the Karaton-Sarkamys block on GeoVisor technology realizing the complex analysis of geologic-geophysical information: well logging given data, drillings, seismic exploration, electroprospecting, gravic and magnetic survey.

The leading place in this complex is taken by the seismic exploration providing the solution of structural tasks without which the correct interpretation of the nature of observed geophysical anomalies is impossible.

Electric prospecting owing to the high sensitivity to variability of the litologo-facial characteristic of deposits and, the most important, to character of a fluid saturation of its pore space when imposing on a time seismic section provides opportunity:

differentiations of the studied section on the carrying-out and nonconducting complexes and creation of geoelectric model of the environment;

coordination and mutual correction of uniform seismogeoelectric complexes on the basis of borehole data;

estimates of oil-and-gas content of perspective intervals of a section for the purpose of "grading" of the revealed perspective objects on "empty" and "productive".

Gravimetry has added seismogeoelectric model with information about location of troughs, salt structures, anticlinal raisings, relief the gravity borders and density inhomogeneity. Magnetic exploration will give information about magnetoactive complexes of rocks and magnetic inhomogeneity in deposits of a sedimentary cover and the crystal base.

**Chapter 5** describes geological results of researches. On the basics physiogeological model has been executed geological interpretations of MT data, it is shown a possibility of the MT for the local estimate of oil content of suprasalt sediments and subsalt deposits of the researches area.

On the MT electroprospecting model on a profile A on electric signs (taking into account resolution of electroinvestigation of MT) in the studied part of a section the following geoelectric complexes are allocated:

1. The PG-K complex uniting deposits of the Paleogene, Neogene and cretaceous.

2. Complex between seismic borders III and V including deposits of top, average and lower Jura characterized by differential geoelectric properties on lateral .

3. Complex between seismic borders V and VI (P1kg). The most thick Permian-Triassic complex of deposits uniting rocks of various lithologic structure and wide stratigraphical range. This complex is characterized by changeable geoelectric properties and thickness on which size the salt tectonics exerts impact.

4. The Lower Permian halogen complex (which roof is the reflecting horizon VI (P1kg)) uniting saliferous deposits of Kungur. On formation of its modern structure the great influence was exerted by a salt tectogenesis in the course of which the salt objects of irregular isometric shape divided by mainly saltless troughs were formed. In the electromagnetic field it is shown as the high-resistance

complex serving as a good reference point for allocation of the first rigid reflecting border (P1kg) – a salt roof.

5. The Lower Permian subsalt complex between seismic borders P1 and P2 is presented by dense, soapstones of sakmaro-artinsky age with the low-impedance geoelectric properties. This complex is rather surely allocated on curves of resistance and is the regional low-impedance reference point dividing high-resistance saliferous deposits of the lower Perm and high-resistance deposits of the Bashkir tier.

6. The subsalt complex between the seismic reflecting borders P2 and P21 is connected with the upper Visean-Bashkir carbonate oil-and-gas complex presented mainly by porous, cavernous, fracture organogenic limestones. This and other complexes exert impact on variability of geoelectric properties, both litologo-facial variability of deposits and existence of deposits of hydrocarbons in a section.

7. The late Tournaisian- early Visean complex of deposits (a roof is the seismic horizon P21) is also perspective in the oil-and-gas relation that defines variability of its geoelectric properties on lateral.

8. A subsalt complex of upper Frasnian-lower Tournaisian (the third petrogeological object) (a roof is the seismic horizon Dt) with the changing geoelectric characteristics on lateral.

9. The subsalt complex of Eifelian-lower Frasnian carbonate and clay complex (a roof is the seismic horizon P2d) is presented by low impedance deposits;

10. The base F presented by high-resistance formations.

At an assessment of oil-and-gas content of target intervals of a section of researches area the technique of the estimate of oil-and-gas content for a complex of data seismo - and electroinvestigations of GeoVisor technology has been used (Smilevets N. P., "SK Geovizor", Moscow). The estimate of oil-and-gas content of perspective intervals of model was based on calculation of the complex seismo-electroprospecting parameter considering litologo-facial variability of deposits and which is responsible for change of character of their fluid saturation and the parameters of the overvoltage reacting to existence of a deposit of HC in a section. Positive anomalies of the complex parameter correspond to productive intervals of a section, anomalies of KP, negative or close to zero demonstrate that the probability of detection of a deposit of HC is improbable.

On the basis of the KP parameter analysis in a chapter 6 criteria of allocation of oil and gas potential zones are developed and recommendations about application of a magnetotelluric method when studying a sedimentary cover and identification of oil and gas potential structures are made.

By results of processing and interpretation of MT data the productive scheme of imposing of a complex of parameters of geophysical fields and the accompanying settlement factors for assessment of perspective sites has been constructed. The scheme is constructed for three horizons: The 5th horizon (Suprasalt) – the Jurassic sediments, 7 and 8 horizons (subsalt) Upper Paleozoic deposits.

On the basis of the analysis of geologic-geophysical these of known fields of the Karaton-Sarkamys block a number of indirect signs (factors) on which productive areas were allocated has been developed:

1. Structural factor on compliance of planned position of electroprospecting and seismic structures (traps);
  2. Factor on existence of tectonic restrictions of structures;
  3. Factor of existence of traps in the range of the productive zones predicted according to seismic exploration;
  4. On existence of structures (raisings) of the base according to electroinvestigation;
  5. Factor of compliance of structures to anomalies (increase in SER) of electroinvestigation;
  6. Factor of compliance of increase in SER to anomalies of gravitational field;
- Factor of compliance of increase in SER to decrease in values of magnetic field.

The main conclusions by results of researches according to the purpose and the solved tasks are reflected in the conclusion, recommendations on search drilling are made.

1. Inclusion in a complex search and (under favorable conditions) prospecting works of a method of magnetotelluric sounding on oil and gas fields of Kazakhstan can increase efficiency of oil and gas exploration of the region.

2. Results of MT-researches differ in rather good reliability when studying a geological structure the suprasalt sediments and (to a lesser extent) subsalt structures, and in a complex with seismic exploration allow to estimate the studied objects concerning oil-and-gas content.

3. Carrying out electroinvestigation of MT has allowed to create modern digital geoelectric model of the Karaton-Sarkamys block of high precision. On the Karaton-Sarkamys block:

- It is characterized the structure of Paleozoic complexes with allocation of alleged explosive violations;
- It is allocated the perspective sites in mesozoic terrigenous and sedimentary complexes of rocks;
- the assessment of efficiency of the structures revealed by seismic exploration is carried out and sites of profiles with the improved collection properties are confirmed;
- on the basis of MT results made recommendations of further detailed exploration works.